The Causes of Preference Reversal
Author(s): Amos Tversky, Paul Slovic and Daniel Kahneman
Source: *The American Economic Review,* Vol. 80, No. 1 (Mar., 1990), pp. 204-217
Published by: American Economic Association
Stable URL: http://www.jstor.org/stable/2006743
Accessed: 17-01-2017 19:44 UTC

The Causes of Preference Reversal

By Amos Tversky, Paul Slovic, and Daniel Kahneman[*]

Observed preference reversal (PR) cannot be adequately explained by violations of independence, the reduction axiom, or transitivity. The primary cause of PR is the failure of procedure invariance, especially the overpricing of low-probability high-payoff bets. This result violates regret theory and generalized (nonindependent) utility models. PR and a new reversal involving time preferences are explained by scale compatibility, which implies that payoffs are weighted more heavily in pricing than in choice. (JEL 215)

Axiomatic theories of choice introduce preference as a primitive relation, which is interpreted through specific empirical procedures such as choice or pricing. Models of rational choice assume a principle of procedure invariance, which requires strategically equivalent methods of elicitation to yield the same preference order. Thus, if the decision maker prefers A to B, then the cash equivalent, or minimum selling price, of A should exceed that of B. However, there is a substantial body of evidence showing that the price ordering of risky prospects is systematically different from the choice ordering, contrary to standard theories of choice.

The effect of elicitation method on preference between gambles was first observed by Paul Slovic and Sarah Lichtenstein (1968) who found that both buying and selling prices of gambles were primarily determined by the payoffs, whereas choices between gambles (and ratings of their attractiveness) were primarily influenced by the probabilities of winning and losing. Slovic and Lichtenstein reasoned that, if the method used to elicit preferences affected the weighting of the gambles' components, it should be possible to construct pairs of gambles such that the same individual would choose one member of the pair but set a higher price for the other. Lichtenstein and Slovic (1971, 1973) demonstrated such reversals in a series of studies, one of which was conducted on the floor of the Four Queens Casino in Las Vegas with experienced gamblers playing for real money.

The preference-reversal phenomenon involves a pair of gambles of comparable expected value. One gamble (the H bet) offers a high probability of winning a modest sum of money; the other gamble (the L bet) offers a low probability of winning a relatively large amount of money. These bets were also called the P bet and the $ bet, respectively. For example,

H bet: 28/36 chance to win $10

L bet: 3/36 chance to win $100

When offered a choice between the two options, most subjects choose the H bet over the L bet. However, when asked to state their lowest selling price, the majority state a higher price for the L bet than for the H bet.

There have been three waves of studies of preference reversal (PR). The first included the original experiments of Paul Slovic and Sarah Lichtenstein (1968), Lichtenstein and

Slovic (1971, 1973), and the study of Harold Lindman (1971). The second wave of studies, conducted during the late 1970s and early 1980s, consisted of critical replications and attempts to eliminate preference reversals by procedural variations and by increased incentives. A particularly careful replication was performed by David Grether and Charles Plott (1979) who designed a series of experiments "to discredit the psychologists' work as applied to economics" (p. 623). Grether and Plott generated a list of 13 objections and potential artifacts that would render the preference-reversal phenomenon irrelevant to economic theory. Their list included poor motivation, income effects, strategic responding, and the fact that the experimenters were psychologists (which might have led the respondents to be suspicious and behave peculiarly). Grether and Plott attempted to eliminate PR by careful experimental procedures, including a special incentive system, but the effect was hardly diminished. Further studies by Robert Hamm (1984), Werner Pommerehne, Fredrich Schneider, and Peter Zweifel (1982), and Robert Reilly (1982) led to similar conclusions. PR was also observed by John Mowen and James Gentry (1980) in both individual and group choices concerning product development, by Marc Knez and Vernon Smith (1986) who allowed their subjects to trade bets in an experimental market, and by Joyce Berg, John Dickhaut, and John O'Brien (1985) who introduced arbitrage. See also Slovic and Lichtenstein (1983).

The robustness of preference reversals led to the third wave of articles, which attempted to explain the phenomenon rather than eliminate it. Three classes of models for PR were introduced: a) nontransitive choice models were developed independently by Graham Loomes and Robert Sugden (1982, 1983), and by Peter Fishburn (1984, 1985); b) response bias models were proposed by Amos Tversky, Shmuel Sattath, and Paul Slovic (1988), and by William Goldstein and Hillel Einhorn (1987); and c) generalized utility models, which maintain transitivity but abandon the independence axiom, were applied to PR by Charles Holt (1986), and Edi Karni and Zvi Safra (1987). The three families of models respectively attribute PR

to violations of transitivity, procedure invariance, or the independence axiom. Violations of these principles have been observed in other contexts, but their contributions to PR have not been assessed. The present paper provides such assessment. To accomplish this goal, we extend the traditional experimental design, introduce an ordinal payoff scheme, and develop a new diagnostic analysis to determine the causes of PR.

A. *Diagnostic Analysis.* Let C_H and C_L denote, respectively, the cash equivalent (or minimum selling price) of H and L, and $\succ$ and $\approx$ denote strict preference and indifference, respectively. (The elicitation of cash equivalents is discussed in the next section.) A standard preference reversal (PR) is said to occur when H is preferred to L, but L is priced higher than H, that is, $H \succ L$, and $C_L > C_H$. Note that $\succ$ refers to preference between options, whereas $>$ refers to the ordering of cash amounts. We assume that the two relations are consistent in the sense that $X > Y$ implies $X \succ Y$; more money is preferred to less. We now show that PR implies either intransitivity or a failure of procedure invariance, or both. Procedure invariance holds whenever the decision maker prefers a bet B to a cash amount X if and only if his or her selling price for B exceeds X; that is, $B \succ X$ iff $C_B > X$. In particular, invariance implies that $C_B = X$ iff $B \approx X$. If invariance holds, PR entails the following cycle

$$C_H \approx H \succ L \approx C_L > C_H,$$

where the two inequalities are implied by PR and the two equivalences follow from invariance.

Because procedure invariance is commonly taken for granted, many authors have interpreted PR as an instance of intransitivity. The finding that strategically equivalent methods of elicitation yield systematically different preferences (see, for example, Tversky et al., 1988) suggests that PR may be caused by a failure of procedure invariance, not of transitivity. Two types of discrepancy between choice and pricing could produce PR: overpricing of L and underpricing of H. *Overpricing* of L is said to

occur if the decision maker prefers the price over the bet when offered a choice between them (i.e., $C_L \succ L$). *Underpricing* of H is said to occur if the decision maker prefers the bet over its price in a direct choice (i.e., $H \succ C_H$). The two other forms of a choice-pricing discrepancy—underpricing of L and overpricing of H—produce a nonstandard pattern of reversals. Note that overpricing and underpricing merely identify the sign of the discrepancy between pricing and choice; the labels do not imply that the bias resides in the pricing.

If PR is due to an intransitivity, it should be observable in binary choice data without the use of a pricing task. On the other hand, choice could be transitive if PR is due to overpricing of L or to underpricing of H. In order to find out whether PR is caused by intransitivity or by non-invariance, we extend the usual experimental design to include an option of receiving $\$X$ for sure. In this design, the decision maker provides three choices (H-L, H-X, L-X) and two assessments of price (C_H and C_L). The relevant data for diagnosing the sources of PR consists of all patterns of preferences satisfying

$$H \succ L \text{ and } C_L > X > C_H.$$

These are the patterns that exhibit PR and satisfy the condition that X lies between the two prices. Note that for any PR pattern it is possible to select a cash amount X that falls between the two prices stated by a given individual. For an experiment, however, it is more convenient to determine X in advance and to restrict the analysis to all PR patterns in which the prices stated by the subject straddle the predetermined value of X. The critical data, then, are the observed choices between X and H and between X and L. Ignoring ties, there are four possible response patterns.

(1) *Intransitivity*: $L \succ X$ and $X \succ H$, yielding $L \succ X \succ H \succ L$.

(2) *Overpricing of L (OL)*: $X \succ H$ and $X \succ L$, yielding $C_L \succ X \succ L$.

(3) *Underpricing of H (UH)*: $H \succ X$ and $L \succ X$, yielding $H \succ X \succ C_H$.

(4) *Both OL and UH*: $H \succ X$ and $X \succ L$, yielding $H \succ X > C_H$ and $C_L \succ X \succ L$.

Note that the present diagnostic procedure classifies all test patterns according to whether they violate transitivity but not invariance (pattern 1) or invariance but not transitivity (patterns 2, 3, and 4) because no test pattern can violate both. The relative frequencies of these patterns can be used to test PR models that assume invariance but not transitivity (for example, the regret theory of Graham Loomes and Robert Sugden, 1982) against models that assume transitivity but not invariance (for example, the contingent weighting model of Tversky et al., 1988). The relative incidence of violations of transitivity and invariance could be different in a more elaborate diagnostic procedure (involving more than three options) which yields patterns of preference that can violate transitivity and invariance at once. The preceding discussion is summarized as follows.

Any pattern of preferences that satisfies the test conditions ($H \succ L$ and $C_L > X > C_H$) and monetary consistency ($X > Y$ implies $X \succ Y$) obeys the following propositions:

(i) Either transitivity or invariance ($B \succ X$ iff $C_B > X$) is violated.

(ii) Intransitivity holds iff $L \succ X \succ H$, yielding pattern (1).

(iii) Overpricing of L occurs iff $X \succ L$, yielding patterns (2) or (4).

(iv) Underpricing of H occurs iff $H \succ X$, yielding patterns (3) or (4).

This analysis provides a simple method for the diagnosis of all preference patterns satisfying the test condition according to the implied cause of PR. The applications of this method to experimental data are described in Studies 1 and 2.

B. *Elicitation Procedures*. The preceding analysis provides an effective method for diagnosing PR, assuming preferences and selling prices are observable. Such data are routinely elicited in experiments and surveys, and are normally taken at face value—provided the results are reproducible and the respondents have no reason to conceal or misrepresent their preferences. Nevertheless, students of choice favor elicitation procedures that are incentive compatible. Gordon Becker, Morris DeGroot, and Jacob

Marschak (1964) devised such a scheme for the elicitation of cash equivalents, which has often been used in PR studies. In this procedure, called the BDM scheme, the subject states a selling price for a gamble. An offer is then generated by some random process. The subject receives the offer if it exceeds the stated selling price, and plays the gamble if the stated price exceeds the offer.

Recently, Holt (1986), and Karni and Safra (1987) pointed out that the justification of the BDM scheme and of similar procedures assumes the independence axiom of expected utility theory. If this axiom fails, the stated price of a bet is no longer equal to its cash equivalent, hence the presence of PR in some experiments can be attributed to violations of independence. In particular, Holt argued that the usual payoff schemes in which the subject plays only one bet, selected at random, assume independence among the subject's responses. This argument, however, invokes the independence axiom in a sequential setup where no systematic violations of this axiom have been observed. Moreover, Tversky and Daniel Kahneman (1986) showed that the common violations of independence and substitution generally disappear when the choice is presented in a sequential form. This finding undermines the empirical basis of Holt's argument. Karni and Safra analyzed the actual lottery induced by the BDM scheme and showed that a generalized utility model with a nonlinear (probability) weighting function can explain the observed discrepancy between choice and stated prices in this scheme. According to this interpretation, PR data do not reflect inconsistent preferences because the choices and the pricing do not involve the same bets. Consequently, PR can be explained by a model that satisfies transitivity and invariance, but not independence. In a closely related development, Uzi Segal (1988) suggested that PR may be produced by a failure of the reduction axiom, which reduces a two-stage lottery to the equivalent one-stage lottery. The preceding accounts, however, cannot explain the basic finding that the same pattern of PR obtained under the BDM scheme (for example, Grether and Plott, 1979) is equally prevalent in experiments that do not use any incentive compatible elicitation scheme (for example, Lichtenstein and Slovic, 1971) and therefore do not invoke the independence or the reduction axioms. If PR is caused by a failure of these axioms, the frequency of reversals should increase when the BDM scheme is used, contrary to fact.

As noted by Karni and Safra (1987), there may be no incentive compatible scheme for the elicitation of selling prices that does not rely on the independence axiom. To demonstrate preference reversals, however, it is not necessary to elicit the actual selling prices; it is sufficient to establish their *order*. The ordering of selling prices can be obtained under weaker conditions, as demonstrated by the following incentive compatible procedure, which we call the ordinal payoff scheme. The subject is first presented with each bet separately and asked to state its lowest selling price. The subject is then presented with pairs of bets and asked to select the preferred prospect in each pair. Subjects know that one of these pairs will be selected at random at the end of the session, and that a random device will determine whether they play the bet they preferred in the choice task or the bet they priced higher. Because the prices are merely used to order the bets within each pair, choice and pricing are strategically equivalent. A reversal then amounts to an inconsistency in which the subject expresses in the choice task a preference for playing the H bet, and in the pricing task a preference for playing the L bet. To rationalize this pattern within a generalized (nonindependent) utility model, it is necessary to assume that subjects prefer an even chance to play either H or L over the option of playing H, and over the option of playing L. Such a mixed strategy, however, could explain random reversals, but not systematic ones. The presence of systematic reversals in the ordinal payoff scheme, therefore, cannot be explained by violations of independence or of the reduction axiom.

I. Study 1 (Monetary Bets)

The participants in the studies reported in this article (unless specified otherwise) were

TABLE 1—THE MONETARY BETS USED IN STUDY 1.[a]

	Triple	1	2	3	4	5	6
Set							
	H	(0.97,4)	(0.81,2)	(0.94,3)	(0.89,4)	(0.94,2.5)	(0.92,2)
I	L	(0.31,16)	(0.19,9)	(0.50,6.5)	(0.11,40)	(0.39,8.5)	(0.50,5)
	X	(3.85)	(1.50)	(2.75)	(3.25)	(2.40)	(1.85)
	H	(0.97,100)	(0.81,50)	(0.94,75)	(0.89,100)	(0.94,65)	(0.92,50)
II	L	(0.31,400)	(0.19,225)	(0.50,160)	(0.11,1000)	(0.39,210)	(0.50,125)
	X	(95)	(40)	(70)	(80)	(60)	(45)
	H	(0.78,10)	(0.69,7)	(0.86,3)	(0.94,4)	(0.92,12)	(0.89,11)
III	L	(0.08,100)	(0.17,40)	(0.19,13)	(0.03,150)	(0.06,175)	(0.08,135)
	X	(8)	(5.50)	(2.75)	(3.75)	(10)	(9)

[a] The pair (P, X) denotes a bet that offers a probability P to win $\$X$, and nothing otherwise, and (X) denotes $\$X$ for sure. The probabilities were expressed as multiples of $1/36$.

recruited by ads in the University of Oregon newspaper. The number of men and women was roughly the same and their median age was 22 years. They were run in a class setting and were paid for participation. One hundred and ninety-eight individuals (called the main group) participated in the main part of Study 1.

We constructed 18 triples that consisted of a high probability bet (H), a low probability bet (L), and a cash amount (X), with roughly the same expected value. The 18 triples were divided into 3 sets of 6 triples each, displayed in Table 1. Set I included relatively small bets like those used in previous studies, without negative outcomes. Set II was obtained by multiplying all payoffs in Set I by a factor of 25. Set III was a mixture of small and large bets including a few long shots. The options were presented in written form. All probabilities were expressed as multiples of $1/36$ (for example, $11/36$ to win $\$16.00$), and interpreted with reference to a roulette wheel with 36 numbered sectors. Within each set, the respondents first assessed the cash equivalent for each of the 12 bets and then chose between the options of each triple: H vs. L, H vs. X, L vs. X. The order of the options within each set was randomized. The order of the sets was I, II, III for half of the participants, and III, II, I for the others. As part of the general instructions, the participants were asked to imagine that one pair of bets would be selected at

random and they would have a chance to play either the bet they had chosen or the bet for which they had stated a higher cash equivalent.

To investigate the effect of monetary incentives, we ran an additional group of subjects whose payoffs were contingent on their responses. These subjects ($N = 179$) evaluated only Set I. They received the same instructions as the main group, but were told that 15 percent of the participants, selected at random, would actually play one bet determined as follows. A pair of bets would be selected at random and the chosen subjects would play the bet that they had favored either in the choice or in the pricing task. Because each subject plays at most one bet, this procedure defines a compound lottery in which the probability of winning a prize is considerably smaller than in the original bet. Exactly the same compound lottery, however, is induced by the choice and by the pricing. Assuming invariance, therefore, there is no reason for reversals in the ordinal payoff scheme.

A. *Results.* Table 2 presents, for each (H, L) pair, the percentage of subjects who chose H over L ($H \succ L$), the percentage of subjects who priced H above L ($C_H > C_L$), and the percentage of subjects who exhibited PR($H \succ L$ and $C_L > C_H$). Only the subjects ($N = 179$) who had no missing data were included in this analysis. Because no indif-

TABLE 2—PERCENTAGE OF PREFERENCES FOR ALL SUBJECTS IN STUDY 1

Set	Triple	1	2	3	4	5	6	Mean
I	$H \succ L$	83	68	71	71	73	62	71
	$C_H > C_L$	26	22	30	33	17	14	24
	PR	59	53	45	41	59	49	51
II	$H \succ L$	91	86	77	84	82	70	82
	$C_H > C_L$	54	48	46	47	48	32	46
	PR	38	44	36	41	40	44	41
III	$H \succ L$	81	68	74	74	81	79	76
	$C_H > C_L$	38	21	39	38	58	46	40
	PR	48	48	42	39	29	36	40
I_s	$H \succ L$	67	75	62	67	62	56	65
	$C_H > C_L$	44	18	22	44	12	9	25
	PR	32	60	51	36	50	49	46

ference was allowed in choice, we excluded tied prices from the analysis. Their inclusion, of course, would have inflated the PR rate. The I_s data refer to the subjects who evaluated Set I with monetary incentives.

The PR phenomenon is clearly evident in Table 2. Overall, H is chosen over L in 74 percent of the cases, but C_H exceeds C_L in only 34 percent of the cases. Nearly half of the response patterns are inconsistent and the standard reversals (45 percent) are overwhelmingly more frequent than the nonstandard ones (4 percent). Table 2 also shows that there are no major differences among three sets of gambles that span a wide range of payoffs. Furthermore, the use of monetary incentives in the I_s condition had no systematic effect on the prevalence of PR, in agreement with previous studies (see, for example, Slovic and Lichtenstein, 1983). The overall percentage of PR with real payoffs is 46 percent (Set I_s) compared to an overall rate of 44 percent without payoffs (Sets I, II, III).

The hypothesis that subjects prefer mixtures was tested by presenting 42 Stanford students with the six pairs of H and L bets from Set I. They were told that one-third of the participants, selected at random, would play one of their chosen bets. For each pair, they were given three options: (i) select the H bet, (ii) select the L bet, and (iii) let the experimenter select between H and L at random. None of the responses favored the mixed strategy.

The results of Study 1 cannot be explained as a failure of the independence axiom, or of the reduction axiom, for two reasons. First, this account assumes that the subjects favor a mixed strategy, contrary to the responses of the Stanford students. Second, even if—contrary to these data—we assume that subjects adopt a mixed strategy, the standard and the nonstandard reversals should have been equally frequent. We conclude that PR is not an elicitation artifact caused by nonindependence; hence it must violate either transitivity or procedure invariance.

Having established the validity of PR, we turn now to the diagnostic analysis described earlier. Unlike the preceding discussion that was based only on the price ordering, the following analysis assumes that the stated prices C_H and C_L are the actual cash equivalents of H and L. We shall address this assumption in the next section. The diagnostic analysis is based on the data of all subjects from the main group who completed all tasks. About half of the PR patterns in Sets I, II, and III met the test condition $C_L > X > C_H$, yielding 620 individual patterns of preference that satisfied

$$H \succ L \text{ and } C_L > X > C_H.$$

TABLE 3—DISTRIBUTION OF RESPONSE PATTERNS IN STUDY 1

Pattern	N	Percent	Diagnosis
(1) $L \succ X, X \succ H$	62	10.0	Intransitivity
(2) $X \succ L, X \succ H$	406	65.5	Overpricing of L (OL)
(3) $L \succ X, H \succ X$	38	6.1	Underpricing of H (UH)
(4) $H \succ X, X \succ L$	114	18.4	Both OL and UH
Total	620	100	

These data were classified into four types according to the observed relation of X to L and to H, and the distribution of the four types is presented in Table 3. The data show that only 10 percent of the preference patterns are intransitive and 90 percent exhibit non-invariance. Among the non-invariant patterns, the overpricing of L is much more common than the underpricing of H. Further evidence for this conclusion comes from a study by Raphael Bostic, Richard Herrnstein, and Duncan Luce (1990) who used a series of successive choices to determine, for each subject, a cash amount X that is indifferent to a given bet. They found that this cash amount was roughly the same as the stated price for H bets and substantially below it for L bets. That is, $X = C_H$ and $X < C_L$, as entailed by the overpricing of L.

B. *Discussion.* The high incidence of preference reversal (45 percent) obtained using the ordinal payoff scheme indicates that PR cannot be explained by a generalized utility model, as proposed by Holt (1986), by Karni and Safra (1987), and by Segal (1988). Recall that these authors provided no direct evidence for this proposal; they only showed that PR could be consistent with transitivity and invariance if independence (or the reduction axiom) is discarded. The data refute this interpretation. The present analysis demonstrates that abandoning independence or the reduction axiom is neither necessary nor sufficient to account for PR. The results summarized in Table 3 show that the PR observed in Study 1 are produced primarily by the failure of procedure invariance. The finding that 90 percent of test patterns violated this condition rules out all models of PR that assume procedure invariance, including regret theory (Loomes and Sugden,

1982, 1983). Because this theory attributes all PR to intransitivity, it entails that 100 percent of the test patterns in Table 3 should be intransitive. The fact that only 10 percent of the test patterns conformed to this prediction indicates that regret theory does not provide an adequate explanation of PR.

This conclusion does not imply that intransitivity plays no role in PR. Loomes, Chris Starmer, and Sugden (1989) have demonstrated that the cycle $H \succ L \succ X \succ H$, implied by regret theory, is significantly more frequent than the opposite cycle $L \succ H \succ X \succ L$. The present study confirmed this result; the observed frequencies of the two cycles were 132 and 44, respectively (see Appendix 1). It is noteworthy that the incidence of intransitivity reported by these investigators (15–20 percent) is higher than that observed in the present study, but the rates of PR are roughly the same. Although the difference in the incidence of intransitivity does not affect our main conclusion regarding the prevalence of non-invariance, it raises the question as to whether the present methodology underestimates the contribution of intransitivity of PR. Because the ordinal payoff scheme requires, in effect, the ranking of all bets, it might induce intransitive subjects to behave transitively. But if our procedure reduces the number of cycles, it should also reduce the incidence of PR. In fact, the PR rate in the present study is slightly higher than in other studies. Moreover, the finding that the rate of PR is generally insensitive to the payoff scheme makes this possibility even less likely. Finally, Appendix 1 shows that the percentage of cycles that satisfy the test condition (10 percent) is higher than the percentage of cycles among PR patterns that do not satisfy the test condition (5.2 percent). The available evidence,

therefore, does not support the hypothesis that the present diagnostic procedure under-estimates intransitivity, although this possibility cannot be ruled out.

It could be argued that the subjects in Study 1 did not state their actual selling prices but rather some monotone transformation of these prices because only their order—not the actual values—is relevant to the present payoff scheme. The subjects, however, had no strategic or any other reason to transform their prices. Moreover, the present procedure discourages such transformation because the subject has to evaluate each bet separately, without knowing how it will be paired. Stating the cash equivalent of each bet, as requested, is obviously the simplest way to achieve a ranking without having to remember the responses to previous bets. Indeed, the standard deviations (across subjects) of observed prices in Study 1 did not exceed those obtained from comparable bets in studies that used the BDM scheme (for example, Bostic, Herrnstein, and Luce, 1990), contrary to what might be expected if our subjects reported monotone transformations of their selling prices. As in other studies, the standard deviations were considerably smaller for H bets than for L bets.

In contrast to the present design where each bet was priced separately and the subject did not know which bets would be paired, James Cox and Seth Epstein (1989) employed a different procedure in which the subject priced each pair of H and L bets concurrently, and then played the higher-priced bet. This procedure allows the subject to generate a price ordering by comparing the two bets without performing the more difficult task of assessing their actual selling prices. Indeed, Cox and Epstein acknowledged (on the basis of the subjects' responses) that their procedure did not elicit proper cash equivalents. Because the bets were framed differently in choice and in pricing (by translating all outcomes), many response patterns were inconsistent (32 percent), but the reversals were random rather than systematic.

C. *Scale Compatibility.* Why do people overprice the low-probability high-payoff bets? Following Tversky et al. (1988), we interpret this finding as an instance of a more general principle of compatibility: the weight of any aspect (for example, probability, payoff) of an object of evaluation is enhanced by compatibility with the response (for example, choice, pricing). The effect of scale compatibility is illustrated in a study by Slovic, Dale Griffin, and Tversky (1990). Participants predicted the 1987 market value of twelve companies (taken from *Business Week* top 100) on the basis of their 1986 market value (in billions of dollars), and their rank (among the top 100) with respect to 1987 profits. One-half of the subjects predicted 1987 market value in billions of dollars, whereas the other half predicted the company's rank with respect to its 1987 market value. As implied by compatibility, each predictor was given more weight when the criterion was expressed on the same scale (for example, money, rank). As a consequence, the relative weight of the 1986 market value was twice as high for those who predicted in dollars than for those who predicted the corresponding rank. This effect produced many reversals of judgment in which one company was ranked above another but the order of their predicted value was reversed.

Because the selling price of a bet is expressed in dollars, compatibility entails that the payoffs, which are expressed in the same units, will be weighted more heavily in pricing than in choice. (Since the payoffs are much larger in the L bets than in the H bets, the major consequence of a compatibility bias is overpricing of L bets.) To accommodate violations of procedure invariance, Tversky et al. (1988) developed a family of models in which the weighting of attributes is contingent on the method of elicitation. The simplest model of this type, called the contingent weighting model, assumes that the bet $B = (P, X)$ is chosen over $B' = (P', X')$ iff

$$\log P + \alpha \log X > \log P' + \alpha \log X'.$$

and that B is priced above B' iff

$$\log P + \beta \log X > \log P' + \beta \log X'.$$

This loglinear form represents the ordering of bets according to both choice and pricing by a multiplicative probability-value model with a power function for gains. In this representation, procedure invariance entails $\beta = \alpha$, whereas compatibility implies $\beta > \alpha$. Slovic et al. (1990) applied this model to the choice and the price ordering from Study 1 and assessed α and β separately for each subject. In accord with compatibility, β exceeded α for 87 percent of the subjects ($N = 179$) indicating greater risk aversion in choice than in pricing.

The role of compatibility in PR was investigated in two additional studies reported by Slovic et al. (1990). In the first study, subjects were presented with six pairs of H and L bets. Three pairs involved monetary payoffs as in Study 1, and three pairs involved nonmonetary outcomes, such as a one-week pass for all movie theaters in town, or a dinner for two at a good restaurant. If preference reversals are due primarily to the compatibility of prices and payoffs, which are both expressed in dollars, their incidence should be substantially reduced by the use of nonmonetary outcomes. This prediction was confirmed: the percentage of choice of H over L was roughly the same in the monetary (63 percent) and the nonmonetary bets (66 percent), but the percentage of cases in which $C_L > C_H$ was substantially greater in the former (54 percent) than in the latter (33 percent), and the overall incidence of PR decreased significantly from 41 percent to 24 percent.

A second study by Slovic et al. (1990) investigated reversals in a matching task. This experiment employed the 12 pairs of H and L bets from Sets I and II, described in Table 1. In each pair, one value—either a probability or a payoff—was missing, and the subjects were asked to set the missing value so that they would be indifferent between the two bets. Consider, for example, the bets $H = (0.92, \$50)$ and $L = (0.50, \$125)$ from Set II, Table 1. If we replace the 0.5 probability in L by a question mark, the subject is asked in effect "what chance to win $125 is equally attractive as a 0.92 chance to win $50?," The value set by the subject implies a preference between the original

bets. If the value exceeds 0.50, we infer that the subject prefers H to L, and if the value is less than 0.50, we reach the opposite conclusion. Using all four components as missing values, the authors obtained the preferences inferred from matching either the probability or the payoff of each bet. Because compatibility applies to matching, not only to pricing, the attribute on which that match is made is expected to be weighted more heavily than the other attribute. As a consequence, the inferred percentage of preference for H over L should be higher for probability matches than for payoff matches. Indeed, the overall percentage of preference for H over L derived from probability matches (73 percent) was significantly higher than that derived from payoff matches (49 percent).

The matching data suggest an additional factor, besides scale compatibility, that might contribute to PR. In an extensive comparison of choice and matching, Tversky et al. (1988) have shown that the more prominent attribute of options looms larger in choice than in matching. Thus, the choice order is more lexicographic than that induced by matching. If probability is perceived by subjects as more important than payoffs, as suggested by the finding that the rating of bets is dominated by probability (Goldstein and Einhorn, 1987; Slovic and Lichtenstein, 1968), then the prominence effect may contribute to PR over and above the effect of scale compatibility. This could help explain the robustness of PR, as well as the similarity between the choice data and the preferences derived from probability matches. Note that in pricing and payoff matches, both compatibility and prominence enhance the PR effect, whereas in probability matches, they operate in opposite directions (see, Slovic et al., 1990).

II. Study 2 (Time Preferences)

According to compatibility, reversals of preference are not restricted to risky prospects; they should also occur in other situations in which decision makers both choose and price options with a monetary component. In the next study, we test this

TABLE 4—THE OPTIONS USED IN STUDY 2 AND THE RESPECTIVE PERCENTAGE
OF PREFERENCES. THE PAIR (X, T) DENOTES THE OPTION OF RECEIVING
X, T YEARS FROM NOW, AND (X) DENOTES AN IMMEDIATE CASH PAYMENT

Triple	1	2	3	4	Mean
S	(1600,1.5)	(1600,1.5)	(2500,5)	(1525,0.5)	
L	(2500,5)	(3550,10)	(3550,10)	(1900,2.5)	
X	(1250)	(1250)	(1250)	(1350)	
$S \succ L$	57	72	83	83	74
$C_S > C_L$	12	19	29	40	25
PR	49	56	57	46	52

prediction in the context of time preferences. Consider a delayed payment of the form (X, T) that offers a payment of X, T years from now. Following the design of Study 1, we constructed four triples of options that consisted of a long-term prospect L (for example, $2500, 5 years from now), a short-term prospect S (for example, $1600, 1.5 years from now), and an immediate payment X (for example, $1250 now).

One hundred and sixty-nine subjects participated in the study. One-half of the subjects first chose between the three pairs of options (S vs. L, S vs. X, L vs. X) in each triple. The order of the pairs was randomized across triples. Following the choice, these subjects priced each of the S and L options by stating "the smallest immediate cash payment for which they would be willing to exchange the delayed payment." The other subjects performed the choice and pricing tasks in the opposite order. There were no systematic differences between the groups, so their data were combined.

The upper part of Table 4 presents the four triples of options employed in this study. The lower part of the table includes, for each triples, the percentage of subjects who chose S over L ($S \succ L$), the percentage of subjects who priced S above L ($C_S > C_L$), and the percentage of PR patterns ($S \succ L$ and $C_L > C_S$). Table 4 reveals a massive amount of PR. Overall, the short-term option (S) was chosen over the long-term option (L) 74 percent of the time, but was priced higher only 25 percent of the time, yielding more than 50 percent PR patterns.

Note that in the pricing task each option is evaluated singly whereas choice involves a comparison between options. The observed reversals, therefore, are consistent with an alternative hypothesis that payoffs are weighted more heavily in a singular than in a comparative evaluation. To test this hypothesis, we replicated the study in a new group of 184 subjects, with one change. Instead of pricing the options, the subjects were asked to rate the attractiveness of each option on a scale from 0 (not at all attractive) to 20 (extremely attractive). If PR is controlled, in part at least, by the nature of the task (singular vs. comparative), rating and pricing should yield similar results. On the other hand, if PR is produced primarily by the compatibility between payoffs and prices, rating and choice should yield similar results. The data reveal no discrepancy between choice and rating. Overall, S was chosen over L 75 percent of the time (as in the original study) and the rating of S exceeded the rating of L in 76 percent of the cases, in accord with procedure invariance. Only 11 percent of the patterns exhibited PR.

We also applied the diagnostic analysis to the results of Study 2. Recall that the relevant test data consisted of all patterns of the form

$$S \succ L \text{ and } C_L > X > C_S.$$

These are the patterns that exhibit preference reversal, and the immediate payment of X falls between the two cash equivalents. These data were classified into four types according to the observed relation of X to L and to S. The distribution of the four types is presented in Table 5 along with the appropriate diagnoses. The table shows that the

TABLE 5—DISTRIBUTION OF RESPONSE PATTERNS IN STUDY 2.

Pattern	N	Percent	Diagnosis
(1) $L \succ X, X \succ S$	16	15.4	Intransitivity
(2) $X \succ L, X \succ S$	57	54.8	Overpricing of L (OL)
(3) $L \succ X, S \succ X$	12	11.5	Underpricing of S (US)
(4) $S \succ X, X \succ L$	19	18.3	Both OL and US
Total	104	100	

major determinant of PR in delayed pay-
ments is the overpricing of the long-term
prospect (L), and that the underpricing of
the short-term prospect (S) and the intransi-
tivity of $\succ$ play a relatively minor role (see
also Appendix 2). Evidently, payoffs are
weighted more heavily in pricing than in
choice.

III. General Discussion

The preference-reversal phenomenon has
been demonstrated in numerous studies but
its causes have not been established. The
present article attempts to determine these
causes by comparing several accounts that
attribute PR to violations of transitivity,
procedure invariance, independence, or the
reduction axiom. To assess the relative con-
tributions of these effects we extend the
standard experimental design, employ an or-
dinal payoff scheme, and introduce a new
diagnostic analysis. The results appear quite
clear.

First, PR cannot be attributed to viola-
tions of the independence or the reduction
axioms and therefore cannot be rationalized
by a generalized (nonindependent) utility
model, as proposed by Holt (1986), Karni
and Safra (1987), and Segal (1988). Note
that the basic PR pattern does not involve
these axioms, which are only needed to jus-
tify payoff procedures such as the BDM
scheme. If PR were caused by nonindepen-
dence, or by a failure of the reduction ax-
iom, it should be observed in the BDM
scheme but not in the present ordinal scheme
or in experiments where the payoffs are not
contingent on the subject's responses. The
finding that PR is no more frequent in the
BDM scheme, which assumes independence,
than in elicitation procedures that do not

assume this axiom, rules out nonindepen-
dence as a viable explanation of PR. Evi-
dently, the effect of response mode (for ex-
ample, choice, pricing) cannot be explained
by the payoff scheme.

If PR does not represent a violation of
independence or of the reduction axiom, it
must be due either to intransitivity or to a
failure of procedure invariance. The diagnos-
tic procedure indicates that only 10 percent
of PR patterns are intransitive while the
remaining 90 percent represent non-invari-
ance. Because Fishburn's (1984, 1985) SSB
model and Loomes and Sugden's (1982,
1983) regret theory assume procedure invari-
ance and attribute all PR to intransitivity,
they do not provide an adequate account of
preference reversals. It is also noteworthy
that regret theory is consistent with the pre-
dominant direction of the (relatively small
percentage of) intransitive triples observed
in Study 1, but is not consistent with the
pronounced intransitivity of choices between
gambles demonstrated by Tversky (1969).

The overpricing of the low-probability
high-payoffs bets emerges from the present
analysis as the major cause of PR. The re-
sults of Raphael Bostic, Richard Herrnstein,
and Duncan Luce (1990) provide further
support for this conclusion. We have inter-
preted the overpricing of long shots as an
effect of scale compatibility: because the
prices and the payoffs are expressed in the
same units, payoffs are weighted more heav-
ily in pricing than in choice. Compatibility
also implies new preference reversals in other
domains, such as time preferences. Study 2
shows that when faced with a choice be-
tween delayed payments, people frequently
select the short-term prospect but assign a
higher cash equivalent to the long-term
prospect. Other consequences of compatibil-

ity have been confirmed in other studies showing (i) that the prevalence of PR is substantially reduced by using nonmonetary payoffs, and (ii) that the matched attribute is weighted more heavily than the other attribute in a matching task. Further evidence on the role of compatibility in PR, based on attention and anchoring data, is presented by David Schkade and Eric Johnson (1989). We conclude that scale compatibility explains, at least in part, the primary cause of PR, namely the overpricing of L bets. It should be noted, however, that compatibility does not explain several secondary effects commonly observed in PR studies, including the occurrence of systematic intransitivities and the occasional underpricing of H bets.

Experimental studies of choice challenge the classical analysis of decision making. Violations of the independence axiom of expected utility theory have attracted much attention. In addition, a growing body of empirical evidence questions the assumption of invariance, which is essential to the theory of rational choice. In particular, alternative framings of the same options (for example, in terms of gains vs. losses, or in terms of survival vs. mortality) produce inconsistent preferences (Tversky and Kahneman, 1986), and alternative elicitation procedures (for example, choice, pricing) give rise to reversal of preferences (Tversky, et al. 1988). These results confirm the conclusion of Grether and Plott:

Taken at face value the data are simply inconsistent with preference theory and have broad implications about research

priorities within economics. The inconsistency is deeper than the mere lack of transitivity or even stochastic transitivity. It suggests that no optimization principles of any sort lie behind the simplest of human choices and that the uniformities in human choice behavior which lie behind market behavior may result from principles which are of a completely different sort from those generally accepted.

[1979, p. 623]

Indeed, the failures of description invariance (framing effects) and procedure invariance (elicitation effects) pose a greater problem for rational choice models than the failure of specific axioms, such as independence or transitivity, and they demand descriptive models of much greater complexity. Violations of description invariance require an explicit treatment of the framing process, which precedes the evaluation of prospects (Kahneman and Tversky, 1979). Violations of procedure invariance require context-dependent models (for example, Tversky et al., 1988) in which the weighting of attributes is contingent on the method of elicitation. These developments highlight the discrepancy between the normative and the descriptive approaches to decision making, which many choice theorists (see Mark Machina, 1987) have tried to reconcile. Because invariance—unlike independence or even transitivity—is normatively unassailable and descriptively incorrect, it does not seem possible to construct a theory of choice that is both normatively acceptable and descriptively adequate.

APPENDIX 1–DISTRIBUTION OF
RESPONSE
PATTERNS IN STUDY 1

	1	2	3	4	5	6	
	$C_L > X > C_H$	$C_H > X > C_L$	$C_L > C_H > X$	$C_H > C_L > X$	$X > C_L > C_H$	$X > C_H > C_L$	Total
1. $X > H, H > L, X > L$	406	142	154	2	203	427	1334
2. $H > X, L > H, L > X$	81	8	61	0	13	25	188
3. $X > H, H > L, L > X$	62	8	15	0	25	22	132
4. $H > X, L > H, X > L$	20	4	7	0	2	11	44
5. $X > H, L > H, X > L$	81	10	17	1	32	26	167
6. $H > X, H > L, L > X$	38	11	33	0	13	11	106
7. $X > H, L > H, L > X$	158	15	54	1	52	19	299
8. $H > X, H > L, X > L$	114	114	89	2	22	128	469
Total	960	312	430	6	362	669	2739

APPENDIX 2–DISTRIBUTION OF RESPONSE PATTERNS IN STUDY 2

	1	2	3	4	5	6	
	$C_L > X > C_S$	$C_S > X > C_L$	$C_L > C_S > X$	$C_S > C_L > X$	$X > C_L > C_S$	$X > C_S > C_L$	Total
1. $X \succ S, S \succ L, X \succ L$	57	14	63	5	32	65	236
2. $S \succ X, L \succ S, L \succ X$	19	0	59	1	4	1	84
3. $X \succ S, S \succ L, L \succ X$	16	1	10	1	4	1	33
4. $S \succ X, L \succ S, X \succ L$	1	2	7	0	4	4	18
5. $X \succ S, L \succ S, X \succ L$	14	3	9	0	2	3	31
6. $S \succ X, S \succ L, L \succ X$	12	2	24	3	5	1	47
7. $X \succ S, L \succ S, L \succ X$	9	1	12	1	2	2	27
8. $S \succ X, S \succ L, X \succ L$	19	11	42	8	12	18	110
Total	147	34	226	19	65	95	586

REFERENCES

Becker, Gordon M., DeGroot, Morris H. and Marschak, Jacob, "Measuring Utility by a Single-Response Sequential Method," *Behavioral Science*, July 1964, *9*, 226–32.

Berg, Joyce E., Dickhaut, John W. and O'Brien, John R., "Preference Reversal and Arbitrage," in V. L. Smith, ed., *Research in Experimental Economics*, Vol. 3, Greenwich: JAI Press, 1985.

Bostic, Raphael, Herrnstein, Richard J. and Luce, R. Duncan, "The Effect on the Preference-Reversal Phenomenon of Using Choice Indifferences," *Journal of Economic Behavior and Organization*, 1990, in press.

Cox, James C. and Epstein, Seth, "Preference Reversals Without the Independence Axiom," *American Economic Review*, June 1989, *79*, 408–26.

Fishburn, Peter C., "SSB Utility Theory: An Economic Perspective," *Mathematical Social Sciences*, August 1984, *8*, 63–94.

____, "Nontransitive Preference Theory and the Preference Reversal Phenomenon," *Rivista Internazionale di Scienze Economiche e Commerciali*, January 1985, *32*, 39–50.

Goldstein, William M. and Einhorn, Hillel J., "Expression Theory and the Preference Reversal Phenomena," *Psychological Review*, April 1987, *94*, 236–54.

Grether, David M. and Plott, Charles R., "Economic Theory of Choice and the Preference Reversal Phenomenon," *American Economic Review*, September 1979, *69*, 623–38.

Hamm, Robert M., "The Conditions of Occurrence of the Preference Reversal Phenomenon," Technical Report, Center for Research on Judgment and Policy, University of Colorado, 1984.

Holt, Charles A., "Preference Reversals and the Independence Axiom," *American Economic Review*, June 1986, *76*, 508–15.

Kahneman, Daniel and Tversky, Amos, "Prospect Theory: An Analysis of Decision Under Risk," *Econometrica*, March 1979, *47*, 263–91.

Karni, Edi and Safra, Zvi, "'Preference Reversal' and the Observability of Preferences by Experimental Methods," *Econometrica*, May 1987, *55*, 675–85.

Knez, Marc and Smith, Vernon L., "Hypothetical Valuations and Preference Reversals in the Context of Asset Trading," unpublished manuscript, University of Arizona, 1986.

Lichtenstein, Sarah and Slovic, Paul, "Reversals of Preference between Bids and Choices in Gambling Decisions," *Journal of Experimental Psychology*, January 1971, *89*, 46–55.

____, "Response-Induced Reversals of Preference in Gambling: An Extended Replication in Las Vegas," *Journal of Experimental Psychology*, November 1973, *101*, 16–20.

Lindman, Harold R., "Inconsistent Preferences Among Gambles," *Journal of Experimental Psychology*, May 1971, *89*, 390–97.

Loomes, Graham and Sugden, Robert, "Regret Theory: An Alternative Theory of Ratio-

nal Choice Under Uncertainty," *Economic Journal*, December 1982, *92*, 805–24.

_____ and _____, "A Rationale for Preference Reversal," *American Economic Review*, June 1983, *73*, 428–32.

_____, Starmer, Chris and Sugden, Robert, "Preference Reversal: Information-Processing Effect or Rational Nontransitive Choice," *Economic Journal* (Conference Supplement), 1989, *99*, 140–51.

Machina, Mark J., "Choice Under Uncertainty: Problems Solved and Unsolved," *Economic Perspectives*, Summer 1987, *1*, 121–54.

Mowen, John C. and Gentry, James W., "Investigation of the Preference-Reversal Phenomenon in a New Product Introduction Task," *Journal of Applied Psychology*, December 1980, *65*, 715–22.

Pommerehne, Werner W., Schneider, Fredrich and Zweifel, Peter, "Economic Theory of Choice and the Preference Reversal Phenomenon: A Reexamination," *American Economic Review*, June 1982, *72*, 569–74.

Reilly, Robert J., "Preference Reversal: Further Evidence and Some Suggested Modifications in Experimental Design," *American Economic Review*, June 1982, *72*, 576–84.

Schkade, David A. and Johnson, Eric J., "Cognitive Processes in Preference Reversals,"

Organizational Behavior and Human Performance, June, 1989, *44*, 203–31.

Segal, Uzi, "Does the Preference Reversal Phenomenon Necessarily Contradict the Independence Axiom?," *American Economic Review*, March 1988, *78*, 233–36.

Slovic, Paul, Griffin, Dale and Tversky, Amos, "Compatibility Effects in Judgment and Choice," in R. M . Hogarth, ed., *Insights in Decision Making: Theory and Applications*, Chicago: University of Chicago Press, 1990.

_____, and Lichtenstein, Sarah, "The Relative Importance of Probabilities and Payoffs in Risk-Taking," *Journal of Experimental Psychology Monograph Supplement*, November 1968, Part 2, *78*, 1–18.

_____, "Preference Reversals: A Broader Perspective," *American Economic Review*, September 1983, *73*, 596–605.

Tversky, Amos, "Intransitivity of Preferences," *Psychological Review*, January 1969, *76*, 31–48.

_____, and Kahneman, Daniel, "Rational Choice and the Framing of Decisions," *Journal of Business*, October 1986, *59*, 251–78.

_____, Sattath, Shmuel and Slovic, Paul, "Contingent Weighting in Judgment and Choice," *Psychological Review*, July 1988, *95*, 371–84.