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Contingent Weighting in Judgment and Choice

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Preference can be inferred from direct choice between options or from a matching procedure in which the decision maker adjusts one option to match another. Studies of preferences between two-dimensional options (e.g., public policies, job applicants, benefit plans) show that the more prominent dimension looms larger in choice than in matching. Thus, choice is more lexicographic than matching. This finding is viewed as an instance of a general principle of compatibility: The weighting of inputs is enhanced by their compatibility with the output. To account for such effects, we develop a hierarchy of models in which the trade-off between attributes is contingent on the nature of the response. The simplest theory of this type, called the contingent weighting model, is applied to the analysis of various compatibility effects, including the choice-matching discrepancy and the preference-reversal phenomenon. These results raise both conceptual and practical questions concerning the nature, the meaning and the assessment of preference.

The relation of preference between acts or options is the key element of decision theory that provides the basis for the measurement of utility or value. In axiomatic treatments of decision theory, the concept of preference appears as an abstract relation that is given an empirical interpretation through specific methods of elicitation, such as choice and matching. In choice the decision maker selects an option from an offered set of two or more alternatives. In matching the decision maker is required to set the value of some variable in order to achieve an equivalence between options (e.g., what chance to win $750 is as attractive as 1 chance in 10 to win $2,500?).

The standard analysis of choice assumes procedure invariance: Normatively equivalent procedures for assessing preferences should give rise to the same preference order. Indeed, theories of measurement generally require the ordering of objects to be independent of the particular method of assessment. In classical physical measurement, it is commonly assumed that each object possesses a well-defined quantity of the attribute in question (e.g., length, mass) and that different measurement procedures elicit the same ordering of objects with respect to this attribute. Analogously, the classical theory of preference assumes that each individual has a well-defined preference order (or a utility function) and that different methods of elicitation produce the same ordering of options. To determine the heavier of two objects, for example, we can place them on the two sides of a pan balance and observe which side goes down. Alternatively, we can place each object separately on a sliding scale and observe the position at which the sliding scale is balanced. Similarly, to determine the preference order between options we can use either choice or matching. Note that the pan balance is analogous to binary choice, whereas the sliding scale resembles matching.

The assumption of procedure invariance is likely to hold when people have well-articulated preferences and beliefs, as is commonly assumed in the classical theory. If one likes opera but not ballet, for example, this preference is likely to emerge regardless of whether one compares the two directly or evaluates them independently. Procedure invariance may hold even in the absence of precomputed preferences, if people use a consistent algorithm. We do not immediately know the value of $7(8 + 9)$, but we have an algorithm for computing it that yields the same answer regardless of whether the addition is performed before or after the multiplication. Similarly, procedure invariance is likely to be satisfied if the value of each option is computed by a well-defined criterion, such as expected utility.

Studies of decision and judgment, however, indicate that the foregoing conditions for procedure invariance are not generally true and that people often do not have well-defined values and beliefs (e.g., Fischhoff, Slovic & Lichtenstein, 1980; March, 1978; Shafer & Tversky, 1985). In these situations, observed preferences are not simply read off from some master list: they are actually constructed in the elicitation process. Furthermore, choice is contingent or context sensitive: It depends on the framing of the problem and on the method of elicitation (Payne, 1982; Slovic & Lichtenstein, 1983; Tversky & Kahneman, 1986). Different elicitation procedures highlight different aspects of options and suggest alternative heuristics, which may give rise to inconsistent responses. An adequate account of choice, therefore, requires a psychological analysis of the elicitation process and its effect on the observed response.

What are the differences between choice and matching, and how do they affect people's responses? Because our understanding of the mental processes involved is limited, the analysis is necessarily sketchy and incomplete. Nevertheless, there is reason to expect that choice and matching may differ in a predictable manner. Consider the following example. Suppose Joan

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faces a choice between two job offers that vary in interest and salary. As a natural first step, Joan examines whether one option dominates the other (i.e., is superior in all respects). If not, she may try to reframe the problem (e.g., by representing the options in terms of higher order attributes) to produce a dominant alternative (Montgomery, 1983). If no dominance emerges, she may examine next whether one option enjoys a decisive advantage: that is, whether the advantage of one option far outweighs the advantage of the other. If neither option has a decisive advantage, the decision maker seeks a procedure for resolving the conflict. Because it is often unclear how to trade one attribute against another, a common procedure for resolving conflict in such situations is to select the option that is superior on the more important attribute. This procedure, which is essentially lexicographic, has two attractive features. First, it does not require the decision maker to assess the trade-off between the attributes, thereby reducing mental effort and cognitive strain. Second, it provides a compelling argument for choice that can be used to justify the decision to oneself as well as to others.

Consider next the matching version of the problem. Suppose Joan has to determine the salary at which the less interesting job would be as attractive as the more interesting one. The qualitative procedure described earlier cannot be used to solve the matching problem, which requires a quantitative assessment or a matching of intervals. To perform this task adequately, the decision maker should take into account both the size of the intervals (defined relative to the natural range of variation of the attributes in question) and the relative weights of these attributes. One method of matching first equates the size of the two intervals, and then adjusts the constructed interval according to the relative weight of the attribute. This approach is particularly compelling when the attributes are expressed in the same units (e.g., money, percent, test scores), but it may also be applied in other situations where it is easier to compare ranges than to establish a rate of exchange. Because adjustments are generally insufficient (Tversky & Kahneman, 1974) this procedure is likely to induce a relatively flat or uniform weighting of attributes.

The preceding discussion is not meant to provide a comprehensive account of choice or of matching. It merely suggests different heuristics or computational schemes that are likely to be used in the two tasks. If people tend to choose according to the more important dimension, or if they match options by adjusting unweighed intervals, then the two procedures are likely to yield different results. In particular, choice is expected to be more lexicographic than matching: That is, the more prominent attribute will weigh more heavily in choice than in matching. This is the *prominence hypothesis* investigated in the following section.

The discrepancy between choice and matching was first observed in a study by Slovic (1975) that was motivated by the ancient philosophical puzzle of how to choose between equally attractive alternatives. In this study the respondents first matched different pairs of (two-dimensional) options and, in a later session, chose between the matched options. Slovic found that the subjects did not choose randomly but rather tended to select the option that was superior on the more important dimension. This observation supports the prominence hypothesis, but the evidence is not conclusive for two reasons. First, the participants always matched the options prior to the choice hence the data could be explained by the hypothesis that the more important dimension looms larger in the later trial. Second, and more important, each participant chose between matched options hence the results could reflect a common tie-breaking procedure rather than a genuine reversal of preferences. After all, rationality does not entail a random breaking of ties. A rational person may be indifferent between a cash amount and a gamble but always pick the cash when forced to take one of the two.

To overcome these difficulties we develop in the next section a method for testing the prominence hypothesis that is based entirely on interpersonal (between-subjects) comparisons, and we apply this method to a variety of choice problems. In the following two sections we present a conceptual and mathematical analysis of the elicitation process and apply it to several phenomena of judgment and choice. The theoretical and practical implications of the work are discussed in the final section.

Tests of the Prominence Hypothesis

Interpersonal Tests

We illustrate the experimental procedure and the logic of the test of the prominence hypothesis in a problem involving a choice between job candidates. The participants in the first set of studies were young men and women (ages 20–30 years) who were taking a series of aptitude tests at a vocational testing institute in Tel Aviv, Israel. The problems were presented in writing, and the participants were tested in small groups. They all agreed to take part in the study, knowing it had no bearing on their test scores. Some of the results were replicated with Stanford undergraduates.

Problem 1 (Production Engineer)
Imagine that, as an executive of a company, you have to select between two candidates for a position of a Production Engineer. The candidates were interviewed by a committee who scored them on two attributes (technical knowledge and human relations) on a scale from 100 (superb) to 40 (very weak). Both attributes are important for the position in question, but technical knowledge is more important than human relations. On the basis of the following scores, which of the two candidates would you choose?

	Technical Knowledge	Human Relations	[N = 63]
Candidate X	86	76	[65%]
Candidate Y	78	91	[35%]

The number of respondents (N) and the percentage who chose each option are given in brackets on the right side of the table. In this problem, about two thirds of the respondents selected the candidate who has a higher score on the more important attribute (technical knowledge).

Another group of respondents received the same data except that one of the four scores was missing. They were asked "to complete the missing score so that the two candidates would be equally suitable for the job." Suppose, for example, that the lower left value (78) were missing from the table. The respondent's task would then be to generate a score for Candidate Y in technical knowledge so as to match the two candidates. The participants were reminded that "Y has a higher score than X in human relations, hence, to match the two candidates Y must have a lower score than X in technical knowledge."

Assuming that higher scores are preferable to lower ones, it is possible to infer the response to the choice task from the response to the matching task. Suppose, for example, that one produces a value of 80 in the matching task (when the missing value is 78). This means that X's score profile (86,76) is judged equivalent to the profile (80,91), which in turn dominates Y's profile (78,91). Thus, a matching value of 80 indicates that X is preferable to Y. More generally, a matching response above 78 implies a preference for X; a matching response below 78 implies a preference for Y; and a matching response of 78 implies indifference between X and Y.

Formally, let (X_1,X_2) and (Y_1,Y_2) denote the values of options X and Y on Attributes 1 and 2, respectively. Let V be the value of Y_1 for which the options are matched. We show that, under the standard assumptions, X is preferred to Y if and only if $V > Y_1$. Suppose $V > Y_1$, then (X_1,X_2) is equivalent to (V,Y_2) by matching, (V,Y_2) is preferred to (Y_1,Y_2) by dominance, hence, X is preferred to Y by transitivity. The other cases are similar.

We use the subscript 1 to denote the primary, or the more important dimension, and the subscript 2 to denote the secondary, or the less important dimension—whenever they are defined. If neither option dominates the other, X denotes the option that is superior on the primary dimension and Y denotes the option that is superior on the secondary dimension. Thus, X_1 is better than Y_1 and Y_2 is better than X_2.

Let C denote the percentage of respondents who chose X over Y, and let M denote the percentage of people whose matching response favored X over Y. Thus, C and M measure the tendency to decide according to the more important dimension in the choice and in the matching tasks, respectively. Assuming random allocation of subjects, procedure invariance implies $C = M$, whereas the prominence hypothesis implies $C > M$. As was shown earlier, the two contrasting predictions can be tested by using aggregate between-subjects data.

To estimate M, we presented four different groups of about 60 respondents each with the data of Problem 1, each with a different missing value, and we asked them to match the two candidates. The following table presents the values of M derived from the matching data for each of the four missing values, which are given in parentheses.

	1. Technical Knowledge	2. Human Relations
Candidate X	32% (86)	33% (76)
Candidate Y	44% (78)	26% (91)

There were no significant differences among the four matching groups, although M was greater when the missing value was low rather than high ($M_L = 39 > 29 = M_H$) and when the missing value referred to the primary rather than to the secondary attribute ($M_1 = 38 > 30 = M_2$). Overall, the matching data yielded $M = 34\%$ as compared with $C = 65\%$ obtained from choice ($p < .01$). This result supports the hypothesis that the more important attribute (e.g., technical knowledge) looms larger in choice than in matching.

In Problem 1, it is reasonable to assume—as stated—that for a production engineer, technical knowledge is more important than human relations. Problem 2 had the same structure as Problem 1, except that the primary and secondary attributes were manipulated. Problem 2 dealt with the choice between candidates for the position of an advertising agent. The candidates were characterized by their scores on two dimensions: creativity and competence. One half of the participants were told that "for the position in question, creativity is more important than competence," whereas the other half of the participants were told the opposite. As in Problem 1, most participants (65%, $N = 60$) chose according to the more important attribute (whether it was creativity or competence) but only 38% ($N = 276$) of the matching responses favored X over Y. Again, M was higher for the primary than for the secondary attribute, but all four values of M were smaller than C. The next two problems involve policy choices concerning safety and the environment.

Problem 3 (Traffic Accidents)

About 600 people are killed each year in Israel in traffic accidents. The ministry of transportation investigates various programs to reduce the number of casualties. Consider the following two programs, described in terms of yearly costs (in millions of dollars) and the number of casualties per year that is expected following the implementation of each program.

	Expected number of casualties	Cost	[$N = 96$]
Program X	500	$55M	[67%]
Program Y	570	$12M	[33%]

Which program do you favor?

The data on the right side of the table indicate that two thirds of the respondents chose Program X, which saves more lives at a higher cost per life saved. Two other groups matched the cost of either Program X or Program Y so as to make the two programs equally attractive. The overwhelming majority of matching responses in both groups (96%, $N = 146$) favored the more economical Program Y that saves fewer lives. Problem 3 yields a dramatic violation of invariance: $C = 68\%$ but $M = 4\%$. This pattern follows from the prominence hypothesis, assuming the number of casualties is more important than cost. There was no difference between the groups that matched the high ($55M) or the low ($12M) values.

A similar pattern of responses was observed in Problem 4, which involves an environmental issue. The participants were asked to compare two programs for the control of a polluted beach:

Program X: A comprehensive program for a complete clean-up of the beach at a yearly cost of $750,000 to the taxpayers.
Program Y: A limited program for a partial clean-up of the beach (that will not make it suitable for swimming) at a yearly cost of $250,000 to the taxpayers.

Assuming the control of pollution is the primary dimension and the cost is secondary, we expect that the comprehensive program will be more popular in choice than in matching. This prediction was confirmed: $C = 48\%$ ($N = 104$) and $M = 12\%$ ($N = 170$). The matching data were obtained from two groups of respondents who assessed the cost of each program so as to match the other. As in Problem 3, these groups gave rise to practically identical values of M.

Because the choice and the matching procedures are strategically equivalent, the rational theory of choice implies $C = M$. The two procedures, however, are not informationally equivalent because the missing value in the matching task is available in the choice task. To create an informationally equivalent task we modified the matching task by asking respondents, prior to the assessment of the missing value, (a) to consider the value

Table 1
Percentages of Responses Favoring the Primary Dimension Under Different Elicitation Procedures

	Dimensions			Information control			
	Primary	Secondary	Choice (C)	C^*	M^*	Matching (M)	θ
Problem:							
1. Engineer	Technical knowledge	Human relations	65	57	47	34	.82
N			63	156	151	267	
2. Agent	Competence	Creativity	65	52	41	38	.72
N			60	155	152	276	
3. Accidents	Casualities	Cost	68	50	18	4	.19
N			105	96	82	146	
4. Pollution	Health	Cost	48	32	12	12	.45
N			104	103	94	170	
5. Benefits	1 year	4 years	59			46	.86
N			56			46	
6. Coupons	Books	Travel	66			11	.57
N			58			193	
Unweighted mean			62	48	30	24	

C = percentage of respondents who chose X over Y; M = percentage of respondents whose matching responses favored X over Y; C^* = percentage of responses to Question a that lead to the choice of X; M^* = percentage of matching responses to Question b that favor option X.

used in the choice problem and indicate first whether it is too high or too low, and (b) to write down the value that they consider appropriate. In Problem 3, for example, the modified procedure read as follows:

	Expected number of casualties	Cost
Program X	500	?
Program Y	570	$12M

You are asked to determine the cost of Program X that would make it equivalent to Program Y. (a) Is the value of $55M too high or too low? (b) What is the value you consider appropriate?

The modified matching procedure is equivalent to choice not only strategically but also informationally. Let C^* be the proportion of responses to question (a) that lead to the choice of X (e.g., "too low" in the preceding example). Let M^* be the proportion of (matching) responses to question (b) that favor option X (e.g., a value that exceeds $55M in the preceding example). Thus, we may view C^* as choice in a matching context and M^* as matching in a choice context. The values of C^* and M^* for Problems 1–4 are presented in Table 1, which yields the ordering $C > C^* > M^* > M$. The finding $C > C^*$ shows that merely framing the question in a matching context reduces the relative weight of the primary dimension. Conversely, $M^* > M$ indicates that placing the matching task after a choice-like task increases the relative weight of the primary dimension. Finally, $C^* > M^*$ implies a within-subject and within-problem violation of invariance in which the response to Question a favors X and the response to Question b favors Y. This pattern of responses indicates a failure, on the part of some subjects, to appreciate the logical connection between Questions a and b. It is noteworthy, however, that 86% of these inconsistencies follow the pattern implied by the prominence hypothesis.

In the previous problems, the primary and the secondary attributes were controlled by the instructions, as in Problems 1 and 2, or by the intrinsic value of the attributes, as in Problems 3 and 4. (People generally agree that saving lives and eliminating pollution are more important goals than cutting public expenditures.) The next two problems involved benefit plans in which the primary and the secondary dimensions were determined by economic considerations.

Problem 5 (Benefit Plans)
Imagine that, as a part of a profit-sharing program, your employer offers you a choice between the following plans. Each plan offers two payments, in one year and in four years.

	Payment in 1 year	Payment in 4 years	[N = 36]
Plan X	$2,000	$2,000	[59%]
Plan Y	$1,000	$4,000	[41%]

Which plan do you prefer?

Because people surely prefer to receive a payment sooner rather than later, we assume that the earlier payment (in 1 year) acts as the primary attribute, and the later payment (in 4 years) acts as the secondary attribute. The results support the hypothesis: C = 59% (N = 56) whereas M = 46% (N = 46).

Problem 6 resembled Problem 5 except that the employee was offered a choice between two bonus plans consisting of a different combination of coupons for books and for travel. Because the former could be used in a large chain of bookstores, whereas the latter were limited to organized tours with a particular travel agency, we assumed that the book coupons would serve as the primary dimension. Under this interpretation, the prominence effect emerged again: C = 66% (N = 58) and M = 11% (N = 193). As in previous problems, M was greater when the missing value was low rather than high ($M_L = 17 > 3 = M_H$) and when the missing value referred to the primary rather than the secondary attribute ($M_1 = 19 > 4 = M_2$). All values of M, however, were substantially smaller than C.

Table 2
Percentages of Respondents (N = 101) Who Chose Between-Matched Alternatives (M = 50%) According to the Primary Dimension (After Slovic, 1975)

Alternatives	Dimensions: Primary	Dimensions: Secondary	Choice criterion	C
1. Baseball players	Batting average	Home runs	Value to team	62
2. College applicants	Motivation	English	Potential success	69
3. Gifts	Cash	Coupons	Attractiveness	85
4. Typists	Accuracy	Speed	Typing ability	84
5. Athletes	Chin-ups	Push-ups	Fitness	68
6. Routes to work	Time	Distance	Attractiveness	75
7. Auto tires	Quality	Price	Attractiveness	67
8. TV commercials	Number	Time	Annoyance	83
9. Readers	Comprehension	Speed	Reading ability	79
10. Baseball teams	% of games won against first place team	% of games won agains last place team	Standing	86
Unweighted mean				76

C = percentage of respondents who chose *X* over *Y*.

Intrapersonal Tests

Slovic's (1975) original demonstration of the choice-matching discrepancy was based entirely on an intrapersonal analysis. In his design, the participants first matched the relevant option and then selected between the matched options at a later date. They were also asked afterward to indicate the more important attribute in each case. The main results are summarized in Table 2, which presents for each choice problem the options, the primary and the secondary attributes, and the resulting values of *C*. In every case, the value of *M* is 50% by construction.

The results indicate that, in all problems, the majority of participants broke the tie between the matched options in the direction of the more important dimension as implied by the prominence hypothesis. This conclusion held regardless of whether the estimated missing value belonged to the primary or the secondary dimension, or whether it was the high value or the low value on the dimension. Note that the results of Table 2 alone could be explained by a shift in weight following the matching procedure (because the matching always preceded the choice) or by the application of a common tie-breaking procedure (because for each participant the two options were matched). These explanations, however, do not apply to the interpersonal data of Table 1.

On the other hand, Table 2 demonstrates the prominence effect within the data of each subject. The value of *C* was only slightly higher (unweighted mean: 78) when computed relative to each subject's ordering of the importance of the dimensions (as was done in the original analysis), presumably because of the general agreement among the respondents about which dimension was primary.

Theoretical Analysis

The data described in the previous section show that the primary dimension looms larger in choice than in matching. This effect gives rise to a marked discrepancy between choice and matching, which violates the principle of procedure invariance assumed in the rational theory of choice. The prominence effect raises three general questions. First, what are the psychological mechanisms that underlie the choice-matching discrepancy and other failures of procedure invariance? Second, what changes in the traditional theory are required in order to accommodate these effects? Third, what are the implications of the present results to the analysis of choice in general, and the elicitation of preference in particular? The remainder of this article is devoted to these questions.

The Compatibility Principle

One possible explanation of the prominence effect, introduced earlier in this article, is the tendency to select the option that is superior on the primary dimension, in situations where the other option does not have a decisive advantage on the secondary dimension. This procedure is easy to apply and justify because it resolves conflict on the basis of qualitative arguments (i.e., the prominence ordering of the dimensions) without establishing a rate of exchange. The matching task, on the other hand, cannot be resolved in the same manner. The decision maker must resort to quantitative comparisons to determine what interval on one dimension matches a given interval on the second dimension. This requires the setting of a common metric in which the attributes are likely to be weighted more equally, particularly when it is natural to match their ranges or to compute cost per unit (e.g., the amount of money spent to save a single life).

It is instructive to distinguish between qualitative and quantitative arguments for choice. Qualitative, or ordinal, arguments are based on the ordering of the levels within each dimension, or on the prominence ordering of the dimensions. Quantitative, or cardinal, arguments are based on the comparison of value differences along the primary and the secondary dimensions. Thus, dominance and a lexicographic ordering are purely qualitative decision rules, whereas most other models of multiattribute choice make essential use of quantitative considerations. The prominence effect indicates that qualitative considerations loom larger in the ordinal procedure of choice than in the cardinal procedure of matching, or equivalently, that quantitative considerations loom larger in matching than in choice. The prominence hypothesis, therefore, may be construed as an example of a more general principle of compatibility.

The choice-matching discrepancy, like other violations of procedure invariance, indicates that the weighting of the attributes is influenced by the method of elicitation. Alternative procedures appear to highlight different aspects of the options and thereby induce different weights. To interpret and predict such effects, we seek explanatory principles that relate task characteristics to the weighting of attributes and the evaluation of options. One such explanation is the compatibility principle. According to this principle, the weight of any input component is enhanced by its compatibility with the output. The rationale for this principle is that the characteristics of the task and the response scale prime the most compatible features of the stimulus. For example, the pricing of gambles is likely to emphasize payoffs more than probability because both the response and the payoffs are expressed in dollars. Furthermore, noncompatibility (in content, scale, or display) between the input and the output requires additional mental transformations, which increase effort and error, and reduce confidence and impact (Fitts & Seeger, 1953; Wickens, 1984). We shall next illustrate the compatibility principle in studies of prediction and similarity and then develop a formal theory that encompasses a variety of compatibility effects, including the choice-matching discrepancy and the preference reversal phenomenon.

A simple demonstration of scale compatibility was obtained in a study by Slovic, Griffin, and, Tversky (1988). The subjects ($N = 234$) were asked to predict the judgments of an admission committee of a small, selective college. For each of 10 applicants the subjects received two items of information: a rank on the verbal section of the Scholastic Aptitude Test (SAT) and the presence or absence of strong extracurricular activities. The subjects were told that the admission committee ranks all 500 applicants and accepts about the top fourth. Half of the subjects predicted the rank assigned to each applicant, whereas the other half predicted whether each applicant was accepted or rejected.

The compatibility principle implies that the numerical data (i.e., SAT rank) will loom larger in the numerical prediction task, whereas the categorical data (i.e., the presence or absence of extracurricular activities) will loom larger in the categotical prediction of acceptance or rejection. The results confirmed the hypothesis. For each pair of applicants, in which neither one dominates the other, the percentage of responses that favored the applicant with the higher SAT was recorded. Summing across all pairs, this value was 61.4% in the numerical prediction task and 44.6% in the categorical prediction task. The difference between the groups is highly significant. Evidently, the numerical data had more impact in the numerical task, whereas the categorical data had more impact in the categorical task. This result demonstrates the compatibility principle and reinforces the proposed interpretation of the choice-matching discrepancy in which the relative weight of qualitative arguments is larger in the qualitative method of choice than in the quantitative matching procedure.

In the previous example, compatibility was induced by the formal correspondence between the scales of the dependent and the independent variables. Compatibility effects can also be induced by semantic correspondence, as illustrated in the following example, taken from the study of similarity. In general, the similarity of objects (e.g., faces, people, letters) increases with the salience of the features they share and decreases with the salience of the features that distinguish between them. More specifically, the contrast model (Tversky, 1977) represents the similarity of objects as a linear combination of the measures of their common and their distinctive features. Thus, the similarity of a and b is monotonically related to

$$\theta f(A \cap B) - g(A \Delta B),$$

where $A \cap B$ is the set of features shared by a and b, and $A \Delta B = (A - B) \cup (B - A)$ is the set of features that belongs to one object and not to the other. The scales f and g are the measures of the respective feature sets.

The compatibility hypothesis suggests that common features loom larger in judgments of similarity than in judgments of dissimilarity, whereas distinctive features loom larger in judgments of dissimilarity than in judgments of similarity. As a consequence, the two judgments are not mirror images. A pair of objects with many common and many distinctive features could be judged as more similar, as well as more dissimilar, than another pair of objects with fewer common and fewer distinctive features. Tversky and Gati (1978) observed this pattern in the comparison of pairs of well-known countries with pairs of countries that were less well-known to the respondents. For example, most subjects in the similarity condition selected East Germany and West Germany as more similar to each other than Sri Lanka and Nepal, whereas most subjects in the dissimilarity condition selected East Germany and West Germany as more different from each other than Sri Lanka and Nepal. These observations were explained by the contrast model with the added assumption that the relative weight of the common features is greater in similarity than in disimilarity judgments (Tversky, 1977).

Contingent Trade-Off Models

To accommodate the compatibility effects observed in studies of preference, prediction and judgment, we need models in which the trade-offs among inputs depend on the nature of the output. In the present section we develop a hierarchy of models of this type, called contingent trade-off models. For simplicity, we investigate the two-dimensional case and follow the choice-matching terminology. Extensions and applications are discussed later. It is convenient to use $A = \{a,b,c, \ldots\}$ and $Z = \{z,y,x, \ldots\}$ to denote the primary and the secondary attributes, respectively, whenever they are properly defined. The object set S is given by the product set $A \times Z$, with typical elements az, by, and so on. Let $\geq_c$ be the preference relation obtained by choice, and let $\geq_m$ be the preference relation derived from matching.

As in the standard analysis of indifference curves (e.g., Varian, 1984, chap. 3), we assume that each $\geq_i$, $i = c,m$, is a weak order, that is, reflexive, connected, and transitive. We also assume that the levels of each attribute are consistently ordered, independent of the (fixed) level of the other attribute. That is,

$$az \geq_i bz \text{ iff } ay \geq_i by \text{ and } az \geq_i ay \text{ iff } bz \geq_i by,\ i = c,m.$$

Under these assumptions, in conjunction with the appropriate

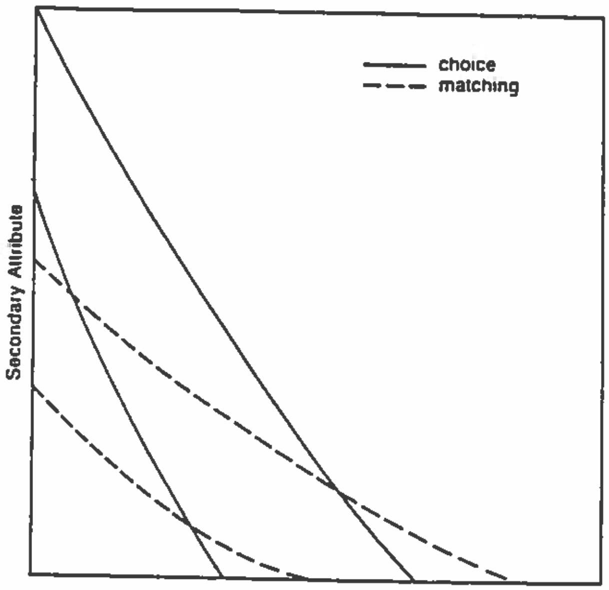

Figure 1. A dual indifference map induced by the general model (Equations 1 and 2).

structural conditions (see, e.g., Krantz, Luce, Suppes & Tversky, 1971, chap. 7), there exist functions F_i, G_i, and U_i, defined on A, Z, and $Re \times Re$, respectively, such that

$$az \geq_i by \text{ iff } U_i[F_i(a), G_i(z)] \geq U_i[F_i(b), G_i(y)], \quad (1)$$

where U_i, $i = c,m$ is monotonically increasing in each of its arguments.

Equation 1 imposes no constraints on the relation between choice and matching. Although our data show that the two orders do not generally coincide, it seems reasonable to suppose that they do coincide in unidimensional comparisons. Thus, we assume

$$az \geq_c bz \text{ iff } az \geq_m bz \text{ and } az \geq_c ay \text{ iff } az \geq_m ay.$$

It is easy to see that this condition is both necessary and sufficient for the monotonicity of the respective scales. That is,

$$F_c(b) \geq F_c(a) \text{ iff } F_m(b) \geq F_m(a) \text{ and} \quad (2)$$

$$G_c(z) \geq G_c(y) \text{ iff } G_m(z) \geq G_m(y).$$

Equations 1 and 2 define the general contingent trade-off model that is assumed throughout. The other models discussed in this section are obtained by imposing further restrictions on the relation between choice and matching. The general model corresponds to a dual indifference map, that is, two families of indifference curves, one induced by choice and one induced by matching. A graphical illustration of a dual map is presented in Figure 1.

We next consider a more restrictive model that constrains the relation between the rates of substitution of the two attributes obtained by the two elicitation procedures. Suppose the indifference curves are differentiable, and let RS_i denote the rate of substitution between the two attributes (A and Z) according to procedure $i = c,m$. Thus, $RS_i = F'_i/G'_i$, where F'_i and G'_i, respectively, are the partial derivatives of U_i with respect to F_i and G_i. Hence, $RS_i(az)$ is the negative of the slope of the indifference curve at the point az. Note that RS_i is a meaningful quantity even though F_i, G_i and U_i are only ordinal scales.

A contingent trade-off model is proportional if the ratio of RS_c to RS_m is the same at each point. That is,

$$RS_c(az)/RS_m(az) = \text{constant}. \quad (3)$$

Recall that in the standard economic model, the foregoing ratio equals 1. The proportional model assumes that this ratio is a constant, but not necessarily one. The indifference maps induced by choice and by matching, therefore, can be mapped into each other by multiplying the RS value at every point by the same constant.

Both the general and the proportional model impose few constraints on the utility functions U_i. In many situations, preferences between multiattribute options can be represented additively. That is, there exist functions F_i and G_i defined on A and Z, respectively, such that

$$az \geq_i by \text{ iff } F_i(a) + G_i(z) \geq F_i(b) + G_i(y),\ i = c,m, \quad (4)$$

where F_i and G_i are interval scales with a common unit. The existence of such an additive representation is tantamount to the existence of a monotone transformation of the axes that maps all indifference curves into parallel straight lines.

Assuming the contingent trade-off model, with the appropriate structural conditions, the following cancellation condition is both necessary and sufficient for additivity (Equation 4), see Krantz et al. (1971, chap. 6):

$$ay \geq_i bx \text{ and } bz \geq_i cy \text{ imply } az \geq_i cx,\ i = c,m.$$

If both proportionality and additivity are assumed, we obtain a particularly simple form, called the contingent weighting model, in which the utility scales F_c, F_m and G_c, G_m are linearly related. In other words, there is a monotone transformation of the axes that simultaneously linearizes both sets of indifference curves. Thus, if both Equations 3 and 4 hold, there exist functions F and G defined on A and Z, respectively, and constants α_i, β_i, $i = c,m$, such that

$$az \geq_i by \text{ iff } \alpha_i F(a) + \beta_i G(z) \geq \alpha_i F(b) + \beta_i G(y) \quad (5)$$

$$\text{iff } F(a) + \theta_i G(z) \geq F(b) + \theta_i G(y),$$

where $\theta_i = \beta_i/\alpha_i$. In this model, therefore, the indifference maps induced by choice and by matching are represented as two sets of parallel straight lines that differ only in slope $-\theta_i$, $i = c,m$ (see Figure 2). We are primarily interested in the ratio $\theta = \theta_c/\theta_m$ of these slopes.

Because the rate of substitution in the additive model is constant, it is possible to test proportionality (Equation 3) without assessing local RS_i. In particular, the contingent weighting model (Equation 5) implies the following interlocking condition:

$$ax \geq_c bw,\ dw \geq_c cx, \text{ and } by \geq_m az \text{ imply } dy \geq_m cz,$$

and the same holds when the attributes (A and Z) and the orders ($\geq_c$ and $\geq_m$) are interchanged. Figure 3 presents a graphic illustration of this condition. The interlocking condition is closely related to triple cancellation, or the Reidemeister condition (see

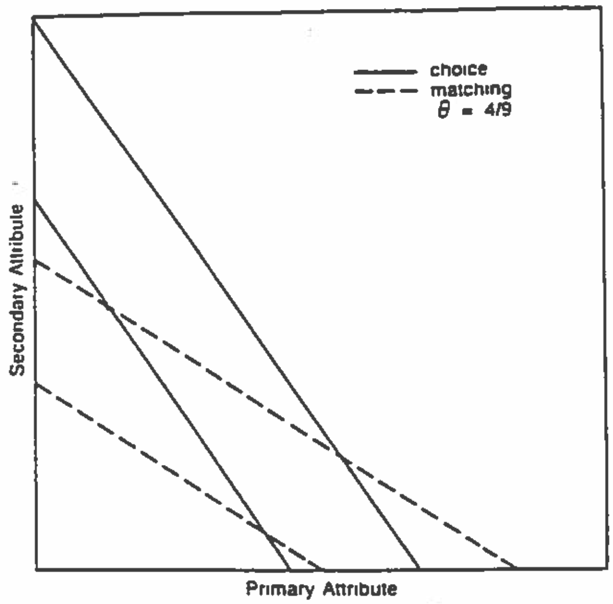

Figure 2. A dual indifference map induced by the additive model (Equation 4).

Krantz et al., 1971, 6.2.1), tested by Coombs, Bezembinder, and Goode (1967). The major difference between the assumptions is that the present interlocking condition involves two orders rather than one. This condition says, in effect, that the intradimensional ordering of A-intervals or Z-intervals is independent of the method of elicitation. This can be seen most clearly by deriving the interlocking condition from the contingent weighting model. From the hypotheses of the condition, in conjunction with the model, we obtain

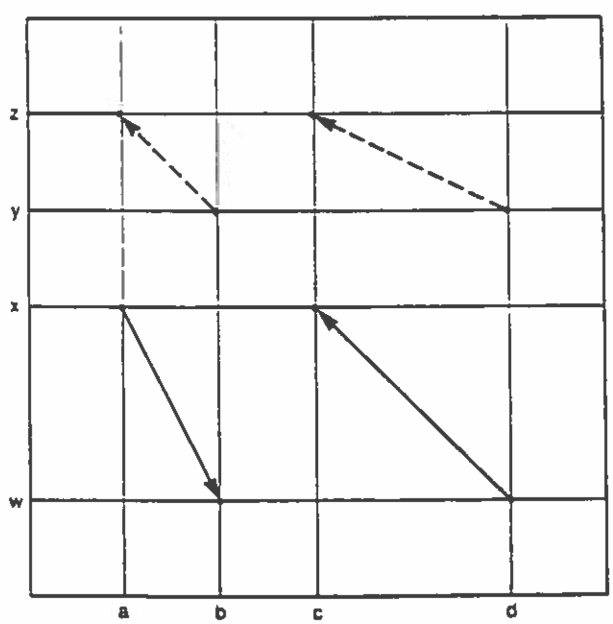

Figure 3. A graphic illustration of the interlocking condition where arrows denote preferences.

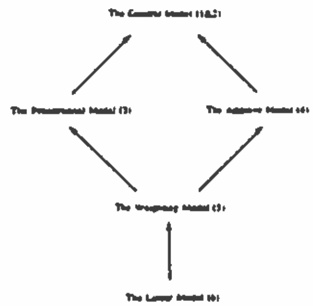

Figure 4. A hierarchy of contingent preference models. (Implications are denoted by arrows.)

$$F(a) + \theta_c G(x) \geq F(b) + \theta_c G(w) \text{ or}$$
$$\theta_c[G(x) - G(w)] \geq F(b) - F(a)$$
$$F(d) + \theta_c G(w) \geq F(c) + \theta_c G(x) \text{ or}$$
$$F(d) - F(c) \geq \theta_c[G(x) - G(w)]$$
$$F(b) + \theta_m G(y) \geq F(a) + \theta_m G(z) \text{ or}$$
$$F(b) - F(a) \geq \theta_m[G(z) - G(y)].$$

The right-hand inequalities yield

$$F(d) - F(c) \geq \theta_m[G(z) - G(y)] \text{ or}$$
$$F(d) + \theta_m G(y) \geq F(c) + \theta_m G(z),$$

hence $dy \succeq_m cz$ as required.

The interlocking condition is not only necessary but also sufficient, because it implies that the inequalities

$$F_i(d) - F_i(c) \geq F_i(b) - F_i(a) \text{ and}$$
$$G_i(z) - G_i(y) \geq G_i(x) - G_i(w)$$

are independent of $i = c,m$, that is, the two procedures yield the same ordering of intradimensional intervals. But because F_c and F_m (as well as G_c and G_m) are interval scales, they must be linearly related. Thus, there exist functions F and G and constants α_i, β_i such that

$$az \succeq_i by \text{ iff } \alpha_i F(a) + \beta_i G(z) \geq \alpha_i F(b) + \beta_i G(y).$$

Thus, we have established the following result.

Theorem: Assuming additivity (Equation 4), the contingent weighting model (Equation 5) holds iff the interlocking condition is satisfied.

Perhaps the simplest, and most restrictive, instance of Equation 5 is the case where A and Z are sets of real numbers and both F and G are linear. In this case, the model reduces to

$$az \succeq_i by \text{ iff } \alpha_i a + \beta_i z \geq \alpha_i b + \beta_i y \quad (6)$$
$$\text{iff } a + \theta_i z \geq b + \theta_i y,\ \theta_i = \beta_i/\alpha_i,\ i = c,m.$$

The hierarchy of contingent trade-off models is presented in Figure 4, where implications are denoted by arrows.

In the following section we apply the contingent weighting model to several sets of data and estimate the relative weights of the two attributes under different elicitation procedures. Naturally, all the models of Figure 4 are consistent with the compatibility hypothesis. We use the linear model (Equation 6) because it is highly parsimonious and reduces the estimation to a single parameter $\theta = \theta_c/\theta_m$. If linearity of scales or additivity of attributes is seriously violated in the data, higher models in the hierarchy should be used. The contingent weighting model can be readily extended to deal with more than two attributes and methods of elicitation.

The same formal model can be applied when the different preference orders $\geq_i$ are generated by different individuals rather than by different procedures. Indeed, the interlocking condition is both necessary and sufficient for representing the (additive) preference orders of different individuals as variations in the weighting of attributes. (This notion underlies the INDSCAL approach to multidimensional scaling, Carroll, 1972). The two representations can be naturally combined to accommodate both individual differences and procedural variations. The following analyses focus on the latter problem.

Applications

The Choice-Matching Discrepancy

We first compute $\theta = \theta_c/\theta_m$ from the choice and matching data, summarized in Table 1. Let $C(az,by)$ be the percentage of respondents who chose az over by, and let $M(az,by)$ be the percentage of respondents whose matching response favored az over by. Consider the respondents who matched the options by adjusting the second component of the second option. Because different respondents produced different values of the missing component (y), we can view $M(az,b.)$ as a (decreasing) function of the missing component. Let $\bar{y}$ be the value of the second attribute for which $M(az,b\bar{y}) = C(az,by)$.

If the choice and the matching agree, $\bar{y}$ should be equal to y, whereas the prominence hypothesis implies that $\bar{y}$ lies between y and z (i.e., $|z - y| > |z - \bar{y}|$). To estimate θ from these data, we introduce an additional assumption, in the spirit of probabilistic conjoint measurement (Falmagne, 1985, chap. 11), which relates the linear model (6) to the observed percentage of responses.

$$M(az,b\bar{y}) = C(az,by) \text{ iff}$$

$$(a + \theta_m z) - (b + \theta_m \bar{y}) = (a + \theta_c z) - (b + \theta_c y) \text{ iff} \quad (7)$$

$$\theta_m(z - \bar{y}) = \theta_c(z - y).$$

Under this assumption we can compute

$$\theta = \theta_c/\theta_m = (z - \bar{y})/(z - y),$$

and the same analysis applies to the other three components (i.e., $\bar{a}$, $\bar{b}$, and $\bar{z}$).

We applied this method to the aggregate data from Problems 1 to 6. The average values of θ, across subjects and components, are displayed in Table 1 for each of the six problems. The values of $\theta = \theta_c/\theta_m$ are all less than unity, as implied by the prominence hypothesis. Note that θ provides an alternative index of the choice-matching discrepancy that is based on Equations 6 and 7—unlike the difference between C and M that does not presuppose any measurement structure.

Prediction of Performance

We next use the contingent weighting model to analyze the effect of scale compatibility observed in a study of the prediction of students' performance, conducted by Slovic et al. (1988). The subjects ($N = 234$) in this study were asked to predict the performance of 10 students in a course (e.g., History) on the basis of their performance in two other courses (e.g., Philosophy and English). For each of the 10 students, the subjects received a grade in one course (from A to D), and a class rank (from 1 to 100) in the other course. One half of the respondents were asked to predict a grade, and the other half were asked to predict class rank. The courses were counterbalanced across respondents. The compatibility principle implies that a given predictor (e.g., grade in Philosophy) will be given more weight when the predicted variable is expressed on the same scale (e.g., grade in History) than when it is expressed on a different scale (e.g., class rank in History). The relative weight of grades to ranks, therefore, will be higher in the group that predicts grades than in the group that predicts ranks.

Let (r_i, g_j) be a student profile with rank i in the first course and grade j in the second. Let r_{ij} and g_{ij} denote, respectively, the predicted rank and grade of that student. The ranks range from 1 to 100, and the grades were scored as A+ = 10, A = 9, . . . , D = 1. Under the linear model (Equation 6), we have

$$r_{ij} = \alpha_r r_i + \beta_r g_j \text{ and } g_{ij} = \alpha_g r_i + \beta_g g_j$$

By regressing the 10 predictions of each respondent against the predictors, r_i and g_j, we obtained for each subject in the rank condition an estimate of $\theta_r = \beta_r/\alpha_r$, and for each subject in the grade condition an estimate of $\theta_g = \beta_g/\alpha_g$. These values reflect the relative weight of grades to ranks in the two prediction tasks. As implied by the compatibility hypothesis, the values of θ_g were significantly higher than the values of θ_r, $p < .001$ by a Mann-Whitney test.

Figure 5 represents each of the 10 students as a point in the rank × grade plane. The slopes of the two lines, θ_r and θ_g, correspond to the relative weights of grade to rank estimated from the average predictions of ranks and grades, respectively. The multiple correlation between the inputs (r_i, g_j) and the average predicted scores was .99 for ranks and .98 for grades, indicating that the linear model provides a good description of the aggregate data. Recall that in the contingent weighting model, the predicted scores are given by the perpendicular projections of the points onto the respective lines, indicated by notches. The two lines, then, are orthogonal to the equal-value sets defined by the two tasks. The figure shows that grades and ranks were roughly equally weighted in the prediction of grades ($\theta_g = 1.06$), but grades were given much less weight than ranks in the prediction of ranks ($\theta_r = .58$). As a consequence, the two groups generated different ordering of the students. For example, the predicted rank of Student 9 was higher than that of Student 8, but the order of the predicted grades was reversed. Note that the numbered points in Figure 5 represent the design, not the data. The discrepancy between the two orderings is determined jointly by the angle between the lines that is estimated from subjects' predictions, and by the correlation between the two dimensions that is determined by the design.

These data suggest a more detailed account based on a process of anchoring and adjustment (Slovic & Lichtenstein, 1971;

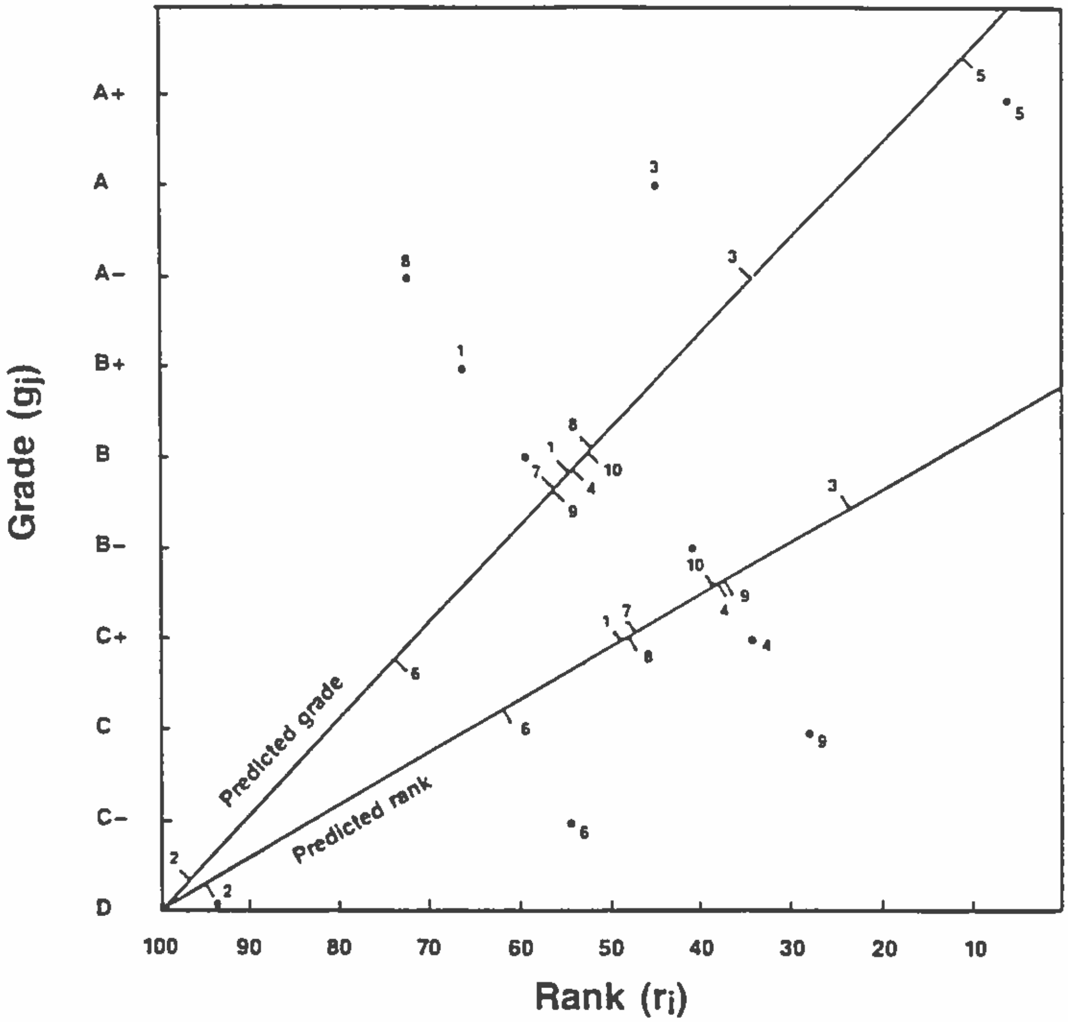

Figure 5. Contingent weighting representation of predicted ranks and grades. (The dots characterize the input information for each of the 10 students. The slopes of the two lines correspond to the relative weight of grades to ranks in the two prediction tasks.)

Tversky & Kahneman, 1974). According to this heuristic, the subject uses the score on the compatible attribute (either rank or grade) as an anchor, and adjusts it upward or downward on the basis of the other score. Because adjustments are generally insufficient, the compatible attribute is overweighted. Although the use of anchoring and adjustment probably contribute to the phenomenon in question, Slovic et al. (1988) found a significant compatibility effect even when the subject only predicted which of the two students would obtain a higher grade (or rank), without making any numerical prediction that calls for anchoring and adjustment.

Preference Reversals

The contingent weighting model (Equation 5) and the compatibility principle can also be used to explain the well-known preference reversals discovered by Lichtenstein and Slovic (1971; see also Slovic and Lichtenstein, 1968, 1983). These investigators compared two types of bets with comparable expected values—an H bet that offers a high probability of winning a relatively small amount of money (e.g., 32/36 chance to win $4) and an L bet that offers a low probability of winning a moderate amount of money (e.g., 9/36 chance to win $40). The results show that people generally choose the H bet over the L bet (i.e., $H >_c L$) but assign a higher cash equivalent to the L bet than to the H bet (i.e., $C_L > C_H$, where C_L and C_H are the amounts of money that are as desirable as L and H respectively). This pattern of preferences, which is inconsistent with the theory of rational choice, has been observed in numerous experiments, including a study conducted on the floor of a Las Vegas casino (Lichtenstein & Slovic, 1973), and it persists even in the presence of monetary incentives designed to promote consistent responses (Grether & Plott, 1979).

Although the basic phenomenon has been replicated in many studies, the determinants of preference reversals and their causes have remained elusive heretofore. It is easy to show that the reversal of preferences implies either intransitive choices or a choice-pricing discrepancy (i.e., a failure of invariance), or both. In order to understand this phenomenon, it is necessary to assess the relative contribution of these factors because they imply different explanations. To accomplish this goal, however, one must extend the traditional design and include, in addition to the bets H and L, a cash amount X that is compared with both. If procedure invariance holds and preference reversals are due to intransitive choices, then we should obtain the cycle $L >_c X >_c H >_c L$. If, on the other hand, transitivity holds and preference reversals are due to an inconsistency between choice and pricing, then we should obtain either $X >_c L$ and $C_L > X$, or $H >_c X$ and $X > C_H$. The first pattern indicates that L is *overpriced* relative to choice, and the second pattern indicates that H is *underpriced* relative to choice. Recall that $H >_c X$ refers to the choice between the bet H and the sure thing X, while $X > C_H$ refers to the ordering of cash amounts.

Following this analysis, Tversky, Slovic, and Kahneman (1988) conducted an extensive study of preference reversals, using 18 triples (H,L,X) that cover a wide range of probabilities and payoffs. A detailed analysis of response patterns showed that, by far, the most important determinant of preference reversals is the overpricing of L. Intransitive choices and the underpricing of H play a relatively minor role, each accounting for less than 10% of the total number of reversals. Evidently, preference reversals represent a choice-pricing discrepancy induced by the compatibility principle: Because pricing is expressed in monetary units, the payoffs loom larger in pricing than in choice.

We next apply the contingent weighting model to a study reported by Tversky et al. (1988) in which 179 participants (a) chose between 6 pairs consisting of an H bet and an L bet, (b) rated the attractiveness of all 12 bets, and (c) determined the cash equivalent of each bet. In order to provide monetary incentives and assure the strategic equivalence of the three methods, the participants were informed that a pair of bets would be selected at random, and that they would play the member of the pair that they had chosen, or the bet that they had priced or rated higher. The present discussion focuses on the relation between pricing and rating, which can be readily analyzed using multiple regression. In general, rating resembles choice in favoring the H bets, in contrast to pricing that favors the L bets. Note that in rating and pricing each gamble is evaluated separately, whereas choice (and matching) involve a comparison between gambles. Because the discrepancy between rating and pricing is even more pronounced than that between choice and pricing, the reversal of preferences cannot be explained by the fact that choice is comparative whereas pricing is singular. For further discussions of the relation between rating, choice, and pricing, see Goldstein and Einhorn (1987), and Schkade and Johnson (1987).

We assume that the value of a simple prospect (q,y) is approximated by a multiplicative function of the probability q and the payoff y. Thus, the logarithms of the pricing and the rating can be expressed by

$$\theta_i \log y + \log q, \; i = r,p, \quad (8)$$

where θ_r and θ_p denote the relative weight of the payoff in the rating and in the pricing tasks, respectively. Note that this model implies a power utility function with an exponent θ_i. The average transformed rating and pricing responses for each of the 12 bets were regressed, separately, against $\log q$ and $\log y$. The multiple correlations were .96 and .98 for the ratings and the pricing, respectively, indicating that the relation between rating and pricing can be captured, at least in the aggregate data, by a very simple model with a single parameter.

Figure 6 represents each of the 12 bets as a (numbered) point in the plane whose coordinates are probability and money, plotted on a logarithmic scale. The rating and pricing lines in the figure are perpendicular to the respective sets of linear indifference curves (see Figure 2). Hence, the projections of each bet on the two lines (denoted by notches) correspond to their values derived from rating and pricing, respectively. The angle between these lines equals the (smaller) angle between the intersecting families of indifference curves. Figure 6 reveals a dramatic difference between the slopes: $\theta_r = 2.7$, $\theta_p = .75$, hence $\theta = \theta_p/\theta_r = .28$. Indeed, these data give rise to a negative correlation ($r = -.30$) between the rating and the pricing, yielding numerous reversals of the ordering of the projections on the two lines. For example, the most extreme L bet (No. 8) has the lowest rating and the highest cash equivalent in the set.

The preceding analysis shows that the compatibility principle, incorporated into the contingent weighting model, provides a simple account of the well-known preference reversals. It also yields new predictions, which have been confirmed in a recent study. Note that if preference reversals are caused primarily by the overweighting of payoffs in the pricing task, then the effect should be much smaller for nonmonetary payoffs. Indeed, Slovic et al. (1988) found that the use of nonmonetary payoffs (e.g., a dinner for two at a very good restaurant or a free weekend at a coastal resort) greatly reduced the incidents of preference reversals. Furthermore, according to the present analysis, preference reversals are not limited to risky prospects. Tversky et al. (1988) constructed riskless options of the form ($\$x,t$) that offers a payment of $\$x$ at some future time, t (e.g., 3 years from now). Subjects chose between such options, and evaluated their cash equivalents. The cash equivalent (or the price) of the option ($\$x,t$) is the amount of cash, paid immediately, that is as attractive as receiving $\$x$ at time t. Because both the price and the payment are expressed in dollars, compatibility implies that the payment will loom larger in pricing than in choice. This prediction was confirmed. Subjects generally chose the option that paid sooner, and assigned a higher price to the option that offered the larger payment. For example, 85% of the subjects ($N = 169$) preferred $2,500 in 5 years over $3,550 in 10 years, but 71% assigned a higher price to the second option. Thus, the replacement of risk by time gives rise to a new type of reversals. Evidently, preference reversals are determined primarily by the compatibility between the price and the payoff, regardless of the presence or absence of risk.

We conclude this section with a brief discussion of alternative accounts of preference reversals proposed in the literature. One class of comparative theories, developed by Fishburn (1984, 1985) and Loomes and Sugden (1982, 1983), treat preference reversals as intransitive choices. As was noted earlier, however, the intransitivity of choice accounts for only a small part of the phenomenon in question, hence these theories do not provide a fully satisfactory explanation of preference reversals. A different model, called expression theory, has been developed by Goldstein and Einhorn (1987). This model is a special case of the contingent model defined by Equation 1. It differs from the present treatment in that it focuses on the expression of prefer-

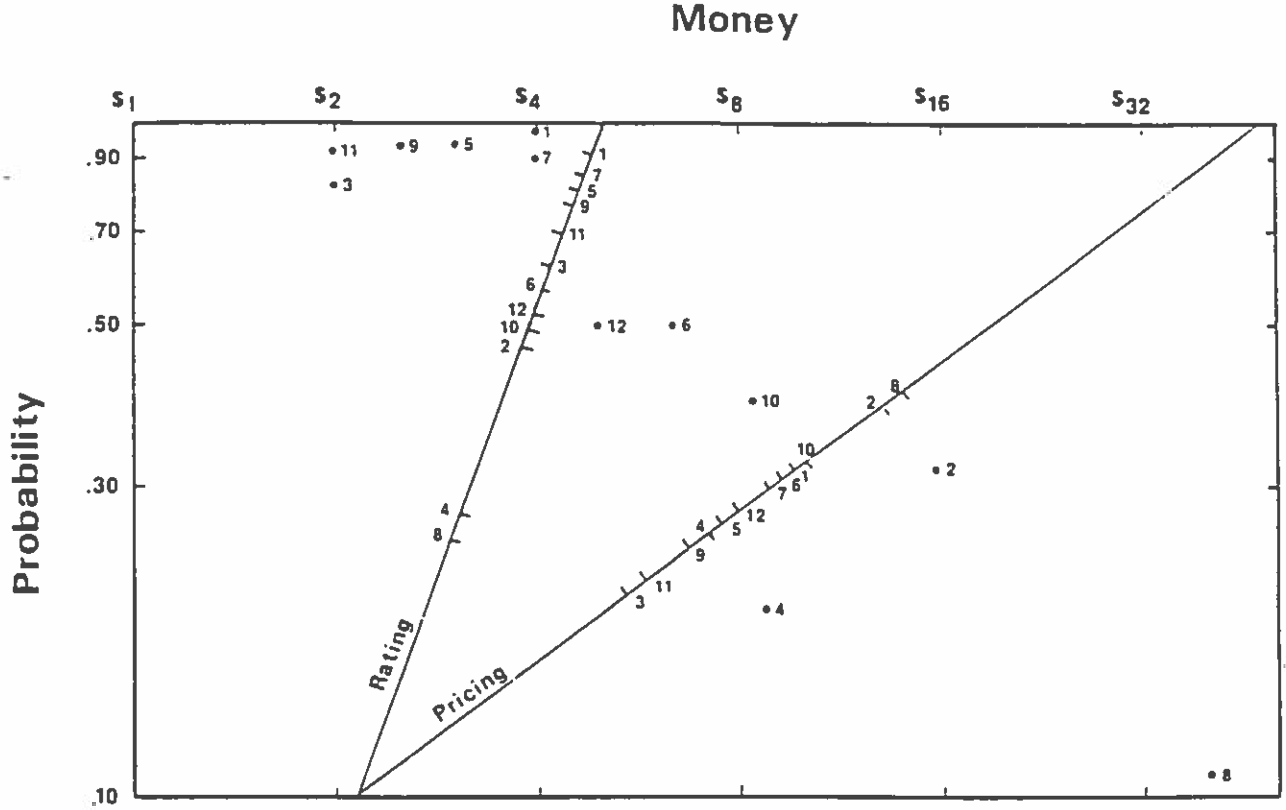

Figure 6. Contingent weighting representation of rating and pricing. (The dots characterize the six *H* bets and six *L* bets denoted by odd and even numbers, respectively, in logarithmic coordinates. The slopes of the two lines correspond to the weight of money relative to probability in rating and pricing.)

ences rather than on the evaluation of prospects. Thus, it attributes preference reversals to the mapping of subjective value onto the appropriate response scale, not to the compatibility between the input and the output. As a consequence, this model does not imply many of the compatibility effects described in this article, such as the contingent weighting of grades and ranks in the prediction of students' performance, the marked reduction in preference reversals with nonmonetary payoffs, and the differential weighting of common and of distinctive features in judgments of similarity and dissimilarity.

A highly pertinent analysis of preference reversals based on attention and anchoring data was proposed by Schkade and Johnson (1987). Using a computer-controlled experiment in which the subject can see only one component of each bet at a time, these investigators measured the amount of time spent by each subject looking at probabilities and at payoffs. The results showed that in the pricing task, the percentage of time spent on the payoffs was significantly greater than that spent on probabilities, whereas in the rating task, the pattern was reversed. This observation supports the hypothesis, suggested by the compatibility principle, that subjects attended to payoffs more in the pricing task than in the rating task.

The relation between preference reversals and the choice-matching discrepancy was explored in a study by Slovic et al. (1988). Subjects matched twelve pairs of *H* and *L* bets by completing the missing probability or payoff. The overall percentage of responses that favored *H* over *L* was 73% for probability matches and 49% for payoff matches. (For comparison, 76% preferred *H* over *L* in a direct choice.) This result follows from scale compatibility: The adjusted attribute, either probability or money, looms larger than the nonadjusted attribute. However, the pattern differs from the prominence effect described earlier, which produced relatively small differences between the matches on the primary and the secondary attributes and large differences between choice and matching (see, e.g., Problem 1). This contrasts with the present finding of large differences between probability and payoff matches, and no difference between probability matches and choice. Evidently, preference reversals are induced primarily by scale compatibility, not by the differential prominence of attributes that underlies the choice-matching discrepancy. Indeed, there is no obvious reason to suppose that probability is more prominent than money or vice versa. For further examples and discussions of elicitation biases in risky choice, see Fischer, Damodaran, Laskey, and Lincoln (1987), and Hershey and Schoemaker (1985).

Discussion

The extensive use of rational theories of choice (e.g., the expected utility model or the theory of revealed preference) as descriptive models (e.g., in economics, management, and political science) has stimulated the experimental investigation of the descriptive validity of the assumptions that underlie these models. Perhaps the most basic assumption of the rational theory of choice is the principle of invariance (Kahneman and Tversky, 1984) or extensionality (Arrow, 1982), which states that the relation of preference should not depend on the description of the options (description invariance) or on the method of elicitation (procedure invariance). Empirical tests of description invariance have shown that alternative framing of the same options can lead to different choices (Tversky and Kahneman, 1986). The present studies provide evidence against the assumption of procedure invariance by demonstrating a systematic discrepancy between choice and matching, as well as between rating and pricing. In this section we discuss the main findings and explore their theoretical and practical implications.

In the first part of the article we showed that the more important dimension of a decision problem looms larger in choice than in matching. We addressed this phenomenon at three levels of analysis. First, we presented a heuristic account of choice and matching that led to the prominence hypothesis; second, we related this account to the general notion of input-output compatibility; and third, we developed the formal theory of contingent weighting that represents the prominence effect as well as other elicitation phenomena, such as preference reversals. The informal analysis, based on compatibility, provides a psychological explanation for the differential weighting induced by the various procedures.

Although the prominence effect was observed in a variety of settings using both intrapersonal and interpersonal comparisons, its boundaries are left to be explored. How does it extend to options that vary on a larger number of attributes? The present analysis implies that the relative weights of any pair of attributes will be less extreme (i.e., closer to unity) in matching than in choice. With three or more attributes, however, additional considerations may come into play. For example, people may select the option that is superior on most attributes (Tversky, 1969, Experiment 2). In this case, the prominence hypothesis does not always result in a lexicographic bias. Another question is whether the choice-matching discrepancy applies to other judgmental or perceptual tasks. The data on the prediction of students' performance indicate that the prominence effect is not limited to preferential choice, but it is not clear whether it applies to psychophysics. Perceived loudness, for example, depends primarily on intensity and to a lesser degree on frequency. It could be interesting to test the prominence hypothesis in such a context.

The finding that the qualitative information about the ordering of the dimensions looms larger in the ordinal method of choice than in the cardinal method of matching has been construed as an instance of the compatibility principle. This principle states that stimulus components that are compatible with the response are weighted more heavily than those that are not presumably because (a) the former are accentuated, and (b) the latter require additional mental transformations that produce error and reduce the diagnosticity of the information. This effect may be induced by the nature of the information (e.g., ordinal vs. cardinal), by the response scale (e.g., grades vs. ranks), or by the affinity between inputs and outputs (e.g., common features loom larger in similarity than in dissimilarity judgments). Compatibility, therefore, appears to provide a common explanation to many phenomena of judgment and choice.

The preceding discussion raises the intriguing normative question as to which method, choice or matching, better reflects people's "true" preferences. Put differently, do people overweigh the primary dimension in choice or do they underweigh it in matching? Without knowing the "correct" weighting, it is unclear how to answer this question, but the following study provides some relevant data. The participants in a decision-making seminar performed both choice and matching in the traffic-accident problem described earlier (Problem 3). The two critical (choice and matching) questions were embedded in a questionnaire that included similar questions with different numerical values. The majority of the respondents (21 out of 32) gave inconsistent responses that conformed to the prominence hypothesis. After the session, each participant was interviewed and confronted with his or her answers. The subjects were surprised to discover that their responses were inconsistent and they offered a variety of explanations, some of which resemble the prominence hypothesis. One participant said, "When I have to choose between programs I go for the one that saves more lives because there is no price for human life. But when I match the programs I have to pay attention to money." When asked to reconsider their answers, all respondents modified the matching in the direction of the choice, and a few reversed the original choice in the direction of the matching. This observation suggests that choice and matching are both biased in opposite directions, but it may reflect a routine compromise rather than the result of a critical reassessment.

Real-world decisions can sometimes be framed either as a direct choice (e.g., should I buy the used car at this price?) or as a pricing decision (e.g., what is the most I should pay for that used car?). Our findings suggest that the answers to the two questions are likely to diverge. Consider, for example, a medical decision problem where the primary dimension is the probability of survival and the secondary dimension is the cost associated with treatment or diagnosis. According to the present analysis, people are likely to choose the option that offers the higher probability of survival with relatively little concern for cost. When asked to price a marginal increase in the probability of survival, however, people are expected to appear less generous. The choice-matching discrepancy may also arise in resource allocation and budgeting decisions. The prominence hypothesis suggests that the most important item in the budget (e.g., health) will tend to dominate a less important item (e.g., culture) in a direct choice between two allocations, but the less important item is expected to fare better in a matching procedure.

The lability of preferences implied by the demonstrations of framing and elicitation effects raises difficult questions concerning the assessment of preferences and values. In the classical analysis, the relation of preference is inferred from observed responses (e.g., choice, matching) and is assumed to reflect the decision maker's underlying utility or value. But if different elicitation procedures produce different ordeaings of options, how can preferences and values be defined? And in what sense do they exist? To be sure, people make choices, set prices, rate options and even explain their decisions to others. Preferences, therefore, exist as observed data. However, if these data do not satisfy the elementary requirements of invariance, it is unclear how to define a relation of preference that can serve as a basis for the measurement of value. In the absence of well-defined preferences, the foundations of choice theory and decision analysis are called into question.

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