ORGANIZATIONAL BEHAVIOR AND HUMAN DECISION PROCESSES 55, 325–378 (1993)

The Advantage Model: A Comparative Theory of Evaluation and Choice under Risk

ELDAR B. SHAFIR

Princeton University

DANIEL N. OSHERSON

IDIAP, Switzerland

AND

EDWARD E. SMITH

University of Michigan

A descriptive model of choice between monetary lotteries—called the Advantage Model of Choice—is proposed. According to the model, people evaluate lotteries in a choice problem by comparing them separately on the dimension of gains and on the dimension of losses. In making these comparisons, people employ both "absolute" and "comparative" strategies that are subsequently combined to yield a choice. The model is evaluated on both qualitative and quantitative grounds. As part of the qualitative evaluation, a number of previously documented phenomena that characterize people's choices between lotteries are reviewed. It is shown that the Advantage Model is consistent with these phenomena. As part of the quantitative evaluation, three experimental tests of the model are reported. The model's ability to predict both individual choice and group preference is evaluated, and the model is shown to compare favorably to particular versions of Prospect Theory and Utility Theory. It is suggested that the Advantage Model captures one of the underlying processes that guide human choice behavior in risky situations. Examples of the model's relevance to nonmonetary domains are provided.

1. INTRODUCTION

The classical theory of decision making under risk, generally known as expected utility theory (and axiomatized by von Neumann and Morgenstern, 1947), constitutes an impressive mathematical achievement in both

This research was supported by US Public Health Service Grant #1-R29-MH46885 from the National Institute of Mental Health and by National Science Foundation Grants #8609201 and #8705444. We thank two anonymous reviewers for helpful comments. Correspondence to Eldar Shafir, Department of Psychology, Princeton University, Princeton, NJ 08544. e-mail: eldar@clarity.princeton.edu.

0749-5978/93 $5.00

scope and simplicity. The theory, however, was intended as a normative model of idealized, rational agents, not as a descriptive model of actual decision makers. A variety of behavioral phenomena show that people's preferences among monetary lotteries systematically violate the axioms of expected utility theory (for a review of the literature, see Slovic, Lichtenstein, & Fischhoff, 1989). As a consequence, it has been argued that the theory is inadequate as a descriptive model, and a search for alternative, descriptive accounts of choice among monetary lotteries has emerged. One such account is proposed in the present paper, which proceeds as follows. We first argue that an adequate descriptive model of choice must be partially "comparative" in character. Contrary to the assumptions of the classical view, the attractiveness of an option depends partially on the options against which it is being compared. We then present a partially comparative model of choice—called the Advantage Model—and proceed to discuss it from a qualitative point of view. We review a number of phenomena that have been shown to characterize human choice behavior and illustrate how the model helps make sense of these qualitative phenomena, some of which remain outside the purview of noncomparative theories. Next, we turn to a quantitative evaluation of the Advantage Model. Three experiments designed to evaluate the model against comparable versions of expected utility theory (henceforth, Utility Theory) and Prospect Theory are reported. Having ascertained that the model compares favorably with these popular theories, we conclude by illustrating how the model may be extended to nonmonetary choices.

2. COMPARATIVE CHOICE

We distinguish two approaches to understanding the preferences exhibited by naive subjects faced with a choice between lotteries (Tversky, 1969). These approaches are called absolute and comparative. Both assign a hypothetical attractiveness coefficient to each lottery in a given choice problem and predict that the lottery assigned the numerically higher coefficient will be preferred. They differ, however, in their conception of the process through which alternatives are evaluated. The classical theory of choice and influential successors like Prospect Theory have adopted the absolute approach. Within the absolute approach the attractiveness of a lottery is assumed to be independent of the alternative with which it is paired. The decision maker is assumed to evaluate each option separately and to choose the option assigned the highest subjective value. In contrast, comparative theories evaluate the attractiveness of lotteries only in the context of a specified choice problem. They assume a choice process in which options are compared to one another, the attractiveness of each option depending partially on the options against which it is being compared.

Recent work on process tracing and context effects has provided experimental evidence for comparative heuristics in choice. Russo and Dosher (1983), for example, present eye-movement data and verbal protocols to demonstrate that subjects first evaluate differences between lotteries on the separate dimensions of probability and payoff before combining these estimates to yield a choice. These findings agree with other studies that use decision tracing methods and report evidence for comparative heuristics in preference judgments. Reviews of the relevant literature are provided by Russo and Dosher (1983) and by Schoemaker (1982).

Recent studies in consumer choice have also revealed phenomena that argue for a comparative framework of choice. These context-dependent phenomena illustrate the ability of inferior options to effect the choice probability of preferred options, a result that is irreconcilable with the predictions of an absolute framework. Consider, for example, three options, W, X, and Z, that differ along two dimensions as illustrated schematically in Fig. 1. The "compromise effect" (Simonson, 1989) refers to the fact that the probability of choosing the middle option—X—is greater when all three options are available than when either W or Z is removed. Using the notation X(X,W,Z) to denote the probability of choosing the alternative X out of the set of alternatives X, W, and Z, the compromise effect may be summarized this way:

$$X(X,W,Z) > X(X,W),\ X(X,Z). \tag{1}$$

The compromise effect violates regularity, i.e., the notion that one cannot increase the probability of choosing a particular option by adding other options to the set, a minimum condition on absolute models of choice (Luce, 1977). Apparently, what contributes to X's attractiveness when all three alternatives are available is its status as a "compromise alternative," not extreme on either dimension, which is a comparative not an absolute notion.

Consider next the "asymmetric dominance" effect, which has been

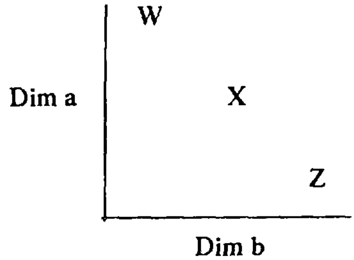


FIG. 1. A schematic illustration of a set of options yielding the compromise effect.

shown to characterize consumer choice in numerous domains (Huber, Payne, & Puto, 1982; Huber & Puto, 1983). In the context of this effect, illustrated schematically in Fig. 2, the probability that one of a pair of options, X, Y, will be selected increases significantly when an option that is inferior to it in all respects, X_0 or Y_0, respectively, is added to the set. That is:

$$X(X_0,X,Y) > X(X,Y) \quad \text{and} \quad Y(Y_0,X,Y) > Y(X,Y). \tag{2}$$

It is easy to see that the inequalities in (2) are incompatible with absolute models of choice, according to which the probability of choosing an option should not be affected by the introduction of a dominated option.

While the asymmetric dominance effect is irreconcilable with the absolute approach, it fits naturally within a comparative framework. To the extent that options are evaluated partially in comparison to other alternatives in the set, the presence of a dominated option is likely to contribute to the attractiveness of the option which dominates it. The dominated option (say, X_0) presents an advantage—uncontested superiority on all dimensions—for the dominating option (X), as opposed to the competing option (Y). This view of the choice process as guided by the relative advantages accruing to each option in the set motivates the model of choice that we present next.

3. THE ADVANTAGE MODEL OF CHOICE

The Advantage Model is a comparative theory, in that the attractiveness of a lottery in a choice problem depends, according to the model, on the lottery against which it is being compared. The model is not *purely* comparative, however, since prior studies of choice suggest a role for absolute as well as comparative strategies in the evaluation of lotteries (see, e.g., Payne, 1976; Payne & Braunstein, 1978; Russo & Dosher, 1983). We thus formulate a model that effects a compromise between

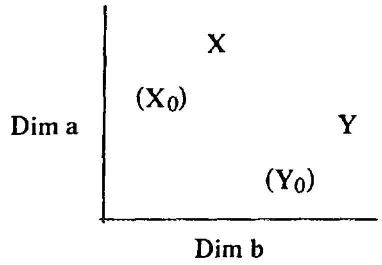


FIG. 2. A schematic illustration of a set of options yielding the asymmetric dominance effect.

comparative and absolute inclinations. The Advantage Model construes the attractiveness of monetary lotteries as the result of absolute and comparative evaluations that are subsequently combined. An earlier version of the model—limited to single outcome lotteries involving only gains or only losses—was presented in Shafir, Osherson, and Smith (1989). The present version constitutes an extension of the earlier treatment into a broader set of contexts and is used to predict a richer set of choice phenomena.

3.1. Terminology

A "positive lottery" means a less-than-certain chance p to win a specified sum of money d. Such a lottery will be represented by the pair $(+d,p)$. A "negative lottery" means a less-than-certain chance p to lose a specified sum of money d. Such a lottery is represented by the pair $(-d,p)$. Positive and negative lotteries in the sense just defined will be called "simple" lotteries. To designate simple lotteries without specifying whether they are positive or negative, we use (d,p). A "simple choice problem" means an invitation to choose between a pair of simple lotteries. Such a pair will be denoted $[(d_1,p_1),(d_2,p_2)]$.

A "mixed" lottery means a less-than-certain chance p to win a specified sum of money d coupled with a chance $1 - p$ to lose a specified sum of money e (where exactly one of these two outcomes must occur). Such a lottery will be represented by the triple (d,p,e), where p is the chance to win d and $1 - p$ is the chance to lose e. A "mixed choice problem" means an invitation to choose between a pair of mixed lotteries. Such a pair will be denoted $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$.

When using the notation $[(d_1,p_1),(d_2,p_2)]$ or $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$, it is always understood that $p_1 < p_2$. Indeed, we shall limit attention in what follows to choice problems that manifest some difference in probabilities p_1,p_2. Pairs of lotteries—either simple or mixed—that fail to exhibit probability or payoff advantages are assumed to trigger choice mechanisms that lie outside the domain of the Advantage Model.[1] Hence, in using the foregoing notation for representing choice problems, we always abide by the convention that $p_1 < p_2$.

3.2. The attractiveness of lotteries

The Advantage Model is motivated by the intuition that when choosing between lotteries, people employ both absolute and comparative strategies, the results of which are subsequently combined. These two kinds of

[1] We call such pairs of lotteries "nonconflictual." For a discussion of nonconflictual lotteries as well as other special kinds of lotteries that remain outside the domain of the present model, see Shafir (1988).

strategic inclinations are captured in the model via the simplest possible mechanisms. According to the model, a person's absolute strategy consists of a rough evaluation of each lottery's "size," to be captured by Expected Monetary Value, $d * p$. This strategy provides an estimate of the magnitude of payoffs independent of their relative advantage. Thus, while $1000 may have a similar advantage over $500 as $100 has over $50 (in both cases one is twice as large as the other), the absolute estimate insures that the former be seen as generally more attractive than the latter. A person's comparative strategy evaluates (a) the relative difference in payoff between the two lotteries and (b) their difference in probabilities. This comparative strategy is consistent with the notion of dimensional commensurability (see, e.g., Slovic & MacPhillamy, 1974), which suggests that comparing alternatives on payoffs and then comparing them on probabilities is easier than attempting to integrate probability and payoff information within each option. Such attribute-by-attribute comparison processes are prevalent in recent work on categorization and induction, ranging from models that involve attribute comparisons among categories (e.g., Smith, Osherson, Rips, & Keane 1988) to work influenced by Artificial Intelligence, wherein frames, slots, and fillers are compared (e.g., Murphy, 1988). In the Advantage Model, the payoff and probability comparisons are employed separately along the dimensions of gains and losses. The attractivenesses of positive and negative lotteries are evaluated separately and are then combined to yield the attractiveness of mixed lotteries.

3.2.1. Simple choice problems. For expositional clarity, we first present a specialization of the Advantage Model to the case of simple choice problems. Consider a person choosing between the two lotteries figuring in the simple choice problem $[(d_1,p_1),(d_2,p_2)]$, (where, by convention, $p_1 < p_2$). According to the model, the person attempts both a rough absolute evaluation of the two lotteries, as well as a heuristic comparative evaluation. To represent the absolute component of the subject's judgment, we define $\text{EMV}_1 = d_1 * p_1$; $\text{EMV}_2 = d_2 * p_2$. For the comparative component, we let $p_2 - p_1$ represent the "probability advantage" of the lottery (d_2,p_2), and we let $(d_1 - d_2)/d_1$ represent the "payoff advantage" of the lottery (d_1,p_1). The subject is assumed to compare the competing lotteries on the dimensions of probabilities and of payoffs. Notice that the payoff advantage has been normalized by d_1 because in these situations people have been shown to be more sensitive to relative rather than absolute payoff magnitudes (as is illustrated in Section 4 below). Thus, a lottery's probability advantage is determined by the difference in probabilities while the competing lottery's payoff advantage is ultimately determined by the payoffs' ratio.

A probability advantage is qualitatively different than a payoff advantage. As a means for comparing these two qualitatively different advantages, we introduce into the model unitless parameters that represent the relative weight of payoffs and probabilities. Each parameter takes the form of a multiplicative coefficient attached to the payoff advantage, $(d_1 - d_2)/d_1$, of the lottery (d_1,p_1). A person's relative weight of payoffs to probabilities, however, is likely to differ when the payoffs represent gains from when they represent losses. Thus, a person may focus his attention on the amounts to be lost when losses are concerned, but care more about the chances involved when gains are at stake. For this reason, we introduce two parameters: one for payoffs that are gains and the other for losses. These parameters are denoted k_G and k_L, respectively. (A number of researchers have similarly perceived the need to introduce sign-dependent utility functions intended to treat gains and losses separately; see, e.g., Hogarth & Einhorn, 1990; Luce, 1991; Tversky & Kahneman, 1992). According to our model, these weighting factors may differ from person to person, but each person has exactly two such factors, k_G and k_L, applicable to all simple choice problems. For other decision situations (e.g., assessing a lottery's monetary value or determining its probability equivalent) the value of these weighting factors is assumed to vary in a systematic manner to be discussed in Section 3.4.

Assembling the absolute and comparative components of the model with the two parameters, we arrive at the following formulation which captures our motivating intuitions regarding the attractiveness of lotteries in simple choice problems.

The attractiveness of lotteries in simple choice problems (3)
For every person S there are k_G, $k_L > 0$ such that for any simple choice problem $[(d_1,p_1),(d_2,p_2)]$ (where $p_1 < p_2$),
the attractiveness for S of (d_2,p_2) in the context of $[(d_1,p_1),(d_2,p_2)]$ equals
$\text{EMV}_2(p_2 - p_1)$, and
the attractiveness for S of (d_1,p_1) in the context of $[(d_1,p_1),(d_2,p_2)]$ equals
$\text{EMV}_1[(d_1 - d_2)/d_1]k_G$ if $d_1,d_2 > 0$; and
$\text{EMV}_1[(d_1 - d_2)/d_1]k_L$ if $d_1,d_2 < 0$.

Thus, in a simple choice problem, according to the Advantage Model, the attractiveness of the lottery offering the higher probability (to gain or lose) equals the lottery's EMV multiplied by its probability advantage. Similarly, the attractiveness of the lottery offering the larger payoff (either a loss or a gain) equals its EMV times its payoff advantage. Finally, the parameters k_G and k_L represent the relative weight of payoffs and probabilities, in the case of gains and in the case of losses, respectively. Given the finding that people generally give more weight to probabilities than to payoffs in choosing between lotteries (see, e.g., Slovic & Lichtenstein, 1968), we expect the parameters k_G and k_L to be less than unity for most people.

Having computed the atractiveness of competing lotteries, the decision maker is predicted to choose the lottery that to him is more attractive. We illustrate with a simple choice problem taken from Kahneman and Tversky (1979), where we assume that $k_G = .50$:

Problem: [(4000, .20), (3000, .25)]

$$\begin{aligned} \text{EMV}_1 &= (4000)(.20) & \text{EMV}_2 &= (3000)(.25) \\ (d_1 - d_2)/d_1 &= 1000/4000 & p_2 - p_1 &= .25 - .20 \\ \text{EMV}_1[(d_1 - d_2)/d_1]k_G &= 100 & \text{EMV}_2(p_2 - p_1) &= 37.5 \end{aligned}$$

Because the problem is a *positive* choice problem, the relative weight of probability and payoff advantages is represented by k_G. While the calculation above used $k_G = .50$, any $1 \geqslant k_G \geqslant .20$ predicts that the left-hand lottery will be preferred over the right. Experiments reported in Section 6 indicate that virtually all subjects' k_G and k_L fall within the interval [.25, .90]. Thus, the Advantage Model predicts that the left-hand lottery will be preferred by most subjects—which agrees with Kahneman and Tversky's data. Indeed, any choice of k_G, k_L in the interval [.25, .90] allows the Advantage Model similarly to predict subjects' choices in the remaining eight simple choice problems appearing in Kahneman and Tversky's (1979; Tversky & Kahneman, 1981) well-known discussion of risky choice.

3.2.2. Mixed choice problems. We now extend the Advantage Model's account of the attractiveness of lotteries from simple to mixed choice problems. Consider the attractiveness of lottery (d_1,p_1,e_1) in mixed choice problem $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$ (where as always, $p_1 < p_2$). The lottery (d_1,p_1,e_1) may be thought of as a composite of two simple lotteries: positive lottery (d_1,p_1) and a negative lottery $(e_1, 1 - p_1)$. Its attractiveness, according to the Advantage Model, is simply the sum of the attractivenesses of these two parts. (This composite picture of mixed lotteries is similar to that adopted by the rank- and sign-dependent utility theories of Luce, 1991, and Luce & Fishburn, 1991, as well as the cumulative prospect theory of Tversky & Kahneman, 1992). As numerous phenomena make clear (see Section 4), people accord different treatment to risky outcomes involving gains than to those involving losses. Thus, according to the model, a person presented with a mixed choice problem evaluates the competing lotteries separately on the dimension of gains and on the dimension of losses. The evaluation on the gain dimension of the problem $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$ reduces to what looks like a choice problem between two simple lotteries: (d_1,p_1) versus (d_2,p_2). Thus, the superiority with respect to gains of lottery (d_1,p_1,e_1) over lottery (d_2,p_2,e_2) equals the extent to which (d_1,p_1) is preferred over (d_2,p_2). Similarly, the evaluation on the loss dimension reduces to a choice between $(e_1, 1 - p_1)$ and $(e_2, 1 - p_2)$. The superiority with respect to losses of lottery (d_1,p_1,e_1) over lottery (d_2,p_2,e_2) equals the extent to which $(e_1, 1 - p_1)$ is preferred over $(e_2, 1 - p_2)$. Finally, the attractiveness of each mixed lottery consists of the sum of its evaluations on the dimension of gains and on the dimension of losses. Thus, the attractiveness of (d_1,p_1,e_1) consists of the attractiveness of (d_1,p_1) (relative to (d_2,p_2)) plus the attractiveness of $(e_1, 1 - p_1)$ (relative to $(e_2, 1 - p_2)$).

The following formulation summarizes our account of the attractiveness of lotteries in mixed choice problems:

The attractiveness of lotteries in mixed choice problems (4)
For every person S there are k_G, $k_L > 0$ such that for any mixed choice problem $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$ $(p_1 < p_2)$, the attractiveness for S of (d_1,p_1,e_1) in the context of $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$ equals the sum of:
(a) the attractiveness of the positive lottery (d_1,p_1) in the context of $[(d_1,p_1),(d_2,p_2)]$ (using k_G), plus
(b) the attractiveness of the negative lottery $(e_1, 1 - p_1)$ in the context of $[(e_2, 1 - p_2),(e_1, 1 - p_1)]$ (using k_L).

Similarly, the attractiveness of (d_2,p_2,e_2) equals the sum of:
(a) the attractiveness of the positive lottery (d_2,p_2) in the context of $[(d_1,p_1),(d_2,p_2)]$ (using k_G), plus
(b) the attractiveness of the negative lottery $(e_2, 1 - p_2)$ in the context of $[(e_2, 1 - p_2),(e_1, 1 - p_1)]$ (using k_L).[2]

As an auxiliary hypothesis under the assumptions of (4) we also assume:

(a) (d_1,p_1,e_1) is preferred to (d_2,p_2,e_2) if the attractiveness of the former is greater than that of the latter, and similarly for preferring (d_2,p_2,e_2) over (d_1,p_1,e_1).
(b) The subject is indifferent between lotteries of equal attractiveness.
(c) The subject is averse to any lottery with negative attractiveness and prone to any lottery with positive attractiveness. (5)

Notice that according to the Advantage Model a person's relative weights of payoffs and probabilities, k_G and k_L, are the same in simple and in mixed choice problems. In fact, the Advantage Model treats simple lotteries as just special kinds of mixed lotteries. A positive (simple) choice

[2] In order to assist the reader to verify later calculations of attractiveness, we provide a computational form that results from performing the addition prescribed in (4) and simplifying terms: Given mixed choice problem $[(d_1,p_1,e_1),(d_2,p_2,e_2)]$ and person S with parameters k_G, k_L, (a) the attractiveness for S of $(d_1,p_1,e_1) = p_1(d_1 - d_2)k_G + e_1(1 - p_1)(p_2 - p_1)$, and (b) the attractiveness for S of $(d_2,p_2,e_2) = (1 - p_2)(e_2 - e_1)k_L + d_2p_2(p_2 - p_1)$.

problem is a mixed choice problem of the form $[(d_1,p_1,0),(d_2,p_2,0)]$, and a negative (simple) choice problem is a mixed problem of the form $[(0,p_1,e_1),(0,p_2,e_2)]$. Consider then a positive choice problem represented as $[(d_1,p_1,0),(d_2,p_2,0)]$ and treated as a mixed choice problem. It is easy to verify that its evaluation along the loss-dimension reduces to zero (since both e_1 and e_2 are zero) and that the problem is finally evaluated only along the gain-dimension—just like a simple choice problem. A similar outcome—due to the reduction to zero of the gain-dimension—may be observed for negative choice problems.

Principles (3) and (4) provide a parameterized description of choice between pairs of monetary lotteries. Choice, however, is just one among several problems that decision makers typically encounter. In the following sections, we extend the Advantage Model to decision problems other than choice.

3.3. Monetary Value

The monetary value of a lottery (either simple or mixed) is defined as that amount of money which, if received for sure, is as attractive as playing the lottery. For example, if receiving \$30 (for certain) is equally attractive to you as playing the lottery (100,.50), then the monetary value of this lottery for you is \$30. Within the perspective of the Advantage Model, it is natural to consider the monetary value of a simple lottery $(+d,p)$ for a person S to be that sum m of money that renders S indifferent between $(+d,p)$ and $(m,1)$. Observe that, according to the model, m may be calculated from the equation $dp[(d - m)/d]k_G = m(1 - p)$ when k_G is known; similarly for negative lotteries. The monetary value of a mixed lottery, according to the model, equals the sum of the monetary values of the two simple lotteries of which it is composed. Thus, the monetary value of mixed lottery (d,p,e) equals the sum of the monetary values of (d,p) and of $(e, 1 - p)$. In other words, using $\approx$ to denote indifference it equals the sum of m and n such that $(d,p) \approx (m,1)$, and $(e, 1 - p) \approx (n,1)$. The monetary value of (d,p,e) may thus be calculated by adding the amounts m and n obtained from $dp[(d - m)/d)]k_G = m(1 - p)$ and $e(1 - p)[(e - n)/e]k_L = n(p)$, respectively. We summarize this discussion with the following principle:

The monetary value of lotteries (6)
The monetary value of simple lottery (d,p) for a person S is the sum m of money such that, for S, $(d,p) \approx (m, 1)$.
The monetary value of mixed lottery (d,p,e) for S is the sum of m and n such that, for S, $(d,p) \approx (m,1)$, and $(e,1 - p) \approx (n,1)$.

Monetary value is used extensively in decision-research contexts and will be discussed further in Section 4.

3.4. *The Parameters k_G and k_L*

We turn now to the stability of the parameters k_G, k_L. The Advantage Model asserts that a person's choices among lotteries are all governed by a single, fixed k_G, k_L pair. Consider, however, the following observations. Tversky, Sattath, and Slovic (1988; see also Lichtenstein & Slovic, 1971; Slovic, Griffin, & Tversky, 1990; and Slovic & MacPhillamy, 1974) describe situations in which strategically equivalent methods of preference-elicitation yield systematically different preferences. To account for this, Tversky and his colleagues advance a principle of "compatibility," according to which the weighting of any feature of the object under consideration (the input) is enhanced to the extent that the feature is compatible with the required response (the output). Thus, because both the monetary value of a lottery and the payoffs offered by the lottery are expressed in the same units, compatibility implies that a lottery's payoffs will be weighted more heavily in monetary value estimation than in choice.

What are the implications of the principle of compatibility to the stability of a person's k_G and k_L parameters in the Advantage Model? Consider the paradigm of monetary value estimation. Recall from the previous section that a person's monetary value of the simple lottery $(+d,p)$ is that sum m of money that renders the person indifferent between $(+d,p)$ and $(m,1)$. Recall further that, in the context of the Advantage Model, m may be calculated from the equation $dp[(d - m)/d]k_G = m(1 - p)$. But according to the compatibility principle, the payoffs in this equation are weighted more heavily than in choice (because the subject's response—a dollar value—is compatible with the payoffs). In terms of the Advantage Model, this enhanced importance of payoffs entails that k_G—the relative weight of payoffs to probabilities—has increased in the monetary value compared to the choice paradigm. Similarly, k_L is expected to increase when the monetary value of negative lotteries is estimated. In summary, by way of incorporating Tversky *et al.*'s compatibility principle into the Advantage Model, we assume that the importance of payoffs relative to probabilities is enhanced in tasks of monetary value estimation, compared to choice. This means that both k_G and k_L are greater in the monetary value paradigm than in the choice paradigm.

Similar reasoning applies to what is known as the probability equivalence paradigm. Here, a person is asked to determine a probability q such that a given lottery (d_1,p_1) is equivalent for him to lottery (d_2,q). To illustrate, presented with (100,.50) and (40,q), you may decide that for you the probability equivalent q is .80, meaning that for you an 80% chance to win $40 is as attractive as a 50% chance to win $100. Attention is here focused on probabilities, thus enhancing their importance relative to payoffs. According to the Advantage Model, the values of k_G and k_L are expected to decrease.

More generally, subjects' differential weighting of payoffs and probabilities may depend not only on response compatibility, but also on other characteristics of the decision context that shift the focus of attention, (see, e.g., Payne, 1982). For example, the weighting of probabilities relative to payoffs may also be influenced by the presence of extreme probabilities, either high or low, that are rendered more salient. We summarize this discussion by the following principle:

(*) In a choice context in which payoffs (either positive or negative) are made particularly salient, the values of a person's k_G and k_L typically increase (thereby increasing the relative weight of payoffs); conversely, if probabilities are salient, the values of k_G and k_L typically decrease (thereby increasing the relative weight of probabilities).

Principle (*) is also consistent with mechanisms proposed by other researchers. Thus, in Tversky and Gati's (1978; Tversky, 1977) work on similarity judgment, the importance that subjects attach to a given feature in a stimulus is shown to vary with the kind of judgment required and with the nature of the other stimuli in view. An increase in the relative weight of payoffs during monetary value estimation, as proposed by principle (*), is also consonant with Lichtenstein and Slovic's (1971) suggestion that greater anchoring on payoffs occurs when monetary values are assigned than when choices are made.

To illustrate the use of principle (*) in explaining specific compatibility effects in decision making, consider the following experimental demonstration. When asked to determine the monetary equivalent m that renders him indifferent between, e.g., (5000,.25) and (m,.75), a person S decides that for him m is, say, 2000. But when then asked to determine the probability equivalent q that renders him indifferent between (5000,q) and (2000,.75), S decides that for him q is .50. A systematic pattern of preferences of this kind—where the probabilities estimated in the latter stage are higher than those which figured in the former—is reported by Delquie, de Neufville, and Mangnan (1987), who gave people the two tasks separated by a 2-week interval. S's stated indifferences above yield the following inconsistent equivalences:

$$(5000,.25) \approx (2000,.75) \qquad \text{and} \qquad (5000,.50) \approx (2000,.75),$$

which, according to the Advantage Model, indicate k_G values of 1.0 in the first judgment and .25 in the second. This shift in k_G values is predicted by principle (*), according to which the value of S's k_G in the first judgment (where S focuses on payoffs) should be greater than that of the second judgment (where S focuses on probabilities). The Advantage Model supplemented by principle (*) thus predicts the inconsistent indifference judgments exhibited by Delquie et al.'s subjects. We shall observe other examples of the use of principle (*) in Section 4.

Empirical estimates of subjects' values for k_G and k_L are reported in Section 6. Assuming that the Advantage Model is right, these estimates suggest that in choice situations most people's k_G and k_L fall in the interval [.25, .90]. Of course, some people's k_G and k_L may fall well outside this interval. Certain qualitative phenomena, as discussed further below, may in fact be less common because they are characteristic of people with uncommon k_G, k_L. Typically, however, these empirically estimated values are consistent with those required to predict the qualitative phenomena to which we turn next.

4. QUALITATIVE PHENOMENA

In the present section we describe a number of well-documented phenomena that characterize people's choices between monetary lotteries. We show that the Advantage Model is consistent with these qualitative phenomena.

4.1. Risk Aversion and Risk Seeking

Consider a choice between a simple lottery (1000,.80) and the alternative of receiving $800 for sure. A large majority of people prefer the sure gain over the gamble, despite the fact that the two have equal expected monetary value. A preference for a sure outcome over a gamble that has higher or equal expected monetary value (EMV) is called risk averse. Now consider a choice between the lottery (−1000,.80) and the alternative of losing $800 for sure. A large majority of subjects prefer the gamble over the sure loss, despite the fact that the two, again, have equal EMV's. A preference for a gamble over a sure outcome with equal or higher EMV is called risk seeking. As the examples above illustrate, people's choices are generally risk averse in the domain of gains and risk seeking in the domain of losses. (Risk aversion and risk seeking for gains and losses, respectively, have been confirmed by Fishburn & Kochenberger, 1979; Payne, Laughhunn, & Crum, 1980; Hershey & Schoemaker, 1980a; and Slovic, Fischhoff, & Lichtenstein, 1982, among others.)

The foregoing attitudes toward risk follow from the Advantage Model by way of its parameters k_G and k_L, which are assumed to be smaller than 1 for most people. To illustrate, a choice between the lottery (1000,.80) and the sure outcome of $800 leads to a comparison between $EMV_1[(1000 - 800)/1000]k_G$ and $EMV_2(1.0 - .80)$ (where EMV_1 and EMV_2 are the EMV's of the gamble and the sure outcome, respectively). Since the EMV's are identical, the comparison reduces to $.20(k_G)$ versus .20. For any $k_G < 1$, the Advantage Model predicts a preference for the sure outcome over the lottery. More generally, for any positive choice problem consisting of a simple lottery and a sure outcome of equal EMV the model predicts a risk averse choice. On the other hand, choosing between (−1000,.80) and −\$800 leads to a comparison between $\text{EMV}_1(.20)k_L$ and $\text{EMV}_2(.20)$, respectively. Since the EMV's are now equal but negative, any $k_L < 1$ leads to a preference for the gamble over the sure loss. For any negative choice problem consisting of a simple lottery and a sure outcome of equal EMV the model predicts risk seeking.[3]

4.2. Loss Aversion

Consider the lottery (100,.50, −100). Most people opt not to play this lottery because the attractiveness of a \$100 gain is perceived as not sufficient to compensate for the aversiveness of an equally likely \$100 loss. People's feeling that a loss causes more pain than an equal gain causes pleasure is known as "loss aversion." (According to Tversky & Kahneman's, 1991, estimate, people's loss aversion coefficient is typically just over two.) The fact that "losses loom larger than gains" need not be confined to payoffs of equal magnitude. (Thus, for example, a person may find the loss of \$100 to be more aversive than he finds the gain of \$150 attractive.) For clarity of exposition, however, we focus here on cases that involve equal gains and losses.

The Advantage Model predicts loss aversion via the parameters k_G and k_L. The empirically derived estimates of subjects' k_G and k_L reported in the next section suggest that $k_L > k_G$ for a majority of people. With this additional assumption, the Advantage Model implies the aversiveness of (100,.50, −100). To see this, observe that (100,.50, −100) is composed of the simple lotteries (100,.50) and (−100,.50). Recall that the monetary value of a lottery is that sum of money, m, that renders the person indifferent between the lottery and m at certainty. More specifically, recall (Section 3.3) that according to the Advantage Model, the monetary value of lottery (100,.50) equals m such that $(100,.50) \approx (m,1)$, and that the monetary value of (−100,.50) equals n such that $(-100,.50) \approx (n,1)$. The values of m and n can be calculated from these indifferences, using k_G in the case of m (a gain) and k_L in the case of n (a loss). It now follows from the arithmetic of the model that for any k_G and k_L such that $k_L > k_G$, $|n| > |m|$. Since n is a negative amount and m a positive one, the lottery (−100,.50) is predicted to be more aversive than the lottery (100,.50) is attractive. Hence, with its loss-dimension more aversive than its gain-dimension is attractive, the lottery (100,.50, −100) is predicted by the Advantage Model to be rejected by most people.

[3] Risk aversion in the case of gains and risk seeking in the case of losses are not limited to choices between lotteries and sure outcomes with equal EMV. The above treatment extends naturally to pairs of lotteries whose EMV's are not equal.

4.3. Noninvariance

All analyses of rational choice incorporate the notion of invariance. Invariance requires that preferences between alternatives not depend on the manner in which the alternatives are described (assuming, of course, that ultimately the same information is provided). Different representations of the same choice problem should yield the same preferences.

Kahneman and Tversky have demonstrated failures of invariance in people's choices (see, e.g., Kahneman and Tversky, 1982, 1984; Tversky and Kahneman, 1986). One example of noninvariance is illustrated in the following problems (where the bracketed numbers indicate the percentage of respondents who chose each option):

Problem 1: Assume yourself richer by $300 than you are today. You have to choose between
a sure gain of $100 [72%]
50% chance to gain $200 and 50% chance to gain nothing [28%]

Problem 2: Assume yourself richer by $500 than you are today. You have to choose between
a sure loss of $100 [36%]
50% chance to lose nothing and 50% chance to lose $200 [64%]

The two problems are essentially identical. In both cases the subject faces a choice between $400 for sure and an even chance at $500 or $300. Despite the fact that these problems offer identical options, their different descriptions—one in terms of gains and the other in terms of losses—had a substantial effect on subjects' preferences. In particular, consonant with the discussion in Section 4.1 above, subjects made a risk averse choice when the problem was framed as a choice between gains, and a risk seeking choice when it was framed as a choice between losses.

The Advantage Model is defined over gains and losses rather than final assets. That is, similar to Prospect Theory and unlike Utility Theory, the model assumes that subjects' decisions in the problems above focus entirely on their departure from the perceived reference point, and do not integrate information regarding current wealth. As with Prospect Theory, this leads the Advantage Model to predict noninvariant choice behavior. In fact, for Problems 1 and 2 above, any values of k_G, $k_L < 1$ lead the model to predict exactly the pattern of preferences exhibited by the majority of subjects. We leave the verification of this fact to the reader.

As Tversky and Kahneman (1986, p. S259) point out, regret theory—a comparative theory proposed in different forms by Bell (1982), Loomes and Sugden (1982), and Fishburn (1982)—is unable to predict subjects' behavior in Problems 1 and 2. This follows from the fact that the two problems yield identical outcomes and therefore identical regret structures. In fact, even without the initial changes in endowment that make the problems extensionally equivalent, regret theory cannot explain the combination of risk aversion in Problem 1 and risk seeking in Problem 2 (cf. Section 4.1).

Subjects' noninvariant choice behavior leads them to violate other principles of rational choice, for example, the dominance principle. The dominance principle states that if one option is better than another on one dimension and at least as good as the other on all the rest, then that option should be chosen. For example, given a choice between

A: 25% chance to win $240 and 75% chance to lose $760
B: 25% chance to win $250 and 75% chance to lose $750

the dominance principle predicts that all subjects should prefer option (B) over option (A). Consider, however, the following two choices, one involving gains and the other losses, presented by Tversky and Kahneman (1981) to a group of 150 undergraduate students:

Imagine that you face the following pair of concurrent decisions. First examine both decisions, then indicate the options you prefer.

Decision (i). Choose between
C: a sure gain of $240 [84%]
D: 25% chance to gain $1000 and 75% chance to gain nothing [16%]
Decision (ii). Choose between
E: a sure loss of $750 [13%]
F: 75% chance to lose $1000 and 25% chance to lose nothing [87%]

The percentage of students who chose each option is indicated in brackets. As expected, the majority choice in decision (i) (which involves gains) is risk averse, while the majority choice in decision (ii) (which involves losses) is risk seeking. It follows from the percentages above that at least 70% of the subjects chose both lotteries C and F. Because these subjects considered the two decisions simultaneously, they expressed, in effect, a preference for the combination of lotteries C and F over the combination D and E. Notice, however, that lotteries C and F combined yield the equivalent of lottery A, while lotteries D and E yield the equivalent of lottery B. Thus, while subjects express one preference when the options are presented in a condensed form, they express the opposite preference when the options appear in a different format. This particular instance of noninvariance leads subjects to choose a dominated alternative.

Observe, finally, that given any k_G, k_L < .95, the Advantage Model predicts a choice of options C over D, and F over E, as exhibited by the majority of subjects.

4.4. Cost–Loss

A special case of noninvariance arises when an aversive situation faced by a decision maker can be framed as involving either a cost or a loss. The price of insurance, for example, is usually regarded as a cost intended to insure against particular risks. Alternatively, the purchase of insurance may be framed as a choice between a sure loss and a risk at a greater loss. Slovic *et al.* (1982) inquired about subjects' willingness to pay \$50 for insurance against a 25% risk of losing \$200. Then, these authors presented subjects with a choice between a sure loss of \$50 and a 25% chance to lose \$200. While in the insurance condition only 35% of the subjects refused to pay the \$50, in the choice condition 80% of the subjects expressed a risk seeking preference for the gamble over the sure loss. Similar results, showing noninvariant patterns of preference between paying costs and choosing losses, are reported by Hershey and Schoemaker (1980a) and by Schoemaker and Kunreuther (1979).

It seems appropriate to classify the foregoing situations as choice in one case and as monetary value estimation in the other. Subjects presented with a choice between a sure loss of \$50 and a 25% chance to lose \$200 face a simple choice problem of the form $[(-200,.25),(-50,1)]$. On the other hand, subjects in the insurance condition are assumed to evaluate whether, for them, a 25% chance to lose \$200 is worth more or less than $-\$50$. They engage, in other words, in monetary value estimation: $(-200,.25) = (m,1)$. The majority's willingness to pay the \$50 indicates that for them m is less than -50: they prefer to pay \$50 than to accept a gamble whose value is lower. Subjects in the insurance condition are asked to consider a price, so their attention is focussed on payoffs. Hence by principle (*), their value of k_L is raised. The reader may verify that with $k_L < 1$ for choice and $k_L > 1$ for monetary value estimation, the Advantage Model predicts exactly the pattern of preferences exhibited by the majority of subjects in the cost–loss phenomenon above.

An interesting variant of the cost–loss phenomenon may be observed with mixed lotteries, involving gains as well as losses. Consider the following pair of problems which were posed, separated by a short filler question, to 132 subjects by Kahneman and Tversky (1984):

Problem 1: Would you accept a gamble that offers a 10% chance to win \$95 and a 90% chance to lose \$5?

Problem 2: Would you pay \$5 to participate in a lottery that offers a 10% chance to win \$100 and a 90% chance to win nothing?

Although it is easy to verify that the two problems offer objectively identical outcomes, 55 of the respondents expressed different preferences in the two versions. Of these, 42 rejected the gamble in problem 1 but accepted the objectively equivalent lottery of problem 2. As in the previous case, spending x amount of money as a cost seems less aversive to some subjects than incurring an equal amount x as a loss. Thus, while these subjects rejected the lottery (95,.10, –5), they were willing to pay \$5 for the lottery (100,.10). Unlike the previous case, here both problems are instances of monetary value estimation. The latter, simple lottery was worth more than \$5 to the subjects, while the former, mixed lottery had a negative monetary value.

This pattern of preferences may be explained within the Advantage Model in the following way. In the second problem, where a price (i.e., payoff) is explicitly evoked, the subject's k_G and k_L increase due to the notion of compatibility captured by principle (*). No such increase in k_G, k_L is triggered by the first problem. Let k_G' be the result of increasing k_G in the second problem. Then it can be verified that with $k_G = .4$, $k_L = .6$, and $k_G' = .5$, for example, the Advantage Model implies (via (6)) a negative attractiveness for (95,.10, –5) and a monetary value greater than \$5 for (100,.10). These calculations account (via (5)) for the preferences exhibited by the majority of noninvariant subjects above. The range of k values that leads to the latter pattern of preferences is more restricted than that required to predict the previous instance of the cost–loss phenomenon. It is encouraging to observe, therefore, that the proportion of subjects who exhibited the latter pattern is significantly smaller than that which exhibited the former.

4.5. Gambling and Insurance

The purchase of insurance policies and lottery tickets typically conflicts with people's general tendency (described in Section 4.1) to exhibit risk aversion in the domain of gains and risk seeking in the domain of losses. Thus, a person willing to pay \$5 for a lottery that offers a .005 chance to win \$1000 exhibits risk seeking in the domain of gains. Similarly, Slovic et al.'s subjects in the previous section who chose to pay a \$50 insurance against a 25% risk of losing \$200 exhibited risk aversion toward losses. Of course, what distinguishes these preferences from those discussed in Section 4.1 is that these involve monetary value estimation rather than choice: people must decide whether, to them, the risk at a loss is worth more or less than the price of the insurance and whether the lottery is worth more or less than the price of the ticket. In line with principle (*), the Advantage Model assumes that such monetary value estimation entails an increase in the value of k_G and k_L.

Notice, furthermore, that the conditions under which insurance policies and lottery tickets are sold typically involve small probabilities. In fact, the tendency to buy lotteries and insurance increases as the probabilities become smaller (until they become so small that they fall below a minimal

TABLE 1
TENDENCY TO BUY INSURANCE FOR A POSSIBLE $10000 LOSS

Probability to lose $10000	Price of insurance	% preferring to buy insurance	Ratio of possible loss's subjective monetary value (according to the Advantage Model, with $k_L = 1.5$) to expected monetary value
.001	10	81	1.4993
.01	100	66	1.4925
.10	1,000	59	1.4286
.50	5,000	39	1.2000
.90	9,000	34	1.0345
.99	9,900	27	1.0033
.999	9,990	17	1.0003

threshold for consideration; see Slovic, Fischhoff, & Lichtenstein, 1978). The three left-most columns of Table 1 summarize Hershey and Schoemaker's (1980a) data on decisions concerning whether or not to buy insurance (of equal EMV) against a particular probability to lose $10,000. As these data make clear, the percentage of subjects who prefer to buy the insurance decreases monotonically as the probability to lose goes up.

People are likely to buy insurance when their subjective value of a gamble is lower (i.e., is a greater negative number) than the price of insurance. In particular, when the price of insurance equals the gamble's EMV (as in Slovic *et al.*'s problems above) people will prefer the insurance when their subjective monetary value for the gamble is lower than its EMV. In fact, with $k_L > 1$ during monetary value estimation, the Advantage Model predicts that a subject's monetary value for a gamble will be less than the gamble's EMV. Furthermore, keeping k_L and the payoff constant, the discrepancy between the subject's value for a gamble and the gamble's EMV increases as the probabilities get smaller.[4] The right-hand column of Table 1 lists the ratio, using $k_L = 1.5$, of the Advantage Model's subjective monetary value of each gamble to the gamble's EMV. Observe that as this ratio increases, so does the percentage of subjects who prefer to buy insurance (correlation of .96; In fact, any $k_L \geqslant 1.1$ yields a correlation of .95 or higher). It appears that the Advantage Model's predicted discrepancy between the subjective value of a gamble and the price of insurance against it predicts well the percentage of subjects who opt for the insurance. Similar remarks—concerning positive rather than negative payoffs—apply to the purchase of lotteries. Thus, in line

[4] A gamble's ratio of subjective monetary value to EMV lies between k_L (in the case of losses; otherwise, k_G) and 1. It approaches the value of k_L (or k_G) as the probabilities get smaller and 1 as they increase.

with Table 1, more people are predicted to buy a \$10 ticket for a lottery that gives a .001 chance to win \$10,000 than to buy a \$9,900 ticket for a lottery that gives a .99 chance to win \$10,000.

4.6. Constant Difference

Consider simple choice problem $[(+d_1,p_1),(+d_2,p_2)]$, where $p_1 < p_2$. If person S prefers $(+d_1,p_1)$ in this problem, it is possible to find a sum m of money such that S prefers $(m + d_2,p_2)$ in $[(m + d_1,p_1),(m + d_2,p_2)]$. Thus, if S prefers the left-hand lottery in [(300,.40),(50,.80)], he is likely to prefer the right-hand lottery in [(1300,.40),(1050,.80)]. Notice that while the difference in payoffs has remained constant, preference has reversed. A similar shift of preference—but in the opposite direction—can be shown for negative choice problems. (See also Payne, Laughhunn, & Crum, 1980, for similar effects involving a mixture of positive and negative outcomes.)

The Advantage Model predicts the constant difference phenomenon because it is based on payoff ratios rather than payoff differences. For any simple choice problem $[(d_1,p_1),(d_2,p_2)]$ (where $p_1 < p_2$), as we keep the difference between the two payoffs constant and increase their size, the ratio $(d_1 - d_2)/d_1$—i.e., the payoff advantage of the left-hand lottery—decreases. At the same time, the absolute value of EMV_2 increases faster than that of EMV_1 since $p_2 > p_1$. Hence, as payoffs are increased preference must eventually shift to the right-hand lottery in positive problems and to the left-hand lottery in negative problems. We illustrate with the example above. According to the model, [(300,.40),(50,.80)] gives rise to a comparison between $(300)(.40)[250/300]k_G$ and $(50)(.80)(.80 - .40)$, i.e., between $100k_G$ and 16. On the other hand, [(1300,.40),(1050,.80)] gives rise to a comparison between $(1300)(.40)[250/1300)]k_G$ and $(1050)(.80)(.80 - .40)$, i.e., between $100k_G$ and 336. For a large range of k_G's (specifically, $.16 < k_G < 3.36$) the left-hand lottery will be preferred in the first problem but the right-hand lottery in the second, which predicts the reverse.

4.7. Reflection

The next phenomenon has been called the "reflection effect" by Kahneman and Tversky. It is illustrated by the following pair of problems (where an asterisk indicates the lottery preferred by a significant majority of subjects):

[(4000,.20)*,(3000,.25)]   [(−4000,.20),(−3000,.25)*]

These simple choice problems are identical except that one involves positive and the other negative lotteries. The reflection phenomenon refers to the fact that preferences shift between the problems: people prefer the left-hand lottery in the positive problem, but the right-hand lottery in the negative problem.

The Advantage Model predicts the reflection effect; for, in the transition from $[(+d_1,p_1),(+d_2,p_2)]$ to $[(-d_1,p_1),(-d_2,p_2)]$, the attractiveness coefficients of both lotteries shift from positive to negative. As a result, the direction of the inequality between these coefficients reverses as well. However, since the coefficients are compared using different parameters in the case of positive and negative lotteries (namely, k_G and k_L, respectively), the model does not predict necessary reflection for every pair of positive–negative variants. This is consistent with Hershey and Schoemaker's (1980b) results indicating that while the reflection effect is quite common, it is not pervasive.

4.8. Common Ratio

The common ratio phenomenon is illustrated by the following two problems taken from Kahneman and Tversky (1979):

[(6000,.45),(3000,.90)*] [(6000,.001)*,(3000,.002)]

While most people prefer the right-hand lottery in the first problem, they then prefer the left-hand lottery in the second. Notice that the probability ratios in the two problems are the same (2:1).

It is well known that Utility Theory cannot predict this pattern of choices (since the pattern violates the substitution axiom, or "cancellation" rule, a fundamental requirement of Utility Theory), whereas Prospect Theory can (see Kahneman & Tversky, 1979, for discussion; see, e.g., Fishburn, 1982, 1983; Machina, 1982; and Quiggin, 1982, for alternative accounts involving weakenings of Utility Theory, and Camerer, 1990, for a review.) The Advantage Model predicts the common ratio phenomenon because it is based on probability differences rather than probability ratios. While everything else remains essentially the same, the probability advantage of the right-hand lottery in the problems above changes from (.90 − .45) in the first problem to (.002 − .001) in the second, which for a wide range of k_G values predicts a corresponding shift in preference from the right- to the left-hand lottery.[5]

People seem to overweigh outcomes that are considered certain compared to outcomes that are merely probable. Kahneman and Tversky

[5] In their discussion of the common ratio effect, Kahneman and Tversky (1979) advance the following generalization (here presented for positive lotteries; a similar generalization—in the opposite direction—applies to negative lotteries). If (d_1,pq) is preferentially equivalent to (d_2,p), then (d_1,pqr) is preferred to (d_2,pr), $0 < p,q,r < 1$. This property is incorporated by Kahneman and Tversky into Prospect Theory. It can be shown formally that the above generalization is a necessary outcome of the Advantage Model (see Shafir *et al.*, 1989, for a proof).

(1979) dub this tendency "the certainty effect" and illustrate it with the following pair of problems, in both of which p_1 is 80% of p_2.

$$[(4000,.20)^*,(3000,.25)] \qquad [(4000,.80),(3000,1)^*]$$

These problems also instance the common ratio phenomenon since the probabilities in the first problem are each one-quarter of their counterparts in the second problem. It is not clear, therefore, whether the certainty effect is a separate feature of choice behavior or just a special case of the common ratio phenomenon. Following Kahneman and Tversky, let us assume that the certainty effect is a separate phenomenon and consider how the Advantage Model can account for it.

By definition, the certainty effect occurs in cases where one of the alternatives is not a simple lottery but rather an outcome at certainty. This context renders the probabilities more salient and, in line with principle (*), predicts that a person's k_G and k_L typically diminish (thereby increasing the relative weight of probabilities). Thus, a choice problem $[(+d_1,p_1),(+d_2,1)]$ gives rise to a comparison between $EMV_1[(d_1 - d_2)/d_1](k_G')$ and $EMV_2(1 - p_1)$, where $k_G' < k_G$, whereas problems with $p_2 < 1$ are evaluated using k_G. The result is that (for positive problems) preference is biased toward (d_2,p_2) when $p_2 = 1$.

In the context of negative lotteries, the certainty effect leads subjects to exhibit risk seeking preferences in an attempt to avoid sure losses. This is illustrated in the following pattern of choices (due to Kahneman & Tversky, 1979), which is the "reflection" of the previous one.

$$[(-4000,.20),(-3000,.25)^*] \qquad [(-4000,.80)^*,(-3000,1)]$$

This reflection/certainty phenomenon is predicted by the Advantage Model supplemented by principle (*) since the values of *both* k_G and k_L are expected to decrease in the context of lotteries involving certainty. In negative problems, this means a bias away from the sure losses.

4.9. Intransitivity

Consistent intransitivity of preferences can be demonstrated in people's choices. One such intransitivity, discovered by Tversky (1969), involves the following five lotteries:

(a) (5.00, 7/24)
(b) (4.75, 8/24)
(c) (4.50, 9/24)
(d) (4.25, 10/24)
(e) (4.00, 11/24)

Many subjects prefer (a) to (b), (b) to (c), (c) to (d), (d) to (e), but (e) to (a).

Within absolute theories, lotteries are assigned attractiveness coefficients independently of the alternatives against which they are being compared; these coefficients are then compared numerically. Hence, no absolute theory is able to predict intransitivity.[6] The Advantage Model—in virtue of its comparative component—predicts intransitivity in certain cases. Thus, according to the model, the relative attractiveness of lottery (a) above differs when it is compared with lottery (b) from when it is compared with lottery (e). The reader may verify, for example, that the Tversky-intransitivity above follows from the Advantage Model with $.91 \leq k_G \leq 1.0$.

Although, to the best of our knowledge, intransitivity of preferences has only been demonstrated with simple lotteries, we observe that the Advantage Model predicts cases of intransitivity for mixed lotteries as well. Consider, for example, the following three lotteries:

(f) (20,.20, −5)
(g) (10,.40, −8)
(h) (6,.60, −13)

The Advantage Model predicts that any subject whose $k_G = k_L = .5$ will prefer (f) to (g), (g) to (h), but (h) to (f).

4.10 Preference Reversal

Preference reversal occurs when subjects indicate a preference for one lottery in a choice problem, but then assign a larger monetary value to the other. An example of preference reversal with simple lotteries that we have repeatedly observed is as follows. Given [(10,.60),(5,.80)], subjects often prefer the right-hand lottery but assign a higher monetary value to the left-hand lottery. Numerous experimental studies have revealed consistent preference reversals in a majority of subjects (see Slovic & Lichtenstein, 1983, for a review).

We shall now see that preference reversal follows from the Advantage Model. Recall that the monetary value of a lottery (d,p) for a person S is that sum m of money that renders S indifferent between (d,p) and $(m,1)$. Now, consider a person S for whom $k_G = .25$. The Advantage Model predicts that S prefers the right-hand lottery in the problem [(10,.60), (5,.80)]. The following calculations demonstrate that the Advantage

[6] Tversky and Kahneman (1986) invoke "editing" strategies to explain intransitivity. For the example cited above, it might be assumed that the probabilities of adjacent lotteries are considered—due to editing—to be identical, whereas the probabilities of lotteries (a) and (e) differ enough to affect evaluation and choice. Of course, as Tversky and Kahneman (1986, p. S273) point out, intransitivity of preference may result from more than one psychological mechanism.

Model also predicts that S's monetary value will be larger for the left-hand lottery than for the right.

$$\begin{aligned} (10,.60) &= (m,1) \\ 6(1 - m/10)(.25) &= m(1 - .60) \\ 1.5 - .15m &= .4m \\ m &= 2.73 \end{aligned} \qquad \begin{aligned} (5,.80) &= (m,1) \\ 4(1 - m/5)(.25) &= m(1 - .80) \\ 1 - .2m &= .2m \\ m &= 2.5 \end{aligned}$$

Notice, moreover, that the above calculations are instances not of choice but of monetary value estimation. As discussed earlier (Section 3.3), such estimation is assumed to focus the subject's attention on payoffs and thus—according to principle (*)—to increase the value of his parameters. It is easy to verify that a larger k_G in the monetary value calculations above is likely to produce a still more pronounced preference reversal than that produced by the Advantage Model without principle (*). For example, suppose that k_G rises from its original value of .25 in the context of the choice problem [(10,.60),(5,.80)] to .50 in the associated monetary value estimation task. Then, calculations like those above yield monetary values of 4.29 and 3.33 for the left- and right-hand lotteries, respectively. These differ from each other more than the monetary values predicted without principle (*) and thus yield a more pronounced reversal.

Our account of preference reversals in simple choice problems may be partially tested with the help of data reported by Goldstein and Einhorn (1987). These investigators had subjects choose between lotteries in simple choice problems and also had the subjects determine the monetary value of each lottery appearing in a problem. Following is a list of all the simple choice problems they used. As usual, the problems are listed so that the lottery offering the higher chance at a smaller payoff is on the right.

[(16.00, 11/36),(4.00, 35/36)]
[(9.00, 7/36),(2.00, 29/36)]
[(6.50, 18/36),(3.00, 34/36)]
[(40.00, 4/36),(4.00, 32/36)]
[(8.50, 14/36),(2.50, 34/36)]
[(5.00, 18/36),(2.00, 33/36)]

Over all six problems, 40% of the subjects' responses yielded preference reversals of kind (PR):

(PR) choice of the right-hand lottery coupled with a higher monetary value for the left-hand lottery,

and only 2% of the subjects manifested preference reversals of the opposite sort (OR):

(OR) choice of the left-hand lottery coupled with a higher monetary value for the right-hand lottery.

These results are consistent with the Advantage Model as supplemented by principle (*). Recall that principle (*) entails a higher parameter for monetary value estimation than for choice. And indeed, according to the Advantage Model, a person with $k_G \geqslant .9$ for monetary value estimation and $k_G \leqslant .5$ for choice will manifest preference reversal of kind (PR) in all six of the simple choice problems above. In addition, no subject with a k_G below .5 can manifest preference reversals of kind (OR) on any of Goldstein and Einhorn's simple choice problems. To the extent that subjects' k_G tends to fall below .5, this result concords with the low frequency of this kind of preference reversal observed by Goldstein and Einhorn.

Tversky, Slovic, and Kahneman (1990) argue convincingly that the preference reversal phenomenon is not a simple case of intransitivity, as was initially assumed. Instead, they show that it results mainly from the overpricing of lotteries during monetary value estimation. As demonstrated above, an overpricing of lotteries is the precise effect of an increase in the subject's parameters.

Finally, we extend our account of preference reversal from simple to mixed choice problems. Following is a list of the mixed choice problems used in Experiment 1 of Lichtenstein and Slovic's (1971) well-known exposition of preference reversal. As before, all problems are listed so that the lottery offering the higher chance at a smaller gain is on the right.

[(16.00,.33, − 2.00),(4.00,.99, − 1.00)]
[(8.50,.40, − 1.50),(2.50,.95, − .75)]
[(6.50,.50, − 1.00),(3.00,.95, − 2.00)]
[(5.25,.50, − 1.50),(2.00,.90, − 2.00)]
[(9.00,.20, − .50),(2.00,.80, − 1.00)]
[(40.00,.10, − 1.00),(4.00,.80, − .50)]

The overwhelming majority of reversals on these problems were again of kind (PR) above. In fact, 73% of all subjects *always* assigned a higher monetary value to the left-hand lottery after having indicated a preference for the right-hand lottery.

The foregoing results are consistent with the Advantage Model as supplemented by principle (*). A wide range of k_G, k_L values predict choice of the right-hand lotteries and—following an increase due to principle (*)—a higher monetary value for the left-hand lotteries. For example, any subject with $k_G < .6$ and $k_L < 1$ for choice, and $k_G = k_L > 1.1$ for monetary value estimation, is predicted to exhibit preference reversal of kind (PR) on all of Lichtenstein and Slovic's problems above.

4.11. Summary

Ten phenomena that characterize choice in risky situations have been shown to be consistent with the Advantage Model. Some of the phenomena (e.g., common ratio and noninvariance) cannot be predicted by Utility Theory, whereas others (intransitivity) cannot be predicted by any theory within the absolute framework. Four substantive principles of rationality that form the foundation of the classical theory—cancellation (or substitution; Section 4.8), transitivity (Section 4.9), dominance (Section 4.3), and invariance (Section 4.3)—have all been shown to be violated descriptively (see Tversky & Kahneman, 1986, for a discussion of these principles and the implications of their descriptive inadequacy.) Recent theories have attempted to account for various subsets of these violations. Thus, Camerer (1993) reviews theories that are compatible with violations of cancellation; Bell (1982), Loomes and Sugden (1982), and Fishburn (1982) present theories compatible with intransitivity; and Prospect Theory accounts for failures of cancellation as well as dominance and invariance. The Advantage Model predicts violations of all four principles.

Table 2 summarizes the values of k_G and k_L required by the Advantage Model to predict all the choice and evaluation problems reviewed in this section. Some of these values are inherent to the model (e.g., all and only

TABLE 2
PARAMETER VALUES REQUIRED TO PREDICT QUALITATIVE PHENOMENA

Phenomenon	Parameter values during choice	Parameter values during monetary value estimation (when k_G and k_L increase)
4.1 Risk aversion and risk seeking	$k_G, k_L < 1$	—
4.2 Loss aversion	$k_G < k_L$	—
4.3 Noninvariance	$k_G, k_L < 1$	—
	$k_G, k_L < .95$	
4.4 Cost–loss	$k_L < 1$	$k_L > 1$
	$k_G \leqslant .4; k_L \geqslant .55$	$k_G \geqslant .48$
4.5 Gambling and insurance	—	$k_G, k_L > 1$
4.6 Constant difference	$.16 < k_G < 3.36$	—
4.7 Reflection	$k_G, k_L \geqslant .19$	—
4.8 Common ratio	$.002 < k_G < .9$	—
	$.19 \leqslant k_G, k_L < .75$	
4.9 Intransitivity	$.91 \leqslant k_G \leqslant 1$	—
4.10 Preference reversal	$k_G \leqslant .5$	$k_G \geqslant .9$
	$k_G < .6; k_L < 1$	$k_G, k_L > 1.1$

Note. This table lists the values of the parameters k_G and k_L required to predict the qualitative phenomena reviewed in Section 4. The parameter values for choice and for monetary value estimation are listed in the second and third columns, respectively. Each row provides the parameter values for a different problem covered in the text, in order of occurrence.

k_G, $k_L < 1$ imply the risk attitudes of Section 4.1), whereas others (e.g., the values required to predict phenomena 4.8 through 4.10) are specific to the particular problems used; other problems, capturing the same qualitative phenomena, may entail slightly different parameter values. Observe, nonetheless, that a person with, say, $.19 \leq k_G \leq .40$ and $.55 \leq k_L < .75$ for choice, and k_G, $k_L > 1.1$ for monetary value estimation, is predicted to exhibit all the phenomena on all of the problems reviewed, except for the Tversky-intransitivity of Section 4.9. The intransitive sequence requires a value of k_G somewhat outside the common range, which is compatible with the fact that it characterizes a preselected and, therefore, somewhat atypical group of subjects (see Tversky, 1969). As discussed in Section 4.9, other intransitivities may involve parameter values more within the common range. Of course, few subjects are likely to exhibit all 10 qualitative phenomena. While some behaviors (e.g., problems 1 and 2 of the cost–loss phenomenon) are characteristic of people who, according to the Advantage Model, have lower-than-average k_G values (and, thus, are assumed to attribute a higher-than-average importance to probabilities), other phenomena (e.g., the Tversky-intransitivity) are characteristic of higher-than-average k_G values (and thus assume a higher-than-average importance for payoffs). It is encouraging to observe that both these phenomena are exhibited by smaller proportions of subjects than those which are predicted by a wider and more typical range of k_G values.

Of course, a successful theory of choice should predict quantitative as well as qualitative data. To the extent that the Advantage Model proves to be quantitatively comparable to alternative proposals, its qualitative adequacy provides grounds for considering it a plausible description of human choice behavior. It is to a quantitative evaluation of the model that we turn next.

5. QUANTITATIVE EVALUATION

Three experiments were conducted, designed to evaluate the Advantage Model against comparable versions of Utility Theory and Prospect Theory. The theories are evaluated in terms of their ability to predict both individual choice and group preference. Before describing the experiments, we discuss the alternative theories, as well as the statistical criteria used to compare accuracy of prediction.

5.1. Alternative Theories

For Utility Theory, we consider a power utility function, denoted $U^{c_G c_L}$, employing two real parameters, c_G and c_L. These parameters are the exponents for gains and for losses, respectively. The function is as follows:

$$U^{c_G c_L}(x) = [x^{c_G}] \qquad \text{if } x \geq 0$$
$$U^{c_G c_L}(x) = -[|x|^{c_L}] \qquad \text{if } x \leq 0.$$

As hypothesized by Utility Theory, a mixed lottery (d_1,p_1,e_1) is evaluated according to the formula

$$U^{c_G}(d_1)(p_1) + U^{c_L}(e_1)(1 - p_1).$$

The above function represents a familiar version of Utility Theory (e.g., Coombs, Dawes, & Tversky, 1970; Kahneman & Tversky, 1982). We have analyzed our data according to other Utility functions, including expected monetary value, exponential and various logarithmic functions (see, e.g., Shafir, Osherson, & Smith, 1989, for a one-parameter analysis employing the exponential utility function $u(x) = \text{sign}(x)[1 - e^{-c|x|}]$, suggested by Raiffa, 1968, and Keeney & Raiffa, 1976). However, none of these alternative versions fared as well empirically as the present version of the power function. It should be noted that this formulation departs somewhat from the tradition of Utility Theory in that it computes the attractiveness of lotteries in terms of changes in wealth (i.e., gains and losses) rather than in terms of final assets. This notion of a reference outcome is due to more recent developments in the theory of choice, advanced by Kahneman and Tversky's (1979) Prospect Theory.

Within Prospect Theory, the carriers of value are expressed as positive or negative deviations from a neutral reference point rather than as final monetary assets. Furthermore, the probabilities associated with outcomes are transformed via a decision weight function, π, into their subjective values for the decision maker. Kahneman and Tversky do not suggest specific candidates for Prospect Theory's value function or for its decision weight function. In conformity with the present two-parameter versions of Utility Theory and the Advantage Model, we tested a two-parameter version of Prospect Theory. For Prospect Theory's value function we use the one-parameter rendition of the power utility function presented above:

$$U^c(x) = \text{sign}(x)[|x|^c].$$

(While this rendition captures the general shape of the value function, note that it cannot yield a steeper curve for losses than for gains, as originally hypothesized by Prospect Theory.) For Prospect Theory's decision-weight function, π, we have devised the following family of functions, parameterized by w:

$$\pi_w(p) = wp^2 + (.8 - w)p + .1.$$

This formulation of π captures the essential features of the function suggested by Kahneman and Tversky (1979), at least in the range of

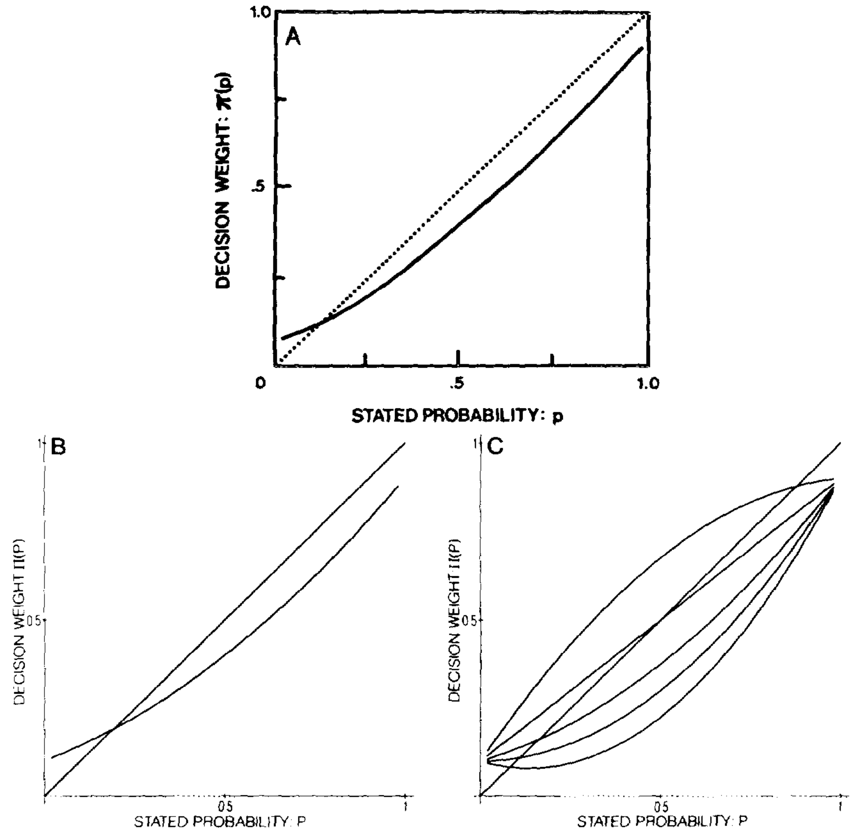


FIG. 3. Prospect Theory's π function. (A) The decision-weight function for Prospect Theory suggested by Kahneman and Tversky (1979). (B) One of the family of decision-weight functions investigated by the current version of Prospect Theory (w = .4). (C) A sample of other decision-weight functions in the family of functions investigated by the current version of Prospect Theory.

probabilities used in the present study. This may be witnessed by a visual comparison of the present function with the schematic suggestion of Kahneman and Tversky, as in Fig. 3. Thus, a range of w values (e.g., $w = .4$, as in Fig. 3B) satisfies π's properties of subcertainty, subproportionality, and subadditivity for small values of p, as discussed by these authors.[7]

[7] Tversky and Kahneman (1992) present an extension of Prospect Theory that incorporates a rank-dependent value function, extends to uncertain as well as risky prospects, and applies to any number of outcomes. While the extended version represents a significant theoretical enrichment, it coincides with the original version on all simple and mixed lotteries of the kind investigated in the present paper.

According to Prospect Theory, the mixed lottery (d_1,p_1,e_1) is evaluated according to the formula

$$U^c(d_1)\pi_w(p_1) + U^c(e_1)\pi_w(1 - p_1).$$

Of course, the above formulations are only two of many possible versions of Utility Theory and Prospect Theory. They are intended mainly to provide a standard against which to compare the predictive capabilities of the Advantage Model.

5.2. Methodological Considerations

5.2.1. Within-subject tests of theories. The Advantage Model yields strong predictions concerning indifference judgments. For example, according to the Advantage Model a person is predicted not to exhibit indifference among any three simple lotteries with equal expected value. Given lotteries (d_1,p_1), (d_2,p_2), and (d_3,p_3), with $d_1p_1 = d_2p_2 = d_3p_3$ and $p_3 > p_2 > p_1$, if person S is indifferent between (d_1,p_1) and (d_2,p_2) then, according to the Advantage Model, S must prefer (d_3,p_3) over either of the former. (This prediction is easily deduced from the arithmetic of the Advantage Model.) The intuition of indifference, however, is usually unstable for even the most cooperative subject. For this reason we have designed our experiments around the sturdier judgment of strict preference. Our experimental procedure (detailed below) thus consisted of asking subjects for a judgment of strict preference between the two lotteries figuring in a choice problem. Numerous problems were presented to each subject. Let us now consider the analysis of the Advantage Model in this situation. Each pair of values assigned to the parameters k_G and k_L leads the Advantage Model to make specific predictions about which lottery should be preferred in each choice problem. At the same time, each subject chooses a specific lottery in each problem. Thus, each pair of values assigned to the parameters k_G and k_L leads the Advantage Model to make a definite number of true predictions about the choices of an individual subject. Because subjects did not have the option to indicate indifference between lotteries, any prediction of indifference by the Advantage Model, using a particular k_G,k_L pair, was counted as a misprediction. We call a k_G,k_L pair "optimizing" with respect to a given subject if no other pair of values k_G,k_L leads the Advantage Model to a greater number of true predictions about that subject's choices. Since more than one pair of k_G,k_L values may lead to an equal, greatest number of correct predictions, we arbitrarily select the lowest such pair in the natural, lexicographical ordering as the optimizing pair. Preliminary searches of the parameter space indicated that a subject's optimizing k_G and k_L are nearly certain to fall in the interval [0, 3]. Consequently, for each subject in each experiment we computed the optimizing k_G,k_L pair in the interval [0, 3], proceeding by increments of .075. Every combination of values between 0 and 3 at intervals of .075 for both k_G and k_L was thus attempted. This constituted a search through 1600 (40*40) different value-pairs for each subject in each experiment. The number of true predictions made by the Advantage Model for each subject, relative to his optimizing k_G,k_L pair, was recorded.

Consider now Utility Theory. Parallel to the Advantage Model, each pair of values assigned to the parameters c_G and c_L leads the present version of Utility Theory to make a definite number of true predictions about the choices of an individual subject. Again, predictions of indifference were counted as incorrect. Call a c_G,c_L pair optimizing with respect to a given subject if no other values of c_G and c_L lead Utility Theory to a greater number of true predictions about that subject's choices. A preliminary sketch of the resulting utility curves indicates that a subject's optimizing c_G and c_L are almost certain to fall in the interval [0, 1.5]. Consequently, for each subject in each experiment we computed the optimizing c_G,c_L pair in the interval [0, 1.5], proceeding by increments of .0375. As before, in the case of multiple optimizing pairs, the lowest such pair was retained. Just as for the Advantage Model, this constitutes a search through 1600 different c_G,c_L pairs per subject per experiment. The number of true predictions made by the present version of Utility Theory for each subject relative to her optimizing c_G,c_L pair was recorded.

The within-subject analyses for Prospect Theory followed exactly the same logic. Each pair of values assigned to the parameters c and w leads Prospect Theory to make a definite number of true predictions about the choices of an individual subject. As before, predictions of indifference were counted as incorrect. Again, we call a c,w pair optimizing with respect to a given subject if no other values of c and w lead Prospect Theory to a greater number of true predictions about that subject's choices. For each subject we computed his optimizing c,w pair by searching for the optimizing c in the interval [0, 1.5] proceeding by increments of .0375, and for the optimizing w in the interval [−1.14, 1.11], proceeding by increments of .05625. The latter interval was motivated by requirements of monotonicity: values of w outside this interval lead to nonmonotone functions, which clearly are rejected by Prospect Theory. As before, these values entail a search through 1600 different c,w pairs per subject in each experiment, and in the case of multiple optimizing pairs, the lowest such pair was retained. The number of true predictions made by the present version of Prospect Theory for each subject relative to his optimizing c,w pair was recorded.

5.2.2. Group tests of theories. The relationship between individual and aggregate behavior is an intricate problem that has recently been addressed by a number of researchers (see, e.g., Akerlof & Yellen, 1985;

Russell & Thaler, 1985). We observe at the outset that the ability of a theory to predict group preferences ought not be confounded with its ability to predict the preferences of particular individuals in the group (for discussion, see Luce, 1959). Consequently, these group analyses do not contribute to the earlier, within-subject analyses, but rather bear on an independent characteristic of the theories, namely, their ability to predict group data. For the group analyses, we shall attempt to use the various theories to predict the proportion of subjects opting for one or another lottery in a choice problem. In this use of the theories, the pair of optimizing parameters attributed to a group of subjects is the average of the optimizing parameter-pairs obtained by each theory from the within-subject analysis of the experiment in question. The details of the group analyses are as follows.

The *observed advantage* of a given lottery in a given choice problem is defined to be the proportion of subjects who chose that lottery in that problem. For example, if the simple choice problem [(2000,.50), (1000,.60)] is presented to 100 subjects and 75 choose the left-hand lottery, then the observed advantage of that lottery in that problem is 75/100. Because of the binary-choice nature of our procedure, it is sufficient to focus attention on the observed advantage of one lottery in each choice problem (the observed advantage of the second lottery being 1 minus that of the first). To carry out our group tests of the theories we correlated the observed advantage of one lottery in each choice problem (in particular, the left-hand lottery of each problem, as listed in Tables 3 and 4) against its *predicted advantage*. A lottery's predicted advantage is defined in the following way.

Recall that all theories under investigation assign a theoretical attractiveness (in the form of a coefficient) to each lottery in a choice problem. The predicted advantage of a lottery captures the extent to which that lottery's theoretical attractiveness is advantageous over the competing lottery's attractiveness. The larger a lottery's theoretical attractiveness relative to its competitor in a choice problem, the larger its predicted advantage. In a simple choice problem the most obvious way to determine a lottery's predicted advantage is to divide that lottery's theoretical attractiveness by the sum of the theoretical attractivenesses of both lotteries figuring in the problem. Thus, if the attractiveness coefficient of one lottery in a problem is twice that of another's, say, 20 versus 10, then its predicted advantage (namely, 20/30) will be twice the other's (whose predicted advantage is 10/30). On the other hand, if the two lotteries are assigned equal attractiveness coefficients (e.g., 10) than the predicted advantage of each is 1/2 (i.e., 10/20). In the case of mixed lotteries, however, this formula is insufficient. For, while in simple choice problems the lotteries' theoretical attractivenesses are either both positive or both neg-

TABLE 3
CHOICE PROBLEMS USED IN EXPERIMENT I

	Set 1 (N = 53)		
1. [(1600,.25)(800,.35)]	{52}	13. [(−1600,.25)(−800,.35)]	{5}
2. [(1500,.30)(750,.50)]	{28}	14. [(1500,.15)(750,.25)]	{38}
3. [(1700,.35)(850,.65)]	{12}	15. [(−1700,.45)(−850,.85)]	{41}
4. [(1500,.40)(750,.80)]	{9}	16. [(−1500,.20)(−750,.40)]	{31}
5. [(1500,.30)(900,.40)]	{49}	17. [(1500,.60)(900,.80)]	{19}
6. [(1250,.55)(750,.75)]	{19}	18. [(−1250,.55)(−750,.75)]	{22}
7. [(1300,.50)(800,.80)]	{7}	19. [(1300,.15)(800,.25)]	{20}
8. [(1750,.30)(1050,.70)]	{1}	20. [(−1750,.30)(−1050,.70)]	{53}
9. [(1650,.50)(1150,.60)]	{43}	21. [(1650,.25)(1150,.30)]	{39}
10. [(1350,.40)(950,.60)]	{17}	22. [(1350,.10)(950,.15)]	{38}
11. [(1700,.20)(1200,.50)]	{2}	23. [(−1700,.20)(−1200,.50)]	{51}
12. [(1400,.40)(1000,.80)]	{1}	24. [(−1400,.40)(−1000,.80)]	{53}
	Set 2 (N = 57)		
1. [(160,.25)(80,.35)]	{57}	13. [(−160,.25)(−80,.35)]	{4}
2. [(150,.30)(75,.50)]	{33}	14. [(150,.15)(75,.25)]	{40}
3. [(170,.35)(85,.65)]	{18}	15. [(−170,.45)(−85,.85)]	{43}
4. [(150,.40)(75,.80)]	{8}	16. [(−150,.20)(−75,.40)]	{33}
5. [(150,.30)(90,.40)]	{54}	17. [(150,.60)(90,.80)]	{23}
6. [(125,.55)(75,.75)]	{26}	18. [(−125,.55)(−75,.75)]	{37}
7. [(130,50)(80,.80)]	{10}	19. [(130,.15)(80,.25)]	{28}
8. [(175,.30)(105,.70)]	{3}	20. [(−175,.30)(−105,.70)]	{56}
9. [(165,.50)(115,.60)]	{51}	21. [(165,.25)(115,.30)]	{48}
10. [(135,.40)(95,.60)]	{21}	22. [(135,.10)(95,.15)]	{43}
11. [(170,.20)(120,.50)]	{1}	23. [(−170,.20)(−120,.50)]	{55}
12. [(140,.40)(100,.80)]	{0}	24. [(−140,.40)(−100,.80)]	{54}
	Set 3 (N = 50)		
1. [(13,.50)(8,.70)]	{25}	13. [(13,.30)(8,.40)]	{37}
2. [(15,.60)(9,.80)]	{28}	14. [(15,.30)(9,.40)]	{40}
3. [(10,.60)(5,.80)]	{37}	15. [(10,.30)(5,.40)]	{47}
4. [(11,.40)(7,.60)]	{16}	16. [(17,.40)(13,.60)]	{8}
5. [(14,.50)(9,.85)]	{7}	17. [(14,.20)(9,.35)]	{28}
6. [(17,.50)(9,.70)]	{39}	18. [(−17,.50)(−9,.70)]	{18}
7. [(16,.30)(5,.50)]	{43}	19. [(−16,.30)(−5,.50)]	{10}
8. [(16,.40)(10,.70)]	{5}	20. [(−16,.40)(−10,.70)]	{46}
9. [(13,.30)(7,.60)]	{9}	21. [(−13,.30)(−7,.60)]	{40}
10. [(15,.40)(11,.60)]	{5}	22. [(−15,.40)(−11,.60)]	{37}
11. [(11,.20)(5,.50)]	{8}	23. [(16,.20)(10,.50)]	{1}
12. [(17,.70)(11,.80)]	{43}	24. [(11,.70)(5,.80)]	{49}

Note. The numbers of subjects who chose left-hand lottery are shown in curly brackets.

ative, in the case of mixed problems it is possible for one lottery to be assigned a positive coefficient while the other is assigned a negative one. Cases of this kind require a slight modification of the formula above.

Consider a mixed choice problem and a theory that assigns to the two

TABLE 4
CHOICE PROBLEMS USED IN EXPERIMENTS 2 AND 3

	Expt 2	Expt 3		Expt 2	Expt 3
Simple Choice Problems	(N = 78)	(N = 62)		(N = 78)	(N = 62)
1. [(−3,.20),(−2,.30)]	{43}	{35}	13. [(−18,.55),(−10,.65)]	{10}	{3}
2. [(15,.45),(10,.65)]	{30}	{17}	14. [(9,.60),(5,.80)]	{45}	{27}
3. [(−9,.50),(−6,.80)]	{69}	{55}	15. [(16,.40),(9,.70)]	{35}	{11}
4. [(6,.45),(4,.85)]	{10}	{2}	16. [(−7,.45),(−4,.85)]	{67}	{55}
5. [(16,.40),(10,.50)]	{56}	{48}	17. [(−15,.20),(−8,.30)]	{17}	{11}
6. [(−20,.60),(−12,.80)]	{33}	{25}	18. [(15,.50),(8,.70)]	{51}	{35}
7. [(8,.45),(5,.75)]	{21}	{6}	19. [(−19,.35),(−10,.65)]	{44}	{35}
8. [(−11,.30),(−7,.70)]	{72}	{61}	20. [(17,.25),(9,.65)]	{21}	{4}
9. [(12,.20),(7,.30)]	{61}	{43}	21. [(6,.70),(3,.80)]	{71}	{58}
10. [(−5,.65),(−3,.85)]	{46}	{34}	22. [(−16,.15),(−8,.35)]	{45}	{47}
11. [(−10,.40),(−6,.70)]	{61}	{55}	23. [(4,.40),(2,.70)]	{3}	{27}
12. {}17,.30),(10,.70)]	{13}	{0}	24. [(−14,.35),(−7,.75)]	{56}	{56}
Mixed Choice Problems	Expt 2 (N = 78)	Expt 3 (N = 62)		Expt 2 (N = 78)	Expt 3 (N = 62)
1. [(20,.20, −8),(10,.30, −5)]	{26}	{17}	13. [(14,.40, −8),(6,.60, −4)]	{25}	{13}
2. [(15,.20, −5),(18,.40, −13)]	{39}	{31}	14. [(8,.40, −2),(10,.70, −12)]	{34}	{29}
3. [(12,.20, −6),(7,.50, −15)]	{46}	{48}	15. [(16,.40, −5),(4,.80, −12)]	{49}	{50}
4. [(14,.20, −4),(4,.60, −3)]	{20}	{23}	16. [(14,.50, −5),(8,.60, −3)]	{50}	{42}
5. [(4,.20, −2),(5,.70, −17)]	{44}	{43}	17. [(6,.50, −2),(10,.70, −8)]	{30}	{24}
6. [(6,.20, −2),(3,.80, −8)]	{24}	{18}	18. [(17,.50, −3),(13,.80, −15)]	{51}	{50}
7. [(12,.30, −4),(4,.40, −3)]	{58}	{51}	19. [(20,.60, −10),(12,.70, −8)]	{52}	{38}
8. [(8,.30, −3),(10,.50, −6)]	{13}	{12}	20. [(5,.60, −9),(7,.80, −16)]	{26}	{14}
9. [(16,.30, −4),(5,.60, −7)]	{50}	{47}	21. [(18,.70, −7),(13,.80, −9)]	{56}	{53}
10. [(20,.30, −5),(4,.70, −3)]	{47}	{26}	22. [(8,.30, −10),(4,.40, −7)]	{26}	{15}
11. [(10,.30, −3),(12,.80, −10)]	{15}	{7}	23. [(4,.50, −3),(5,.70, −10)]	{48}	{43}
12. [(18,.40, −7),(15,.50, −10)]	{51}	{47}	24. [(16,.20, −2),(3,.80, −15)]	{50}	{51}

Note. The numbers of subjects who chose left-hand lottery are shown in curly brackets.

lotteries in this problem attractiveness coefficients of 10 and −10. Notice, first of all, that a simple addition of the attractiveness coefficients places a 0 in our original formula's denominator and no longer provides an adequate measure of the total amount of attractiveness in the problem. Thus, instead of simply adding the attractivenesses we now add their absolute values. This, once again, gives a measure of the total amount of attractiveness (both positive and negative) present in the problem. Next, consider the predicted advantage attributed to the lottery whose attractiveness coefficient is 10. According to the present formulation, this lottery's predicted advantage is 10/20. In fact, it is 10/20 regardless of whether the competing lottery's coefficient is −10 or 10. But this, of course, is wrong. The predicted advantage of a lottery must be higher when its competitor has a negative attractiveness than when it has a positive one. A mixed lottery's predicted advantage must depend on the *difference* between *its* predicted advantage and that of its competitor.

The foregoing discussion leads to the following formulation of a lottery's predicted advantage, which applies to both simple and mixed lotteries. Consider a (simple or mixed) choice problem. We shall call the two lotteries of this problem the left-hand and right-hand lotteries and refer to their attractiveness coefficients as L and R, respectively. According to the present formulation, the predicted advantage of the left-hand lottery equals $L - R/|L| + |R|$. Similarly, the predicted advantage of the right-hand lottery equals $R - L/|L| + |R|$. The predicted advantage of a lottery is the difference between that lottery's attractiveness and that of its competitor, divided by the total amount of attractiveness in the problem. Given a choice problem with lotteries whose attractiveness coefficients are 10 and −10, these lotteries' predicted advantages are 1 and −1, respectively. The lottery with the positive attractiveness is predicted to have total advantage, while the lottery with the negative attractiveness has total disadvantage. On the other hand, the predicted advantages of lotteries whose attractiveness coefficients are 10 and 5 are 1/3 and −1/3, respectively. The preferred lottery's advantage consists of 1/3 of the total atractiveness present in the problem, while the second lottery has a corresponding disadvantage. By this formula, according to all three theories, the predicted advantages of competing lotteries are always the same value and of opposite sign.

As noted earlier, the values of the parameters used in the calculations of theoretical attractiveness are the values of the average optimizing parameter-pair for the experiment in question. These will be denoted k_G(av), k_L(av) for the Advantage Model, c_G(av), c_L(av) for Utility Theory, and c(av), w(av) for Prospect Theory. We will refer to these as "the average optimizing parameter-pair" where it is understood that each theory employs its own pair. For each theory, we thus have two measures pertaining to a lottery in a choice problem: the lottery's predicted advantage, which captures the proportion of that lottery's theoretical attractiveness in the problem, and the lottery's observed advantage, which represents the proportion of subjects who chose that lottery in that problem. The latter is a measure of the lottery's relative attractiveness to the group as a whole; the former is a measure of the lottery's relative attractiveness according to the theory. On this basis we calculated the correlation between the observed and predicted advantages of lotteries in choice problems.

6. EXPERIMENTS

6.1. Experiment 1: Simple Choice Problems

The present experiment was designed to test the Advantage Model's ability to predict choice among simple lotteries only. Experiments 2 and 3 involve both simple and mixed choice problems.

6.1.1. Experimental Method. DESIGN AND MATERIALS. Three sets of 24 simple choice problems were used. No problem figured in more than one set. All 72 problems are listed, by set, in Table 3. Extreme payoff and probability differences were avoided in order to minimize the use of decision strategies that may arise only in extreme circumstances.

In Set 1 payoffs range from $750 to $1750. Twelve problems (numbers 1–12 of Set 1 in Table 3) were constructd so as to include all combinations of 30, 40, and 50% payoff differences and .10, .20, .30, and .40 probability differences between lotteries. To illustrate, problem 1—viz., [(1600,.25), (800,.35)]—represents a 50% payoff difference and a .10 probability difference. The remaining 12 problems (numbered 13–24) are variants of problems 1–12, respectively. Thus, problem 13 is identical to problem 1 except that it involves negative rather than positive lotteries; problem 14 is identical to problem 2 except that the probabilities are halved; problem 16 is the negative and halved version of problem 4, etc.

Set 2 consists of the same problems as Set 1 except that payoffs are uniformly decreased by a factor of 10. Note that both the Advantage Model and the present versions of Utility Theory and Prospect Theory should be equally applicable to all simple choice problems, regardless of payoff-size.

Set 3 ranges over payoffs from $5 to $17. Problems 1–12 constitute new problems and problems 13–24 are, as before, variants of the first 12.

The range of probabilities in the problems is .10–.85. We did not include extreme probabilities in order to avoid "editing" effects. Presented with a probability of .03, for example, the subject might decide that the chance of winning is "essentially zero" and base her choice entirely on that (for further discussion of editing, see Kahneman & Tversky, 1979. Shafir *et al.*, 1989, p. 19., discuss the relevance of editing to the Advantage Model).

For each set, the 24 choice problems appeared on separate pages, assembled into a 24-page booklet. The problems (e.g., problem 1 of set 2) appeared in the following format:

Choose between
25% chance to win $160 ___
35% chance to win $80 ___

The original 12 problems formed an uninterrupted half of the booklet and their 12 variants formed the other half. This was done so as to avoid juxtaposition of two variants of the same problem. The order of the two halves was counterbalanced across booklets. Within each half, the order of problems was randomized for each subject. Finally, within each problem (i.e., on a single page), the order of the two competing lotteries was counterbalanced.

SUBJECTS. The subjects were 160 M.I.T. undergraduate volunteers, recruited from a variety of classes and paid for their participation.

PROCEDURE. Each subject received one booklet corresponding to one of the three sets of choice problems. The administration of the three sets followed the same procedure. Subjects were first presented with written instructions, in which they were asked to choose, from each pair of lotteries that they encounter, the lottery that they prefer to have. Next, each subject was handed a single booklet and asked to work through it at her own speed without referring back to earlier problems. Typically, subjects worked for 10–15 min. No bets were actually played. After completing their booklets, subjects were asked to indicate if they had used any predetermined, mechanical procedure to arrive at their choices, rather than responding intuitively. Data from subjects who had decided at the outset to use some mechanical procedure (e.g., "always choose higher probabilities," "always choose higher payoff," etc.) were discarded. (These subjects, when later presented with examples, all agreed that the strategy they had adopted did not capture their true preferences.) Three to five subjects were thereby eliminated from each set. Apart from those eliminated, 53 subjects completed set 1, 57 completed set 2, and 50 completed set 3.

6.1.2. Results and discussion. PRELIMINARY ANALYSIS. The bracketed number next to each problem in Table 3 indicates the number of subjects who chose the left-hand lottery. Since a forced-choice procedure was employed, the remaining subjects chose the right-hand lottery. Substantial numbers of subjects exhibited the reflection and common ratio effects. This can be seen in Table 3 by comparing, for example, problems 1 and 13, 5 and 17, 8 and 20, and 12 and 24 of set 1. Note further that decreasing all payoffs by a factor of 10 (Sets 1 vs 2) had no significant effect on subjects' preferences between lotteries. This is consistent with what is known in the economic literature as "proportional risk aversion" (e.g., Keeney and Raiffa, 1976) and is predicted by the Advantage Model. Because proportional risk aversion implies a power utility function for both Utility Theory and Prospect Theory, this pattern lends further support to the use of a power function in the analyses of these theories.

WITHIN-SUBJECT TESTS OF THEORIES. Consider first the Advantage Model. Recall that a k_G,k_L pair is considered "optimizing" with respect to a given subject if no other pair of values k_G,k_L leads the Advantage Model to a greater number of true predictions about that subject's (in this case, 24) choices. Each subject's optimizing k_G,k_L pair and number of true predictions were recorded.

There were no significant differences in the model's performance on the three sets of choice problems (average number of correct predictions per subject were 21.28, 21.19, and 21.24, for sets 1, 2, and 3, respectively). Notice that this is consistent with the present theories' assumption of independence from payoff size. The three sets will henceforth be presented as a single group yielding a total of 160 subjects each of which made 24 choices. In this large group, the average number of correct predictions per subject made by the Advantage Model was 21.24 (SD = 1.46). The average optimizing values for the k_G,k_L pair were .406 (SD = .247) for k_G and .337 (SD = .282) for k_L. (Since the parameters k_G,k_L represent the relative weight of payoffs and probabilities, values of $k_G,k_L < 1$ are consistent with findings that people generally perceive probability as more important than payoffs in choice situations; see Goldstein & Einhorn, 1987; Slovic & Lichtenstein, 1968; Tversky, Sattath, & Slovic, 1988.)

We then generated 160 fictitious subjects (53, 57, and 50, for sets 1, 2, and 3, respectively) and randomly assigned 24 choices to each subject. We repeated the analyses on these random data (searching, as before, the interval [0,3] by steps of .075 for an optimizing k_G,k_L pair for each subject). The average number of correct predictions obtained by the Advantage Model for the randomly generated subjects was 16.44 (SD = 1.50), which is significantly lower than the average obtained for the 160 real subjects ($p < .001$, t test).

Consider now Utility Theory. Similar to the Advantage Model, for each subject we computed and recorded his optimizing c_G,c_L pair and the number of true predictions made by Utility Theory relative to that pair. Across all three problem sets, the average number of correct predictions per subject was 20.68; the average optimizing values for the c_G,c_L pair were .713 (SD = .245) for c_G and .592 (SD = .289) for c_L. Utility Theory's average number of true predictions per subject was significantly lower than that of the Advantage Model ($t(159) = 4.26$; $p < .001$).

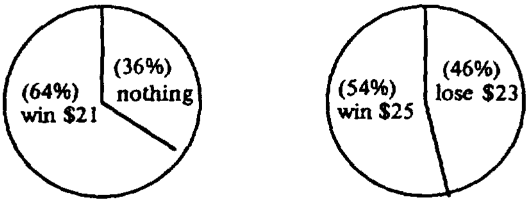
Finally, consider Prospect Theory. As for the previous two theories, the number of true predictions made by the present version of Prospect Theory for each subject, relative to his optimizing c,w pair, and the c,w pair, were recorded. Across the three sets, the average number of correct predictions per subject was 21.39. The average optimizing values for the c,w pair were .582 (SD = .189) for c and $-.115$ (SD = .605) for w. Prospect Theory's average number of true predictions per subject was somewhat higher than that of the Advantage Model but the difference did not reach significance ($t(159) = 1.6$). On the other hand, Prospect Theory's average number of true predictions per subject was significantly higher than that of Utility Theory ($t(159) = 6.23$; $p < .001$).

Group Tests of Theories. We proceed now to a test of the Advantage Model as a description of group preference. We remind the reader that in the group analyses we attempt to use the competing theories to predict the proportion of subjects opting for one or another lottery in a choice problem. In this use of the theories, the pair of optimizing parameters attributed to a group of subjects is the average optimizing parameter-pair obtained by each theory in the within-subject analyses. (Thus, k_G(av) and k_L(av) for the present group analysis are .406, and .337; c_G(av) and c_L(av) are .713 and .592; and c(av) and w(av) are .582 and $-.115$, respectively.) For each theory, we have two measures pertaining to a lottery in a choice problem: the lottery's predicted advantage, which captures the proportion of that lottery's theoretical attractiveness, and the lottery's observed advantage, which represents the proportion of subjects who chose it.

For the left-hand lotteries of all choice problems in Table 3, we correlated the lotteries' observed and predicted advantages. This correlation involves 72 paired numbers. For the Advantage Model, the obtained correlation was .96. The obtained correlation for Prospect Theory was .89, while for Utility Theory it was .83. Prospect Theory does significantly better than Utility Theory (t = 3.63; $p < .001$, significance test between dependent correlations, Bruning & Kintz, 1977, p. 215). The Advantage Model predicts group data significantly better than both Prospect Theory and Utility Theory (t = 4.59 and 6.49, respectively; $p < .001$ in both cases).

6.2. Experiment 2: Simple and Mixed Choice Problems

A second experiment was conducted this time designed to evaluate the predictive capabilities of our model on a combination of both simple and mixed choice problems. Because of the increased complexity inherent to mixed choice problems, we provided the subjects with a visual aid. Each lottery was represented as a circle (or a "pie"), with its probabilities occupying proportional slices of the pie. The payoffs and probabilities appeared inside their respective slices. Thus, the simple lottery ($21,.64) and the mixed lottery ($25,.54, –$23) would be presented, respectively, in the following fashion:



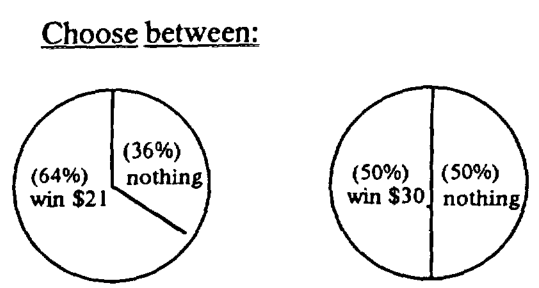
6.2.1. Experimental method. DESIGN AND MATERIALS. The experiment consisted of 48 choice problems. Twenty-four were simple choice problems, and 24 were mixed choice problems. They are listed in Table 4.[8]

[8] An additional 24 problems were administered in the course of the same procedure. These additional problems were designed to test theories of choice among "nonconflictual" problems, in the sense discussed in Section 3.2. As such they lie outside the purview of the Advantage Model and are considered no further here. For more discussion, see Shafir (1988).

Payoffs in this experiment ranged from \$2 to \$20. The range of probabilities was .15–.85. The simple problems were constructed in the following manner. The value of the higher payoff (either a loss or a gain) was 150, 160, 170, 180, 190, or 200% the value of the lower payoff. The probability differences were .10, .20, .30, or .40. The 24 simple choice problems were constructed so as to yield all combinations of these payoff and probability differences.

The mixed choice problems were constructed in the following manner. All probabilities between .20 and .80 that were multiples of .10 were used. Thus, to construct mixed lotteries, there were 7 possible probability combinations (i.e., .10 and .90, .20 and .80, .30 and .70, etc, since the probabilities must add up to 1). Each possible combination was matched with all six other combinations to yield 21 different choice problems. For the remaining 3 problems, some probability combinations were arbitrarily repeated. Now, consider a mixed lottery that offers a higher chance to gain than the competing lottery. This lottery can have both its payoffs (gain and loss) *greater* than the competing lottery's, *smaller* than the competing lottery's, or it can offer a smaller gain and a greater loss (notice that the opposite—a greater gain and a smaller loss—is not permissible since this lottery would then dominate the other). All such payoff-relations were arbitrarily interspersed among the different probability combinations.

The 48 choice problems appeared on separate pages, assembled into a booklet. The problems appeared in the following format:



For each subject, the order of the choice problems was randomized. Within each problem (i.e., on a single page) the order of the two competing lotteries was counterbalanced.

SUBJECTS. The subjects were 78 University of Michigan undergraduate volunteers, recruited by phone and paid for their participation.

PROCEDURE. Subjects were first presented with written instructions, in which they were asked to choose, from each pair of lotteries that they encounter, the lottery that they prefer to have. Next, each subject was handed a single booklet and asked to work through it at his own speed without referring back to earlier problems. Typically, subjects worked for approximately 30 min. After completing the booklet, subjects were asked to indicate if they had used any predetermined, mechanical procedure to arrive at their choices, rather than responding intuitively. Because no subject gave an unequivocal indication of such procedure, no subject's data were discarded. Finally, as had been explained to them in the instructions, subjects had the option to actually play for money the lottery that they had chosen in a randomly picked choice problem. This was done so as to increase subjects' motivation to choose the options that they genuinely preferred.[9]

6.2.2. *Results and discussion.* The within-subject and group analyses of the present experiment follow the same logic as those of the previous experiment.

WITHIN-SUBJECT TESTS OF THEORIES. For each subject we computed his optimizing k_G,k_L pair, separately for the simple problems, for the mixed problems, and for all 48 problems combined. Thus, for each subject, we obtained (1) the greatest number of true predictions made by the Advantage model for that subject's 24 choices among *simple* lotteries; (2) the greatest number of true predictions made by the Advantage model for the subject's 24 choices among *mixed* lotteries; and (3) the greatest number of true predictions made by the Advantage model for the subject's 48 choices among both simple and mixed lotteries combined. (Note that a subject's score for (3) will not necessarily be the sum of the scores for (1) and (2). An analysis of all 48 choices requires a single optimizing pair, whereas the 24-problem analyses can each utilize a different optimizing pair.)

Table 5(A) presents the average number of correct predictions per subject thereby obtained for each set of problems, along with the average optimizing k_G,k_L pair. For the simple choice problems, the average number of correct predictions per subject was 20.85. For the mixed problems, it was 20.21, and for all 48 problems combined, the average number of correct predictions was 38.60.

Next, we randomly generated another 100 fictitious subjects and repeated the analysis (using the same searches as for the real subjects) on these random data. Both for simple problems and for mixed problems, the average number of correct predictions per randomly generated subject (16.42 and 16.35, respectively) was significantly lower than that obtained for the real subjects ($p < .001$ in both cases, t test).

[9] There is, however, ample evidence that subjects' choices tend not to differ significantl between situations involving hypothetical payoffs and situations where real payoffs ar, offered. See, e.g., Grether and Plott (1979), Lichtenstein and Slovic (1971; Slovic & Lichtenstein, 1983), as well as Schoemaker (1982) for a review.

TABLE 5
INDIVIDUAL CHOICE PREDICTIONS, EXPERIMENT 2

(A) Advantage Model

Set of choice problems	Average number of correct predictions	Average optimizing k_G, k_L pair
Simple problems	20.85 (SD = 1.69)	k_G = .533 (SD = .460) k_L = .420 (SD = .353)
Mixed problems	20.21 (SD = 2.11)	k_G = .738 (SD = .690) k_L = .811 (SD = .706)
Simple and mixed problems combined	38.60 (SD = 4.18)	k_G = .644 (SD = .581) k_L = .580 (SD = .503)

(B) Utility Theory

Set of choice problems	Average number of correct predictions	Average optimizing c_G,c_L pair
Simple problems	20.26 (SD = 2.11) ($t(77) = -3.48$)	c_G = .665 (SD = .335) c_L = .644 (SD = .355)
Mixed problems	19.99 (SD = 2.29) ($t(77) = -1.79$)	c_G = .733 (SD = .431) c_L = .810 (SD = .464)
Simple and mixed problems combined	38.67 (SD = 4.38) ($t(77) = 0.29$)	c_G = .777 (SD = .355) c_L = .814 (SD = .349)

(C) Prospect Theory

Set of choice problems	Average number of correct predictions	Average optimizing c,w pair
Simple problems	20.62 (SD = 2.03) ($t(77) = -1.30$)	c = .570 (SD = .236) w = −.212 (SD = .626)
Mixed problems	19.41 (SD = 2.58) ($t(77) = -4.24$)	c = .713 (SD = .355) w = −.517 (SD = .712)
Simple and mixed problems combined	37.85 (SD = 4.44) ($t(77) = -3.03$)	c = .706 (SD = .314) w = −.137 (SD = .612)

Note. This table gives the average number of correct predictions made by each theory for each set of choice problems in Experiment 2, along with the average, lowest optimizing parameter-pair for the theory in question. Also summarized are tests of significance between the average number of correct predictions obtained by Utility Theory and Prospect Theory and the corresponding number obtained by the Advantage Model.

The Advantage Model's percentage of correct predictions per subject was somewhat lower for the set of simple and mixed problems combined than for the simple and mixed problems when analyzed separately. Of course, one reason for this may be that in the former case a single k_G,k_L pair is used to predict more choices than in either of the latter cases. It is also possible, however, that the two kinds of problems—the simple and the mixed—lead subjects to weigh payoffs and probabilities differently. Such context-dependent shifts in weights would be consistent with the "contingent weighting" notions discussed in Section 3.4, and with Slovic and Lichtenstein's (1968) discussion of the relative importance of probabilities and payoffs in risky choice. Although the Advantage Model may be weakened to incorporate this notion, the present, stronger version of the model does not allow for such change in relative weights—it explicitly hypothesizes a single parameter-pair for all of a subject's choices.

Consider now Utility Theory. Similar to the Advantage Model, for each subject we computed his optimizing c_G,c_L pair, separately for the simple problems, for the mixed problems, and for all 48 problems combined. In each case, the number of true predictions made by Utility Theory, relative to the subject's optimizing c_G,c_L pair was recorded. Table 5(B) presents the average number of correct predictions per subject thereby obtained for each set of problems, along with the average optimizing c_G,c_L pair. Utility Theory's average numbers of correct predictions per subject were 20.26, 19.99, and 38.67, for the simple problems, the mixed problems, and all 48 problems combined, respectively.

Finally, consider Prospect Theory. As for the other theories, for each subject we computed his optimizing c,w pair, separately for the simple problems, for the mixed problems, and for all 48 problems combined. The average number of correct predictions per subject thereby obtained for each set of problems along with the average optimizing c,w pair are summarized in Table 5(C). Prospect Theory's average numbers of correct predictions per subject were 20.62, 19.41, and 37.85, for the simple problems, the mixed problems, and all 48 problems combined, respectively.

For simple choice problems, the Advantage Model's average number of true predictions per subject was significantly higher than that of Utility Theory ($t(77) = 3.48$; $p < .001$) and higher than that of Prospect Theory, although the latter difference failed to reach significance ($t(77) = 1.30$). For mixed problems, the Advantage Model's average number of true predictions per subject was significantly higher than that of Prospect Theory ($t(77) = 4.24$; $p < .01$) and was higher than that of Utility Theory but failed to reach significance on a two-tailed test ($t(77) = 1.79$; $p < .10$). Finally, for the simple and mixed choice problems combined, the Advantage Model's average number of true predictions per subject was significantly higher than that of Prospect Theory ($t(77) = 3.03$; $p < .01$) and slightly lower than that of Utility Theory, but this was not significant ($t(77) = .289$). Prospect theory's average number of correct predictions per subject was higher than that of Utility Theory for the simple choice problems ($t(77) = 2.27$; $p < .05$). For the mixed problems and for all 48 problems combined, Utility Theory's average number of true predictions per subject was higher than that of Prospect Theory ($t(77) = 3.25$, and 3.98, respectively; $p < .01$ in both cases).

Group Tests of Theories. As before, we correlated between lotteries' predicted and observed advantages. Predicted advantages were computed using the average optimizing pair for the theory in question. For the simple and for the mixed choice problems the correlations involve 24 paired numbers; for all choice problems combined they involve 48 paired numbers.

The correlations obtained are summarized in Table 6. For the Advantage Model, the obtained correlations were .96 for the simple choice problems, .85 for the mixed choice problems, and .75 for all problems combined. For Utility Theory, the corresponding numbers were .81, .76, and .63. For Prospect Theory, these numbers were .88, .82, and .59, respectively. The Advantage Model's obtained correlations were higher than those of both competing theories in all three cases. For the simple choice problems and for all problems combined, the Advantage Model's obtained correlations were significantly higher ($p < .05$ in both cases), while for the mixed problems alone the difference failed to reach significance.

6.3. Experiment 3: A Replication Using Verbal Display

The foregoing experiment was replicated with 62 M.I.T. undergraduates, using a different mode of presentation. Numerous studies have shown that the mode in which a problem is presented can have significant effects on people's processing and weighing of information (see, e.g., Hogarth, 1987, for a review). In this experiment, rather than presenting the choice problem in a pictorial fashion (as was done in Experiment 2), the problems (e.g., mixed problem 1) appeared in the following format (which follows that of Experiment 1):

Choose between
20% chance to win $20 and 80% chance to lose $8 ___
30% chance to win $10 and 70% chance to lose $5 ___

TABLE 6
GROUP PREFERENCE PREDICTIONS, EXPERIMENT 2

	Simple choice problems	Mixed choice problems	Simple and mixed choice problems
The Advantage Model	.96	.85	.75
Utility Theory	.81 ($t(21) = -4.02$)	.76 ($t(21) = -1.18$)	.63 ($t(45) = -1.89$)
Prospect Theory	.88 ($t(21) = -2.99$)	.82 ($t(21) = -0.43$)	.59 ($t(45) = -2.58$)

Note. This table gives the correlations between lotteries' observed and predicted advantage, obtained by each theory for each set of choice problems in Experiment 2. Also summarized are tests of significance between the correlations obtained by Utility Theory and Prospect Theory and the corresponding correlation obtained by the Advantage Model.

The choice problems used in this experiment were the same 48 problems used in Experiment 2 (and listed in Table 4). The method, procedure, and analyses were identical to those of the previous experiment.

WITHIN-SUBJECT TESTS OF THEORIES. Table 7(A) presents the average number of correct predictions per subject obtained by the Advantage Model for each set of problems (simple, mixed, and combined), along

TABLE 7
INDIVIDUAL CHOICE PREDICTIONS, EXPERIMENT 3

(A) Advantage Model

Set of choice problems	Average number of correct predictions	Average optimizing k_G, k_L-pair
Simple problems	22.00 (SD = 1.20)	k_G = .368 (SD = .225)
		k_L = .379 (SD = .279)
Mixed problems	20.29 (SD = 1.82)	k_G = .740 (SD = .565)
		k_L = .997 (SD = .726)
Simple and mixed	38.76 (SD = 3.01)	k_G = .452 (SD = .235)
problems combined		k_L = .604 (SD = .459)

(B) Utility Theory

Set of choice problems	Average number of correct predictions	Average optimizing c_G, c_L pair
Simple problems	21.76 (SD = 1.35)	c_G = .618 (SD = .289)
	($t(61)$ = −1.65)	c_L = .668 (SD = .340)
Mixed problems	20.34 (SD = 1.67)	c_G = .884 (SD = .273)
	($t(61)$ = 0.33)	c_L = .982 (SD = .388)
Simple and mixed	39.58 (SD = 3.09)	c_G = .740 (SD = .290)
problems combined	($t(61)$ = 4.20)	c_L = .846 (SD = .338)

(C) Prospect Theory

Set of choice problems	Average number of correct predictions	Average optimizing c, w pair
Simple problems	21.79 (SD = 1.77)	c = .540 (SD = .197)
	($t(61)$ = −0.98)	w = −.144 (SD = .600)
Mixed problems	19.76 (SD = 1.94)	c = .696 (SD = .282)
	($t(61)$ = −3.35)	w = −.790 (SD = .614)
Simple and mixed	38.61 (SD = 3.28)	c = .641 (SD = .243)
problems combined	($t(61)$ = −0.49)	w = −.223 (SD = .545)

Note. This table gives the average number of correct predictions made by each theory for each set of choice problems in Experiment 3, along with the average, lowest optimizing parameter pair for the theory in question. Also summarized are tests of significance between the average number of correct predictions obtained by Utility Theory and Prospect Theory and the corresponding number obtained by the Advantage Model.

with the average optimizing k_G,k_L pair. For the simple choice problems, the average number of correct predictions per subject was 22.0. For the mixed problems, the average number of correct predictions was 20.29, and for all 48 problems combined, the number was 38.76.

Except for a more successful prediction of simple choice problems than in Experiment 2, the number of correct predictions obtained by the Advantage Model in the present experiment did not differ significantly from those obtained for the analogous kinds of problems in the previous two experiments. Similarly, the group analyses (discussed below) were essentially identical. This leads us to conclude that the mode of presentation had little influence on subjects' choices, which is further supported by the fact that a similar proportion of subjects chose corresponding lotteries in the two experiments (correlation of .94).

Utility Theory and Prospect Theory are summarized in Tables 7(B) and 7(C), respectively. Utility Theory's average numbers of correct predictions per subject were 21.76, 20.34, and 39.58, respectively, for the simple problems, the mixed problems, and for all 48 problems combined. Prospect Theory's corresponding numbers were 21.79, 19.76, and 38.61. Also summarized in the Tables are the tests of significance between the two theories and the Advantage Model. The Advantage Model's average number of correct predictions per subject did not differ significantly from that of Utility Theory for the simple and for the mixed problems, but was significantly lower for the simple and mixed problems combined. Similarly, it did not differ significantly from that of Prospect Theory for the simple problems and for the simple and mixed problems combined, but was significantly higher for the mixed problems.

Notice, finally, that in both Experiments 2 and 3 all theories predicted the simple choice problems better than the mixed choice problems. One reason for this may be that choices between simple lotteries are easier to make and thus lead to less noisy data. It is also possible, however, that subjects made their choices in the simple problems more carefully than they did in the more complicated mixed problems. Some studies on decision time and task complexity (see, e.g., Kiesler, 1966; Hogarth, 1975) suggest a greater motivation in people to be optimal when simpler rather than more complex choices are required.

Group Tests of Theories. The correlations obtained between observed and predicted advantages are summarized in Table 8. For the Advantage Model, the obtained correlations were .97 for the simple choice problems, .87 for the mixed choice problems, and .74 for all problems combined. For Utility Theory, the corresponding numbers were .89, .87, and .58. For Prospect Theory, these numbers were .92, .81, and .57. Also summarized in Table 8 are tests of significance between the correlations obtained by Utility Theory and Prospect Theory and the Advantage Model.

TABLE 8
GROUP PREFERENCE PREDICTIONS, EXPERIMENT 3

	Simple choice problems	Mixed choice problems	Simple and mixed choice problems
The Advantage Model	.97	.87	.74
Utility Theory	.89	.87	.58
	($t(21) = -3.21$)	($t(21) = -0.12$)	($t(45) = -2.42$)
Prospect Theory	.92	.81	.57
	($t(21) = -2.52$)	($t(21) = -0.97$)	($t(45) = -2.62$)

Note. This table gives the correlations between lotteries' observed and predicted advantage, obtained by each theory for each set of choice problems in Experiment 3. Also summarized are tests of significance between the correlations obtained by Utility Theory and Prospect Theory and the corresponding correlation obtained by the Advantage Model.

6.4. Summarizing the Quantitative Evaluation

Three experimental studies were conducted, designed to test the Advantage Model's ability to predict choice among simple and mixed lotteries. While the empirically estimated values of the parameters k_G and k_L were generally consistent with those required to predict the earlier qualitative phenomena, these estimates should be interpreted with caution. Informal searches show that for most subjects there is likely to be more than one optimizing parameter pair (Shafir *et al.*, 1989, estimate the average range of values for a single, optimizing parameter to be approximately .20). If the Advantage Model is right, a subject's "real" k_G, k_L pair is likely to be within range of the one recorded, but—due to the selection of the first optimizing pair reached in the natural, lexicographic ordering—cannot be assumed to be exactly that one. By definition, of course, any other optimizing parameter pair would obtain the same number of correct predictions. Across all three experiments, the Advantage Model predicted choice between simple lotteries and between mixed lotteries as well as or better than both Utility Theory and Prospect Theory. For the simple and mixed choice problems combined, the Advantage Model did as well on two of the four comparisons, better on one, and significantly less well on the fourth. This last comparison was the only one in all three experiments where either theory predicted individual choice significantly better than the Advantage Model. Finally, out of a total of 14 comparisons involving group preference (7 against Utility Theory and 7 against Prospect Theory), the Advantage Model did significantly better on 10 and as well as its alternatives on the remaining 4.

7. SUMMARY AND DISCUSSION

Contrary to traditional theories which have adopted an absolute perspective, recent work on process tracing and context effects has provided experimental evidence for comparative heuristics in decision making. The Advantage Model—combining absolute and comparative considerations—stipulates a relative weighting of payoff and probability advantages which is assumed to vary in a systematic fashion with the subject's focus of attention. These simple assumptions enable the model to predict and explain, in much the same fashion, a rich set of qualitative phenomena that characterize risky choice. Thus, the Advantage Model's account of intransitive preferences, an inherently comparative phenomenon, is couched in the same terms of weighted payoff and probability advantages as its account of risk aversion or the reflection effect, which can also be predicted by certain absolute theories. The model introduces comparative dimensions to recent work on choice which are consistent with current theorizing and able to account for a large number of empirical observations.

A quantitative evaluation shows the model to be at least comparable to some well-known alternatives. While in many cases the model predicted choice behavior better than its competitors, these results should be interpreted with caution. First, as discussed earlier, the requirement of an equal number of parameters for the different theories yields a version of prospect theory that does not allow a steeper curve for losses than for gains. Naturally, a richer version of Prospect Theory—one with at least three parameters—may do better quantitatively, but of course this is equally true for the remaining theories. In addition, since only certain families of parameters were investigated, there is no guarantee that other candidate parameters would not have improved the performance of either theory. At a minimum, it seems fair to conclude that the quantitative evaluation provided no grounds to question the psychological intuitions of the Advantage Model.

In its present format the model applies only to certain kinds of choice problems. In this respect, the Advantage Model is inferior to Prospect Theory or Utility Theory, which can claim a wider range of applicability. The model's limited applicability is largely due to the very explicit set of assumptions made about the processes that guide decision behavior in specific situations. Other contexts, according to this line of reasoning, may lead to somewhat different processes. In this respect, the model is consistent with a growing body of research indicating that people's preferences are not merely retrieved, but are actually constructed in the elicitation process (see, e.g., Shafir, Simonson, & Tversky, 1993). This construction of preferences depends on the context of decision (i.e., the competing lotteries), the framing of options (Sections 4.3–4.4), and the method of elicitation (Section 4.10). As Kahneman (1991) points out, a successful theory with a limited applicability may be particularly useful for the light that it may shed on other situations. In the following, final section we illustrate how the notion of a relative weighting of comparative advantages as stipulated by the Advantage Model may be extended to nonmonetary domains.

8. EXTENSIONS OF THE MODEL TO NONMONETARY PROBLEMS

Tversky and Kahneman (1981, p. 453) presented subjects with the following scenario, involving a choice between two programs to combat a disease:

Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows:
If Program A is adopted, 200 people will be saved.
If Program B is adopted, there is 1/3 probability that 600 people will be saved and 2/3 probability that no people will be saved.

A second group of subjects were given the same cover story with the following descriptions of the alternative programs:

If Program C is adopted, 400 people will die.
If Program D is adopted, there is 1/3 probability that nobody will die and 2/3 probability that 600 people will die.

The outcomes presented to the two groups are essentially identical. They differ only in that the former are framed in terms of the number of lives saved, whereas the latter are framed in terms of lives lost. This difference in framing, however, had a decisive effect on people's choices, since a significant majority in the first group preferred Program A, whereas a significant majority in the second group opted for Program D.

In an attempt to apply the Advantage Model to the present context, it is natural to replace negative and positive monetary payoffs with human lives lost and saved. Thus, under the present interpretation, the alternative $(-100, .30)$ signifies a 30% chance that 100 people will die. According to the model, Programs A and B yield the following comparison (where, as usual, we abide by the convention that alternatives in a choice problem are ordered so that $p_1 < p_2$):

Program B: $(600, \frac{1}{3})$ Program A: $(200, 1)$

$$[(600, \tfrac{1}{3}), (200, 1)]$$

Attractiveness of Program A: $200(1)(1-\frac{1}{3}) = 133.33$

Attractiveness of Program B: $600(\frac{1}{3})(400/600)k_G = 133.33k_G$

On the other hand, Programs C and D yield the following comparison:

Program D: $(-600, \frac{2}{3})$ Program C: $(-400, 1)$

$[(-600, \frac{2}{3}), (-400, 1)]$

Attractiveness of Program C: $-400(1)(1-\frac{2}{3}) = -133.33$

Attractiveness of Program D: $-600(\frac{2}{3})(200/600)k_L = -133.33k_L$

For any k_G, $k_L < 1$ it follows from the Advantage Model that Program A is preferred to Program B and that Program D is preferred to Program C. This is exactly the pattern of preferences exhibited by the majority of Tversky and Kahneman's subjects.

Consider next the following scenario, presented by Tversky and Kahneman (1986) to 72 physicians at a meeting of the California Medical Association. (Similar responses were obtained by these researchers from a group of 180 college students.)

In the treatment of tumors there is sometimes a choice between two types of therapies: (i) a radical treatment such as extensive surgery, which involves some risk of imminent death, (ii) a moderate treatment, such as limited surgery or radiation therapy. Each of the following problems describes the possible outcome of two alternative treatments, for three different cases. In considering each case, suppose the patient is a 40-year-old male. Assume that without treatment death is imminent (within a month) and that only one of the treatments can be applied. Please indicate the treatment you would prefer in each case.

Case 1

Treatment A: 20% chance of imminent death and 80% chance of normal life, with an expected longevity of 30 years. [35%]
Treatment B: certainty of a normal life, with an expected longevity of 18 years. [65%]

Case 2

Treatment C: 80% chance of imminent death and 20% chance of normal life, with an expected longevity of 30 years. [68%]
Treatment D: 75% chance of imminent death and 25% chance of normal life, with an expected longevity of 18 years. [32%]

Case 3

Consider a new case where there is a 25% chance that the tumor is treatable and a 75% chance that it is not. If the tumor is not treatable, death is imminent. If the tumor is treatable, the outcomes of the treatment are as follows:
Treatment E: 20% chance of imminent death and 80% chance of normal life, with an expected longevity of 30 years. [32%]

Treatment F: certainty of a normal life, with an expected longevity of 18 years. [68%]

The bracketed numbers indicate the proportion of subjects who preferred each alternative. Observe that the ratio of the chances to lead a normal life is identical in Cases 1 and 2 (i.e., in both cases the probability of leading a normal life following the first treatment is 4/5 that of the second treatment). The majority preference, however, reverses between the two cases. Also observe that while, ultimately, Cases 2 and 3 offer objectively identical chances at identical outcomes, here too the majority preference reverses. In fact, the physicians in this experiment expressed identical preference in Cases 1 and 3, indicating that their decision was based entirely on the choice between treatments, with no consideration given (in Case 3) to the prior odds.

Similar to before, in order to apply the Advantage Model to the present context, it is natural to replace monetary payoffs with years of expected longevity. For example, under the present interpretation, the alternative (30,.20) signifies a 20% chance of normal life with an expected longevity of 30 years. According to the Advantage Model, Treatments A and B yield the following comparison:

Treatment A: (30,.80) Treatment B: (18,1)

[(30,.80),(18,1)]

Attractiveness of Treatment A: $30(.80)(^{12}\!/_{30})k_G = 9.6k_G$

Attractiveness of Treatment B: $18(1)(1-.80) = 3.6$

On the other hand, Treatments C and D yield the following comparison:

Treatment C: (30,.20) Treatment D: (18,.25)

[(30,.20),(18,.25)]

Attractiveness of Treatment C: $30(.20)(^{12}\!/_{30})k_G = 2.4k_G$

Attractiveness of Treatment D: $18(.25)(.25-.20) = .225$

Finally, Treatments E and F yield the following comparison (which is a replica of the A–B comparison):

Treatment E: (30,.80) Treatment F: (18,1)

[(30,.80),(18,1)]

Attractiveness of Treatment E: $30(.80)(^{12}\!/_{30})k_G = 9.6k_G$

Attractiveness of Treatment F: $18(1)(1-.80) = 3.6$

The reader may now verify that the Advantage Model is consistent with the physicians' choices in the problems above, using any $.095 < k_G < .375$ (which may substantially overlap people's relative weight of expected longevity to probability of normal life). Any k_G in that range leads the Advantage Model to predict that Treatment B will be preferred to Treatment A, that Treatment C will be preferred to Treatment D, and that Treatment F will be preferred to Treatment E. This is exactly the pattern of preferences exhibited by the physicians above.

Notice that Cases 2 and 3 exhibit a nonmonetary example analogous to the noninvariance phenomenon of Section 4.3. Similarly, Cases 1 and 2 manifest a typical (albeit nonmonetary) common ratio phenomenon (Section 4.8). In addition, a review of the disease-problem presented earlier will show it to instantiate a varient of the reflection effect (Section 4.7). These parallel outcomes in domains ranging from monetary gambles to medical treatments and human lives indicate that a single set of basic principles may guide human decision behavior in a variety of circumstances. To the extent that the Advantage Model provides an adequate description of human behavior in risky situations, it may illuminate some of the fundamental processes that underlie evaluation and choice.

REFERENCES

Akerlof, G. A., & Yellen, J. (1985). Can small deviations from rationality make significant differences to economic equilibria? *American Economic Review*, 75(4), 708–720.

Bell, D. E. (1982). Regret in decision making under uncertainty. *Operations Research*, **30**, 961–981.

Bruning, J. L., & Kintz, B. L. (1977). *Computational handbook of statistics*. Glenview, IL: Scott, Foresman.

Camerer, C. F. (1993). Recent tests of generalizations of expected utility theory. In W. Edwards (Ed.), *Utility Theories: Measurements and Applications*. Kluwer.

Coombs, C. H., Dawes, R. M., & Tversky, A. (1970). *Mathematical psychology: An elementary introduction*. Englewood Cliffs, NJ: Prentice-Hall.

Delquie, P., de Neufville, R., and Mangnan, H. (1987). *Response-mode effects in preference elicitation*. Technology and Policy Program, M.I.T.

Fishburn, P. C. (1982). Nontransitive measurable utility. *Journal of Mathematical Psychology*, **26**, 31–67.

Fishburn, P. C. (1983). Transitive measurable utility. *Journal of Economic Theory*, **31**, 293–317.

Fishburn, P. C., & Kochenberger, G. A. (1979). Two-piece von Neumann-Morgenstern utility functions. *Decision Sciences*, **10**, 503–518.

Goldstein, W. M., & Einhorn, H. J. (1987). Expression theory and the preference reversal phenomena. *Psychological Review*, **94**(2), 236–254.

Hershey, J. C., & Schoemaker, P. J. H. (1980a). Risk taking and problem context in the domain of losses: An expected utility analysis. *Journal of Risk and Insurance*, **47**, 111–132.

Hershey, J. C., & Schoemaker, P. J. H. (1980b). Prospect theory's reflection hypothesis: A critical examination. *Organizational Behavior and Human Performance*, **25**, 395–418.

Hogarth, R. M. (1975). Decision time as a function of task complexity. In D. Wendt & C. A. J. Vlek (Eds.), *Utility, probability, and human decision making* (pp. 321–338). Dordrecht: Reidel.

Hogarth, R. M. (1987). *Judgment and choice: The psychology of decision*. (2nd ed.). New York: Wiley.

Hogarth, R. M., & Einhorn, H. J. (1990). Ventury theory: A model of decision weights. *Management Science*, **36**, 780–803.

Huber, J., Payne, J. W., & Puto, C. (1982). Adding asymmetrically dominated alternatives: Violations of regularity and the similarity hypothesis. *Journal of Consumer Research*, **9**, 90–98.

Huber, J., & Puto, C. (1983). Market boundaries and product choice: Illustrating attraction and substitution effects. *Journal of Consumer Research*, **10**, 31–44.

Kahneman, D. (1991). Judgment and decision making: A personal view. *Psychological Science*, **2**(3), 142–145.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, **47**, 263–291.

Kahneman, D., & Tversky, A. (1982). The psychology of preferences. *Scientific American*, **246**, 160–173.

Kahneman, D., & Tversky, A. (1984). Choices, values and frames. *American Psychologist*, **39**, 341–350.

Keeney, R. L., & Raiffa, H. (1976). *Decisions with multiple objectives*. New York: Wiley.

Kiesler, C. A. (1966). Conflict and number of choice alternatives. *Psychological Reports*, **18**(2), 603–610.

Lichtenstein, S., & Slovic, P. (1971). Reversals of preference between bids and choices in gambling decisions. *Journal of Experimental Psychology*, **89**(1), 46–55.

Loomes, G., & Sugden, R. (1982). Regret theory: An alternative theory of rational choice under uncertainty. *Economic Journal*, **92**, 805–824.

Luce, R. D. (1977). The choice axiom after twenty years. *Journal of Mathematical Psychology*, **15**, 215–233.

Luce, R. D. (1991). Rank- and sign-dependent linear utility models for binary gambles. *Journal of Economic Theory*, **53**, 75–100.

Luce, R. D., & Fishburn, P. C. (1991). Rank- and sign-dependent linear utility models for finite first-order gambles. *Journal of Risk and Uncertainty*, **4**, 29–59.

Machina, M. J. (1982). 'Expected utility' analysis without the independence axiom. *Econometrica*, **50**, 277–323.

Murphy, G. L. (1988). Comprehending complex concepts. *Cognitive Science*, **12**, 529–562.

Payne, J. W. (1976). Task complexity and contingent processing in decision making: An information search and protocol analysis. *Organizational Behavior and Human Performance*, **16**, 366–387.

Payne, J. W. (1982). Contingent decision behavior. *Psychological Bulletin*, **92**, 382–402.

Payne, J. W., & Braunstein, M. L. (1978). Risky choice: An examination of information acquisition behavior. *Memory and Cognition* **6**(5), 554–561.

Payne, J. W., Laughhunn, D. J., & Crum, R. (1980). Translation of gambles and aspiration level effects in risky choice behavior. *Management Science*, **26**, 1039–1060.

Quiggin, J. (1982). A theory of anticipated utility. *Journal of Economic Behavior and Organization*, **3**, 323–343.

Russell, T., & Thaler, R. (1985). The relevance of quasi rationality in competitive markets. *American Economic Review*, **75**, 1071–1082.

Russo, J. E., & Dosher, B. A. (1983). Strategies for multiattribute binary choice. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **9**(4), 676–696.

Schoemaker, P. J. H. (1982). The expected utility model: Its variants, purposes, evidence, and limitations. *Journal of Economic Literature*, **20**, 529–563.

Schoemaker, P. J. H., & Kunreuther, H. C. (1979). An experimental study of insurance decisions. *Journal of Risk and Insurance*, **46**(4), 603–618.

Shafir, E. B. (1988). *An Advantage model of risky choice*. Unpublished Ph.D. dissertation, M.I.T., Cambridge, MA.

Shafir, E. B., Osherson, D. N., & Smith, E. E. (1989). An Advantage model of choice. *Journal of Behavioral Decision Making*, **2**, 1–23.

Shafir, E. B., Osherson, D. N., & Smith, E. E. (1990). Comparative choice and the advantage model. In K. Borcherding, O. I. Larichev, & D. M. Messick (Eds.), *Contemporary issues in decision making*. New York: Elsevier.

Shafir, E., Simonson, I., & Tversky, A. (1993). Reason-based choice. *Cognition*, in press.

Simonson, I. (1989). Choice based on reasons: The case of attraction and compromise effects. *Journal of Consumer Research*, **16**, 158–174.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1978). Accident probabilities and seat belt usage: A psychological perspective. *Accident Analysis and Prevention*, **10**, 281–285.

Slovic, P., Fischhoff, B., & Lichtenstein, S. (1982). Response mode, framing, and information-processing effects in risk assessment. In R. Hogarth (Ed.), *New directions for methodology of social and behavioral science: No. 11. Question framing and response consistency* (pp. 21–36). San Francisco: Jossey-Bass.

Slovic, P. Griffin, D., & Tversky, A. (1990). Compatibility effects in judgment and choice. In R. Hogarth (Ed.), *Insights in decision making: Theory and applications*. Chicago: Univ. of Chicago Press.

Slovic, P., & Lichtenstein, S. (1968). Relative importance of probabilities and payoffs in risk taking. *Journal of Experimental Psychology Monograph*, Pt. 2, **78**, 1–18.

Slovic, P., & Lichtenstein, S. (1983). Preference reversals: A broader perspective. *American Economic Review*, **73**, 596–605.

Slovic, P., Lichtenstein, S., & Fischhoff, B. (1989). Decision making. In R. C. Atkinson, R. J. Herrnstein, G. Lindzey, & R. D. Luce (Eds.), *Steven's handbook of experimental psychology* (2nd ed.). New York: Wiley.

Slovic, P., & MacPhillamy, D. (1974). Dimensional commensurability and cue utilization in comparative judgment. *Organizational Behavior and Human Performance*, **11**, 174–194.

Smith, E. E., Osherson, D. N., Rips, L. J., & Keane, M. (1988). Combining prototypes: A modification model. *Cognitive Science*, **12**, 485–527.

Tversky, A. (1969). Intransitivity of preferences. *Psychological Review*, **76**, 31–48.

Tversky, A. (1977). Features of similarity. *Psychological Review*, **84**, 327–352.

Tversky, A., & Gati, I. (1978). Studies of similarity. In E. Rosch & B. Lloyd (Eds.), *Cognition and categorization*. Hillsdale, NJ: Erlbaum.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, **211**, 453–458.

Tversky, A., & Kahneman, D. (1986). Rational choice and the framing of decisions. *Journal of Business* (Vol. 59, No. 4, Pt. 2, pp. 251–278).

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference dependent model. *Quarterly Journal of Economics*, **107**(4), 1039–1061.

Tversky, A., & Kahneman, D. (1992). Advances in Prospect Theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty*, **5**(4), 297–323.

Tversky, A., Sattath, S., & Slovic, P. (1988). Contingent weighting in judgment and choice. *Psychological Review*, **95**(3), 371–384.

Tversky, A., Slovic, P., & Kahneman, D. (1990). The causes of preference reversal. *American Economic Review*, **80**, 204–217.

von Neumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior* (2nd ed.). Princeton: Princeton Univ. Press.

RECEIVED: December 10, 1990