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Abstract

The form in which attribute values are represented is an important component of choice tasks. However, there is little evidence about the effects 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 numbers, words lead to more alternative-based information search and less compensatory processing. We also find that the number and similarity of alternatives have important moderating influences on the effects of information representation. We conclude with implications for decision research.

Numeric and Linguistic Information Representation in Multiattribute Choice

Information in multiattribute choice tasks is often displayed as the values of alternatives on the attribute scales that describe them. These scale values can be represented in various ways. For example, when choosing a personal computer the amount of random access memory might be represented as numbers (e.g., 640K) or as words (e.g., "maximum available"). Despite previous research showing that other aspects of information displays can influence decision making (Payne, 1982), there has been little research on the differential effects of these two representations (Kleinmuntz & Schkade, 1989). Further, in real situations *numeric* (numbers) and *linguistic* (words) representations for attribute values are not only pervasive, but are often used interchangeably (e.g., in consumer magazines such as *Consumer Reports, PC Magazine,* or *Car and Driver*). In this paper we discuss an experiment in which participants made choices between the same sets of alternatives, described in one case by numbers, and in another by words.

How might representing attribute values as numbers or words affect decision making processes? In a previous study that explored this question (along with other issues), Huber (1980) presented one group of 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" in a 7 word linguistic scale). He found that in participants' 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., "this applicant has very good qualifications") were more frequent with linguistic data.

One possible explanation for changes in decision strategies due to information representation 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). Decision makers are hypothesized to select from among a set of strategies (e.g., additive, additive-difference, conjunctive, elimination-by-aspects; see Svenson, 1979) 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).

Changing the form in which information is presented can affect strategy selection by changing the effort required to execute particular cognitive operations that are components of strategies (Kleinmuntz & Schkade, 1989; Russo, 1977). For example, computing differences within attributes is likely to be less effortful with numbers (e.g., "640K of memory is 128K more than 512K") than with words (e.g., how much more is an "excellent" memory capacity than a "good" one?). If so, then strategies that make heavy use of differences (e.g., additive-difference) are more likely to be selected with numbers than with words. Johnson, Payne, and Bettman (1988) found a similar effect of information display on strategies in a preference reversal task when the probabilities of uncertain alternatives were changed from simple decimals to complex fractions, thus discouraging direct computations.

We predict that with words the greater difficulty of cardinal operations (e.g., requiring an interval scale) will lead to two broader effects. First, intra-attribute operations (e.g., comparisons within attributes) will be discouraged, resulting in less attribute-based search with words than with numbers. Second, the explicit weighting (e.g., multiplication) required by many compensatory strategies (e.g., additive, additive-difference) is more difficult to accomplish with words, more noncompensatory strategies will be used.

Since we hypothesize that information representation affects decision processes through changes in the effort of executing certain operations, the generality of these effects is likely to depend in part on other task and context characteristics that are known to influence effort. *Task complexity*, operationalized here as the number of alternatives, has been one of the most important variables in decision research, and been shown to interact with other characteristics of the decision environment in influencing strategy selection (Ford, Schmitt, Schechtman, Hults & Doherty, 1989; Payne, 1982). Previous research (that has used mostly numeric displays) has found that increases in task complexity lead to increases in the use of attribute-based search (e.g., Bettman, 1979; Payne, 1976). However, with words, making comparisons and computing differences within attributes is more effortful. Thus, we predict that as task complexity increases, information search will quickly become more attribute-based with numbers, but only slowly with words.

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; Tversky, 1977), and has even been called essential to theories of contingent decision making (Payne, 1982). Two alternatives described on the same attributes are similar to the extent that their attribute levels are close together. For example, Russo and Rosen (1975) define similar used cars as being of the same make (e.g., two Toyota subcompact sedans), since they are likely to have similar values for interior room, miles per gallon, ease of service, etc.

The cognitive effort required to compare two alternatives is directly related to the similarity of the alternatives. Similar alternatives require finer, more precise discriminations, thereby increasing the effort required to make a choice (Shugan, 1980; Tversky, 1977). Previous research (again using mostly numeric displays) suggests that decision makers adapt to the difficulty of choosing between similar alternatives by the use of attribute-based search (e.g., Russo & Rosen, 1975) and compensatory processing (e.g., Biggs, *et al.*, 1985). However, similar alternatives described with words create a particularly difficult decision problem. In contrast to their response to similar alternatives, decision makers are predicted to adapt to linguistic information by increasing use of alternative-based search and noncompensatory processing. Consequently, choosing between similar alternatives with linguistic information creates a conflict between the effects of information representation and the similarity structure of the alternatives. Thus, we predict that as similarity of alternatives increases, the cognitive effort expended will increase at a greater rate with words than with numbers.

To summarize, we predict that decision makers will use different strategies when the attribute values of choice alternatives are represented as words rather than as numbers. However, the effects of information representation on search patterns will be moderated by task complexity and effects on total effort will be moderated by the similarity of alternatives. To test these hypotheses, we conducted an experiment in which these three factors were manipulated and detailed data on decision making processes were obtained and evaluated.

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. 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.

Procedure. Twenty-four graduate business students with an average of 5.1 years of work experience and at least one graduate course in information systems management 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. Information representation, the number of alternatives, and the similarity of alternatives were manipulated within-participants. There were two information representations (numeric, linguistic), three levels of complexity (2, 4, and 8 alternatives), and two levels of the similarity of alternatives (similar, distinctive). In each session, each participant made one choice in each of the 12 treatment combinations, for a total of 24 trials. Participants also made five practice choices in each session to familiarize them with the task, with generating verbal protocols, and with the software used in the experiment. The average trial lasted about 100 seconds.

There was a direct correspondence between the numeric and linguistic representations 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 representations in initial task instructions.[2] Based on previous research (Myers & Warner, 1968), adjectives for the linguistic scale labels were chosen to be easily understood and approximately equidistant.[3]

Insert Table 1 about here

Similarity was operationalized using a measure of the geometric distance between alternatives in multiattribute space (cf. Biggs, *et al.*, 1985; Russo & Rosen, 1975; see also Tversky, 1977). Specifically, the variance of alternatives was used to characterize the overall similarity of a set of alternatives. 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, 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 similarity of the choice set is represented by the variance, across alternatives, of the V_is. For example, the variance of choice set A is var(0, 16) = 64. Distinctive choice sets contained alternatives with substantially different variances (e.g., Choice Set A). Similar choice sets contained alternatives with similar variances (e.g., Choice Set B).

Insert Table 2 about here

The sum of the ratings for alternatives was held constant (at 24) for two reasons. First, this made the choice problems more difficult, increasing the likelihood of observing effects due to cognitive effort. Second, it isolated effects due to similarity from those due to the individual attractiveness of alternatives, the presence or absence of dominated alternatives, and other context variables.

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 according to a fractional factorial design (Hays, 1981).

<u>Data Collection</u>. The alternatives 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 set of alternatives first appears on the screen, the attribute values are "hidden" in labeled boxes (Figure 1). 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.

Insert Figure 1 about here

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

The taped 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 adapted from Johnson and Payne (1985) (Table 3). The coding scheme was designed to decompose strategies into "... a small number of simple operators [that] can be viewed as the fundamental underlying components from which subjects construct decision rules" (Bettman *et al.*, in press; see also Chase, 1978). The two raters agreed initially on 79% of codings (Cohen's K = 71%; Bishop, Fienberg, and Holland, 1975). 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: (1) summary measures of strategy characteristics, and (2) elementary processing operations such as reading an item of information, or comparing two items (Bettman *et al.*, in press; Chase, 1978). Two principal types of summary measures are information search patterns and indicators of overall activity (Payne, Braunstein, & Carroll, 1978). Information search patterns concern the sequence in which the attribute values for various alternatives are read and processed. 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 "ease of use", 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.). A direction of search index (Payne, 1976) can be used to measure the extent of attribute-based and alternative-based processing. This index is computed by examining the relationship of the $n^{th} + 1$ piece of information examined to the n^{th} piece of information: (Inter - Intra) / (Inter + Intra), where Inter = the number of inter-attribute transitions, and Intra = the number of intra-attribute transitions. If the $n^{th} + 1$ piece of information searched is within the same attribute as the n^{th} (i.e., an intra-attribute transition), the index moves towards +1. If the $n^{th} + 1$ piece of information searched is within the same alternative (i.e., an intra-alternative transition), the index moves towards -1.

We also measured the percentage of information searched and the variability of search by alternatives, which have been found to be associated with the extent of compensatory processing (Klayman, 1983; Payne, 1976). The percentage of information searched was computed by dividing the number of attribute values examined by the total number available. The variability of information searched by alternatives was calculated by computing the variance of the number of attributes examined for each alternative in a choice set.

Three measures of decision effort were used: (1) total time, (2) total acquisitions (boxes opened), and (3) total elementary processing operations. Total acquisitions indicate the number of attribute values examined, including reexaminations of previously acquired values.

Separate MANOVAs were run for variables derived from protocol data and from computer logs.[4] Protocol operations were stated as proportions of 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) decision strategies, (4) linkages between information search, effort, and decision strategy, and (5) choice. Overall MANOVA results show significant effects of all three independent variables in both the computer log data: information representation, Wilks' $\lambda = .970$, $F(3,539) = 5.83$, $p < .001$, task complexity, Wilks' $\lambda = .553$, $F(6,1078) = 62.0$, $p < .001$, and the similarity of alternatives, Wilks' $\lambda = .927$, $F(3,539) = 14.12$, $p < .001$, and in the protocol data: information representation, Wilks' $\lambda = .588$, $F(10,232) = 16.26$, $p < .001$, task complexity, Wilks' $\lambda = .402$, $F(20,464) = 13.41$, $p < .001$, similarity of alternatives, Wilks' $\lambda = .871$, $F(10,232) = 3.44$, $p < .001$. Additional analysis was conducted to explain these effects.

Information Search. The direction of search index was influenced by all three independent variables (Table 4). The index was predominantly alternative-based and, as predicted, was significantly more alternative-based with words than with numbers, $F(1,541) = 14.2$, $p < .001$. Consistent with previous findings, the index was more alternative-based with less complex problems, $F(2,541) = 5.6$, $p < .018$, and with distinctive alternatives, $F(1,541) = 49.3$, $p < .001$. Also as predicted, as task complexity increased, the index shifted more quickly toward attribute-based processing with numbers than with words, $F(2,541) = 3.5$, $p = .032$. The more significant movement towards attribute-based processing in the numeric condition, relative to the linguistic, suggests that words may have inhibited the adaptation of acquisition processes to task demands.

Insert Table 4 about here

Participants examined a higher percentage of information with words than with numbers, although the difference was only marginally significant, $F(1,541) = 3.0, p = .085$. However, with both words and numbers the percentage of information searched is very high (92.1% for linguistic, 90.6% for numeric). Consistent with previous findings, as the number of alternatives increased, participants examined a smaller percentage of information, $F(2,541) = 47.7, p < .001$. There are no significant effects on the variability of search by alternatives, due in part to a ceiling effect induced by the high percentage of information searched. Thus, participants spent about the same amount of time on each of the alternatives, suggesting a high incidence of compensatory processing.

Cognitive Effort. All measures of cognitive effort were higher with words than with numbers, although the differences were only marginally significant: total operations, $F(1,241) = 3.8, p = .054$, total time, $F(1,541) = 1.4, p = .238$, total acquisitions, $F(1,541) = 2.4, p = .125$. Our results therefore offer weak evidence of slightly greater decision effort with words relative to numbers.

As expected, choosing among similar alternatives was more effortful than among distinctive alternatives. All measures of cognitive effort were higher with similar alternatives: total operations, $F(1,241) = 19.0, p < .001$; total time, $F(1,541) = 29.6, p < .001$; total acquisitions, $F(1,541) = 38.2, p < .001$.[5] Further, our hypothesis that choosing between similar alternatives with linguistic information is highly effortful is confirmed by a significant information representation by similarity interaction. With distinctive alternatives, there was no significant difference in effort between words and numbers, but with similar alternatives words were much more effortful: total time, $F(1,541) = 3.95$, $p = .047$; total acquisitions, $F(1,541) = 5.96$, $p = .015$.

Decision Strategies. As indicated by the relative frequencies of the cognitive operations used, participants used different strategies with words and numbers (Table 5). With numbers, participants used more Compare operations, suggesting greater ease of combining and comparing attribute values. In contrast, with words participants used more Read operations, presumably because acquiring values in pairs or groups was more difficult than with numbers. In addition, participants employed a larger variety of operations in the numeric condition, $F(1,241) = 19.0$, $p < .001$. With words the majority of activity is concentrated on one operation (Read), whereas with numbers activity is more evenly distributed across operations.

Insert Table 5 about here

The differing cognitive operations used by participants suggest greater use of compensatory processing strategies with the numeric representation. With numbers, participants used the Attribute Importance, Tradeoff, Evaluate, and External Standard, and Summarize operations more frequently (Table 5). In contrast, with words participants made more use of the Elimination operation. The use of the Tradeoff, Evaluate, and Summarize operations in particular is often associated with compensatory processing, while the use of the Elimination operation is associated with noncompensatory processing (e.g., Payne, 1976). Our results also provide some support for the idea that attribute-based search is associated with noncompensatory processing. The direction of search index is positively correlated with a higher percentage of information searched, $r = .39$, $p < .01$, greater variety of operations used, $r = .17$, $p < .01$, more summarize operations, $r =. 23$, $p < .01$, and marginally fewer elimination operations, $r = -.09$, $p = .12$.

These results are generally consistent with those of Huber (1980), who found more "direct comparison" operations with numbers and more "evaluate" operations with words. In contrast, we find more Comparisons and Evaluates with numbers and more Reads and Eliminations with words. However, since Huber did not include Read and Elimination operations as categories, statements coded as "evaluates" in his study were probably coded as Reads or Eliminations in our research.

Strategies also varied with the number and similarity of alternatives. 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. With similar alternatives 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.

<u>Information Search and Effort</u>. 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; Russo & Dosher, 1983). However, we find a significant *negative* correlation between the search index and total time, $r = -.19$, $p < .01$, and total acquisitions, $r = -.15$, $p < .01$, 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 acquisitions, $F(1,540) = 3.04$, $p = .082$. The 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 with words, alternative-based search apparently reduced cognitive effort, while with numbers, the direction of search did not affect cognitive effort.

Insert Table 6 about here

Choice. There is limited evidence that information representation can influence the weights given to information cues (Bell, 1984). However, we find no systematic differences in choices between the numeric and linguistic conditions. One possibility is that since the alternatives were generally close in value (they all had the same attribute value total), the extent to which "mistakes" were possible was limited. On the other hand, these (non)results can also be interpreted as a check on the validity of the information representation manipulation. If differences in choice were found, one interpretation would be that the linguistic and numeric representations presented to participants were perceived as substantively nonequivalent.

Discussion and Implications

Our results show that numeric and linguistic representations of attribute values can lead to quite different choice processes. Relative to the linguistic representation, numeric attribute values led to less alternative-based search and more frequent use of cognitive operations associated with compensatory processing. In addition, the relationship between information acquisition processes and effort differed depending upon information representation. With words the use of alternative-based search reduced cognitive effort, particularly with similar alternatives, while with numbers there was no relationship between search and effort. Consequently, our findings contradict previous research indicating that attribute-based search is less effortful and suggest instead that the effort of information search strategies depends upon the joint effects of task, context, and display characteristics.

We also find that task complexity and similarity of alternatives may have important moderating influences on the effects of information representation. As task complexity increased, participants processing numbers quickly switched attribute-based search, while with words this shift happened more slowly, and appeared to approach a limit. As similarity increased, thereby increasing cognitive effort, participants processing numbers exhibited only modest increases in effort relative to those processing words. Both of these results suggest that a larger set of decision strategies may be available with numeric information, resulting in a greater ability to adapt information search and cognitive operations to task demands.

Implications for Decision Research. Two aspects of our experiment may have limited the potential variability in the percentage of information searched, the variability of search across alternatives, and the extent of choice inconsistencies: (1) the relative ease of acquiring information afforded by the mouse-driven software, and (2) the absence of dominated or substantially inferior alternatives. The ease of search may have led participants to examine marginally useful information that would have otherwise been ignored with less facile information display methodologies (e.g., information boards). In fact, the percentage of information searched was so high (over 90%) that variability in this and the variability of search by alternatives measure was constrained by a ceiling effect, thus contributing to insignificant results. Further, in combination with the absence of poor alternatives, the ease of search may also have limited the use of noncompensatory strategies commonly employed to eliminate obviously unacceptable alternatives, resulting in a higher percentage of information searched and less variability in search. The high incidence of compensatory processing, compared to previous studies, may have limited choice inconsistencies, which often result from the use of noncompensatory strategies.

Additional research is needed to delineate the relative impact of methodology and choice set characteristics on our process and performance results.

Our results suggest the 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 robustness to time constraints (Payne, *et al.*, 1988). Information representation is another factor that may limit the set of available decision strategies, thereby limiting the capability to adapt to task demands. Consequently, previous empirical findings obtained with numeric attribute representations may not always generalize to other representations (e.g., words, graphs, symbols).

In our study, the similarity of alternatives had a surprisingly large impact on choice processes. Increasing 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 support the position that similarity increases choice difficulty (Biggs, *et al.* 1985; Shugan, 1980; Tversky, 1977), but contrast with studies of choice quality that indicate that ". . . similarity facilitates choice" (Russo & Rosen, 1975, pg. 267; see also Russo & Dosher, 1983). One reconciliation of these two perspectives may be that, while it is more difficult to distinguish among similar alternatives, choosing among similar alternatives limits the size of potential decision errors, since the opportunity cost of choosing a suboptimal alternative is reduced.

The widely held view that attribute-based processing is less effortful than alternative-based processing seems at first to conflict with our finding that, with words, attribute-based search is associated with *greater* cognitive effort. It is probably true that in studies using numeric, nonuniformly scaled attribute values that attribute-based processing is less effortful. However, our study has two key differences from previous multiattribute choice research: uniformly scaled attributes[6] and linguistic information representation. Both of these differences may have made the relationship between the search index and effort more negative than in previous research. Uniform scaling made cognitive operations associated with alternative-based processing (e.g., Summarize, Tradeoff) easier by eliminating the need to convert between attribute scales. As a result, in the numeric condition, the effect of uniform scaling negated what was previously believed to be a positive relationship. Further, the linguistic representation also discouraged attribute-based processing, and in combination with the effect of uniform scaling actually made the relationship negative.

The high incidence of alternative-based processing in our data may also have been influenced by the uniform scaling of attributes in our task. Prior research has found a predominance of attribute-based processing in multiattribute choice tasks (Bettman, 1979; Russo & Dosher, 1983), except when attributes are logically interdependent (e.g., gambles; Johnson, Payne, & Bettman, 1988; Payne & Braunstein, 1978). 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 in multiattribute choice tasks.

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 expressed 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 expressed 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.

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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] Recall that computer log data was obtained for all choices but verbal protocols were obtained for only the last six choices in each experimental session. There were no significant differences between protocol and non-protocol trials, except that protocol trials took somewhat longer, $F(1,541) = 90.4$, $p < .001$, and produced more total acquisitions, $F(1,541) = 31.5$, $p < .001$.

[5] 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.

[6] Recall that with both linguistic and numeric representations all attributes were identically scaled, using the same five numbers (i.e., "2", "4", etc.) or the same five words (i.e., "very poor", "poor", etc.).

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

Numeric Information

	Similarity of Alternatives		
Task Complexity	Distinctive	Similar	Overall
2 alternatives	.524	.437	.481
4 alternatives	.367	.297	.332
8 alternatives	.151	.142	.146
Overall	.347	.292	.320

Linguistic Information

	Similarity of Alternatives		
Task Complexity	Distinctive	Similar	Overall
2 alternatives	.589	.494	.541
4 alternatives	.385	.338	.361
8 alternatives	.328	.307	.317
Overall	.433	.380	.407

Table 5

Percentage of Operations in Numeric and Linguistic Conditions

	Numeric	Linguistic	F(1,241)	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		

Table 6

Correlations Between the Direction of Search Index and Total Acquisitions

	Number of Alternatives		
	2	4	8
Numeric			
Similar	-.13	.12	.10
Distinctive	.00	.00	.18
Linguistic			
Similar	-.18	-.23	-.32
Distinctive	-.07	-.16	.02

Figure 1

Choice Set With "Opened" Box