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DECISION MAKING: A RULE-BASED MODEL

BY

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DEDICATION

This thesis is dedicated to my dad, who always respected the decisions I made, even when he felt they were wrong; to Tim who was always there with friendship and love when I needed it most; and to my mom who, although she is gone, is never forgotten.

ABSTRACT

The processes underlying decision making in non-reoccurring, concurrent choice situations were investigated in a series of four experiments. A concurrent choice situation is one in which two or more alternatives are available at the same time, and only one of the alternatives can be selected. The choices may be reoccurring, in which case the same alternatives are available time and time again; or they may be non-reoccurring, in which case the same set of alternatives may not be available in the same way again. In Studies 1 and 2 adult decision-making patterns were compared to predictions generated by a number of weighted-value models of decision making. Over 20% of the individuals in these two studies made selections which indicated that the subjective discounting implicit in the weighted-value models was not an integral part of the decision-making process. Based on these findings an information-processing model of the decision-making process was developed which incorporated a series of increasingly complex decision rules. In Study 3 this rule-based model was used to assess adult decision making, and 100% of the observed decision patterns were consistent with predictions based on the model. In Study 4 individuals in three different age groups were tested, and the results from this study indicated that the complexity of available decision rules increases with age. In addition, in Study 4 a form of horizontal décalage emerged across problem types. Specifically, when the decision patterns for equivalent gain and loss problems were compared, just over 25% of the subjects appeared to use less complex rules to evaluate loss problems. This difference may arise because gain and loss problems place different information-processing demands on the decision maker and the evaluation of loss problems requires more cognitive effort. Therefore, the proposed model presents an alternative conceptualization of the decision-making process. This model can account for some of the anomalous results reported in earlier

studies, and also suggests a developmental sequence for the emergence of decision-making skills.

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Chapter One: Introduction

Any time an individual faces a concurrent choice situation he or she must make a decision, even if that decision is to do nothing. A concurrent choice situation is one in which two or more alternatives are available at the same time, and only one of the alternatives can be selected. The choice situation may be reoccurring, in which case the same alternatives are available time and time again; or it may be non-reoccurring, in which case the same alternatives may not be available in the same way again, once a decision has been made. We experience a reoccurring, concurrent choice situation when we must decide which entree to order when dining in a favorite restaurant; we experience a non-reoccurring, concurrent choice situation when we must decide between going to see a hockey game and going to see a play scheduled for the same evening.

There are a number of approaches which can be used to study the behavior of organisms faced with selecting a single alternative from two or more alternatives which are concurrently available. Three of these approaches are: (a) the behavioral approach; (b) the economic approach; and (c) the information-processing approach. Each approach is best suited for studying different types of decision behavior, or for understanding different aspects of the decision making process.

Behavior in reoccurring, concurrent choice situations has traditionally been studied using a behavioral approach. The standard experimental procedure has been to present subjects with two or more response alternatives, and measure how the subjects distribute their time among the available alternatives. The distribution of behavior under these conditions was first formalized in 1961 by Richard Herrnstein. He found that when animals were placed in a reoccurring, concurrent choice situation, the relative rates of responding to each of the available alternatives tended to m..tch the relative rates of reinforcement from those alternatives. He translated this finding into a mathematical relation which he called the "matching law" (see Herrnstein, 1961):

$$R_1/(R_1 + R_2) = r_1/(r_1 + r_2) \quad (1)$$

where R_i is the total number of responses made on schedule i, and r_i is the total number of reinforcers obtained from schedule i. Basically, the matching law states that the proportion of time an organism spends engaging in one specific behavior, relative to all behaviors, will be equal to the amount of reinforcement that is available for that behavior, relative to the amount of reinforcement that is available for all behaviors.

The basic assumption of the matching law is that organisms <u>match</u> relative rates. If the amount of reinforcement available from one alternative goes up, while the amount of reinforcement from the other alternatives remains constant or decreases, the organism will select the improved alternative a higher proportion of the time; if the amount of reinforcement available from one alternative goes down, while the amount of reinforcement from the other alternatives remains constant or increases, the organism will select the impoverished alternative a lower proportion of the time.

Research on response patterns under these conditions has found that t matching law provides a relatively good description of an organism's behavior under these type of schedules, with one notable exception: One result that has been fairly consistently found in this type of procedure is that organisms tend to "undermatch" (Baum, 1974; Baum, 1979; Wearden & Burgess, 1982). Undermatching simply means that organisms spend less time on the richer schedule, and more time on the leaner schedule than the matching law would predict. Undermatching is usually dealt with in a matching analysis by calculating two post-hoc measures: one is presumed to reflect individual bias in responding to one or the other of the alternatives, the other is presumed to reflect individual sensitivity to differences in the reinforcement schedules. These measures are then used to "correct" the obtained data. In other words, deviations from the normative predictions of the matching law are viewed as errors which result from individual differences in sensitivity to reinforcement rates.

However, it may be that in reoccurring, concurrent choice situations organisms are not selecting according to the strategy implied by matching theory, but are instead making use of some other strategy which results in a similar behavioral outcome most of the time (see for example, Baum, 1981; Boelens, 1984; Staddon, Hinson & Kram, 1981; Vaughan, 1981). This is the type of argument made by the proponents of optimality theory (cf. Houston & McNamara, 1981). Optimality theory suggests that organisms distribute their behavior among reoccurring, concurrent alternatives in a pattern that maximizes their overall rate of return. Overall maximization will produce a final, gross behavior pattern that is consistent with matching theory. In contrast, matching will not always result in schedule maximization.

In an optimality analysis the maximum rate of reinforcement that is obtainable from a given set of schedules can be determined. An organism's performance can then be compared to this theoretical maximum to determine its individual level of efficiency. Hensch and Heth (1989) used an optimality analysis to examine the behavior of rats in a reoccurring, concurrent choice situation and found that, although individual efficiency levels varied from 70% to 98%, efficiency levels were consistent within individual subjects across the schedules used. Interestingly, the least efficient animals were not the ones who showed the highest degree of undermatching, and the one animal who did not undermatch was not the most efficient animal of the group. The low correlation between the level of undermatching and the overall level of efficiency suggests that matching and optimizing may be fundamentally different processes, and that undermatching may not be an error, if it results in more efficient behavior.

In contrast to the selection process proposed by matching theory, the central assumption of optimality theory is that organisms make selections that maximize their overall level of reinforcement. This assumption also underlies the economic approach to decision making, which has been used to describe behavior in non-reoccurring, concurrent choice situations. The economic approach assumes that individuals combine the relevant problem dimensions, and then select the alternative which maximizes the benefit they will receive, in the long run. The best way to maximize benefits in the long run is to select the alternative that has the highest expected value. Using this strategy an individual may or may not receive the maximum benefit from each separate selection, but the individual will maximize his or her overall benefits in the long run.

To illustrate, suppose an individual must decide between (a) receiving $10.00 for certain, and (b) gambling on a 50/50 chance of receiving $25.00 or receiving nothing. An individual who decides according to expected value theory logic should select Alternative B in this situation, because the expected value of that alternative is $12.50 [(0.5 x $25.00) + (0.5 x $0.00)], and this exceeds the expected value of Alternative A (1.0 x $10.00). In other words, in any two-alternative, non-reoccurring, concurrent choice situation, an individual deciding on the basis of expected value logic should select the alternative with the higher expected value.

However, empirical testing by researchers such as Edwards (1953, 1954a, 1954b, 1954c) and Kahneman and Tversky (1979, 1984; Tversky & Kahneman, 1981) uncovered consistent deviations from predictions based on expected value theory. As a result, the theory underlying the economic approach to the study of decision making has been modified a number of times in an attempt to account for behavior that was inconsistent with the basic assumptions of expected value theory. See Appendix A for a review of the theoretical developments in this area.

One of the more consistently reported decision patterns in non-reoccurring, concurrent choice situations (see for example, Kahneman & Tversky, 1979, 1984; Tversky & Kahneman, 1981) occurs when individuals select the certain alternative over the risky alternative in situations involving gains (even though the certain alternative may have a lower expected value), and select the risky alternative over the certain alternative in situations involving losses (even though the risky alternative may have a lower expected value). This decision pattern is inconsistent with predictions based on expected value theory, and modifications to expected value theory have tried to account for this type of decision pattern by incorporating post-hoc measures, similar to those used to explain undermatching in a matching-type of analysis: The decision behavior is explained by allowing for the use of subjective measures.

The subjective measures which have been proposed involve either: (a) discounting the amounts involved (Bernoulli, 1738), (b) discounting the probabilities involved (Edwards, 1953, 1954a, 1954b), or (c) discounting both the amounts and the probabilities (Edwards, 1954c; Kahneman & Tversky, 1979). Three alternatives to the expected value formulation of decision making in non-reoccurring, concurrent choice situations have been developed that incorporate the use of these subjective measures: expected utility theory (Bernoulli, 1738), subjective expected utility theory (Edwards, 1954c), and prospect theory (Kahneman & Tversky, 1979). (See Appendix A for a more complete description of each of these theories.)

These alternative theories of decision making all suggest that individuals use a two-dimensional, multiplicative decision strategy of the type suggested by expected value theory. However, each of the theories suggests individuals apply a different type of subjective reformulation to the decision problem before the problem dimensions are combined, and these subjective reformulations can result in selections which are inconsistent with predictions derived from expected value theory. In essence, this is the same type of transformation that was described in the discussion of the matching law. In matching analysis it is assumed that the observed behavior results from the process inferred by the matching law, and that deviations from predictions result from individual differences in sensitivity to reinforcement rates. In much the same way, economic models of decision making in non-reoccurring, concurrent choice situations assume that individuals use a two-dimensional, multiplicative strategy to combine the relevant problem dimensions, and to determine the optimal selection. Selections which are non-optimal (from an expected value perspective) are presumed to result from individual differences in weighting or perceiving the two problem dimensions. This means that economic models of decision making remain normative models, even though they introduce cognitive elements to explain observed deviations. Each of the models evaluates the quality of the decisions, relative to some normative model, and deviations from predictions are explained by allowing for the use of subjective measures on the part of the decision maker.

Empirical support for these revised economic models of decision making has been mixed (see Appendix A) and decision patterns that are inconsistent with predictions based on these revised models have been reported (e.g., Fischhoff, 1983; Hershey & Schoemaker, 1980; Schneider & Lopes, 1986). As a result, some researchers have suggested "that weighted value theories such as prospect theory are inadequate to explain the basic pattern of preferences...[w]e suggest that this is so because such theories pay scant attention to the goals and strategies (emphasis added) that people bring to risky choice" (Schneider & Lopes, 1986, p. 548).

Understanding the decision process is the goal of the information-processing approach to decision making. With this approach individual decisions are not classified as correct or incorrect; instead the pattern of selections across a range of problems is analyzed to determine the process the individual might have used to arrive at his or her decisions. The difference between the economic and information-processing approaches is exemplified by a quote from B. F. Skinner's book Walden Two. At one point the main character, Frazier, says: "I remember the rage I used to feel when a prediction went awry. I could have shouted at the subjects of my experiments, 'Behave, damn you! Behave as you ought!' Eventually I realized that the subjects were always right. They always behaved as they should have behaved. It was I who was wrong. I had made a bad prediction" (Skinner, 1976, p. 271).

The information-processing approach suggests that then individuals make decisions, they may be maximizing some dimension other than expected value, or they may be using some strategy other than maximization to make decisions. The focus of this approach is on the decision process; the strategy an individual uses to decide between alternatives can be discovered by analyzing the pattern of decisions across a number of problems (Jungermann, 1983).

The information-processing approach has been used by researchers modeling decision-making processes with simulated decision heuristics (e.g. Payne, Bettman & Johnson, 1988; Thorngate, 1980). However, although the decision heuristics these researchers have used to approximate choice behavior are comprehensive and fairly exhaustive, one issue not addressed is how these decision heuristics develop. For example, Payne et al. (1988) state: "The implicit viewpoint in our work is that a decision maker possesses a repertoire of well-defined strategies and selects among them when faced with a decision..." (p. 550). While this viewpoint suggests that a number of strategies are available to the decision maker, it does not take into account how these strategies originally evolved. It is not clear in the heuristic modeling approach whether strategies develop in parallel, or whether simple strategies form the foundation for more complex strategies. In contrast, a number of developmental researchers have produced information-processing models of strategy acquisition. These models are based on the premise that "cognitive development can be characterized in large part as the acquisition of increasingly powerful rules for solving problems" (Siegler, 1981, p. 3).

Therefore, decision heuristic modeling and models of strategy acquisition represent two very distinct approaches to the study of decision-making processes. In the first instance, established decision strategies are modeled to determine their overall efficiency; in the second instance the way that the strategies emerge forms the research focus, and the relative efficiency of the various strategies is a peripheral issue.

This second approach, or rule-assessment approach, has been used extensively by Robert Siegler (see, for example, Siegler, 1976, 1981; Siegler & Richards, 1979). The main advantage of Siegler's rule-assessment approach is that it allows investigators to determine which aspects of a problem are being attended to, and how problem information is being combined. This approach does not require consensus among researchers concerning the overall quality of the strategy that is utilized (Siegler, 1981). Therefore, the application of the rule-assessment technique to the area of decision-making may provide a means of analyzing decision-making process without requiring an assessment of the overall quality of the final decisions. Decisions that violate normative models of choice need not be viewed as irrational, or non-optimal, only different. These differences would presumably result from individual differences in processing the information concerning the relevant problem dimensions.

However, before one can start to consider the different types of strategies an individual might use to decide among the available alternatives in a non-reoccurring, concurrent choice situation, it is necessary to look at the structure of these decision problems in greater detail. In previous studies (e.g. Budescu & Weiss, 1987; Fischhoff, 1983; Hershey & Schoemaker, 1980) subjects have been asked to select one alternative from two available alternatives, where each of the alternatives will occur with some probability, and where each will yield some outcome if it should occur. There are seven possible ways to structure two-alternative decision problems of this type (Siegler, 1981). These seven possibilities are outlined in Figure 1, where the amount at stake for each of the alternatives is listed under each circle, and the probability of winning the amount at stake for each alternative is equal to the shaded proportion of the circle. The seven problem types are:

1. Equality problems, where each alternative has the same amount at stake, and the same probability of occurrence. (For example, deciding between receiving either $1 for certain, or $1 for certain.)

2. Amount problems, where each alternative has a different amount at stake, but where the probability of occurrence for each of the alternatives is the same. (For example, deciding between receiving either $1 for certain, or $5 for certain.)

3. Probability problems, where each alternative has the same amount at stake, but where the probability of occurrence for each of the alternatives is different. (For example, deciding between receiving either $1 for certain, or

Problem Type	Problem Structure	Example
Equality $1 $1	Probability 1 = Probability 2 Amount 1 = Amount 2 Expected Value 1 = Expected Value 2	Choose between: (1) Receiving $1 for certain (2) Receiving $1 for certain
Amount $1 $5	Probability 1 = Probability 2 Amount 1 < Amount 2 Expected Value 1 < Expected Value 2	Choose between: (1) Receiving $1 for certain (2) Receiving $5 for certain
Probability $1 $1	Probability 1 > Probability 2 Amount 1 = Amount 2 Expected Value 1 > Expected Value 2	Choose between: (1) Receiving $1 for certain (2) Receiving $1 with p=.5
No Conflict $5 $1	Probability 1 > Probability 2 Amount 1 > Amount 2 Expected Value 1 > Expected Value 2	Choose between: (1) Receiving $5 for certain (2) Receiving $1 with p=.5
Conflict-Amount $2 $5	Probability 1 > Probability 2 Amount 1 < Amount 2 Expected Value 1 < Expected Value 2	Choose between: (1) Receiving $2 for certain (2) Receiving $5 with p=.5
Conflict-Probability $3 $5	Probability 1 > Probability 2 Amount 1 < Amount 2 Expected Value 1 > Expected Value 2	Choose between: (1) Receiving $3 for certain (2) Receiving $5 with p=.5
Conflict-Equivalence $1 $2	Probability 1 > Probability 2 Amount 1 < Amount 2 Expected Value 1 = Expected Value 2	Choose between: (1) Receiving $1 for certain (2) Receiving $2 with p=.5

<u>Figure 1.</u> Problems structures for two-alternative decision problems.

$1 with a probability of 0.5.)

4. No-conflict problems, where each alternative has a different amount at stake, and a different probability of occurrence, but the alternative with the larger amount at stake also has the higher probability of occurrence and therefore the greater expected value. (For example, deciding between receiving either $5 for certain, or $1 with a probability of 0.5.)

5. Conflict-amount problems, where each alternative has a different amount at stake, and a different probability of occurrence, and the alternative with the larger amount at stake has the lower probability of occurrence; in this case the alternative with the larger amount at stake has the greater expected value. (For example, deciding between receiving either $2 for certain, or $5 with a probability of 0.5.)

6. Conflict-probability problems, where each alternative has a different amount at stake, and a different probability of occurrence, and the alternative with the larger amount at stake has the lower probability of occurrence; in this case the alternative with the larger probability of occurrence has the greater expected value. (For example, deciding between receiving either $3 for certain, or $5 with a probability of 0.5.)

7. Conflict-equivalence problems, where each alternative has a different amount at stake, and a different probability of occurrence, and the alternative with the larger amount at stake has the lower probability of occurrence; in this case both the alternatives have the same expected values. (For example, deciding between receiving either $1 for certain, or $2 with a probability of 0.5.)

Equality problems (Type 1) will not be discussed as they serve no diagnostic purpose and are only enumerated for the sake of completeness. Problem types 2, 3, and 4 (amount, probability, and no-conflict) are the type of problems earlier researchers have referred to as dominated problems. In dominated problems one of the alternatives is at least as good as the other on one dimension, and better than the other on the remaining dimension (Keeney & Raiffa, 1976, p. 70). The diagnostic value of these problem types will be discussed in more detail in Chapters 3 and 5.

Problem types 5, 6, and 7 (conflict-amount, conflict-probability and conflict-equivalence) are non-dominated problems. In non-dominated problems each of the alternatives is better on one of the problem dimensions but worse on the other. The ability to make optimal decisions on non-dominated problems will depend to a large extent on an individual's ability to combine the relevant problem dimensions in a logically meaningful and consistent way. If individuals are unable to combine the relevant problem dimensions, one would anticipate non-optimal decisions on one or more of these non-dominated problem types. By analyzing the pattern of selections across a series of decision problems which have different problem structures, it may be possible to discover the different types of decision strategies individuals use in non-reoccurring, concurrent choice situations.

Previous studies of decision-making behavior, based on the economic approach, have treated decision problems as dominated or non-dominated, but within each of these categories the problems have been treated as equivalent in structure (cf. Kahneman & Tversky, 1979; Budescu & Weiss, 1987). In contrast, this series of experiments was designed to determine: (a) if the ability to make optimal decisions is consistent, within an individual, across each of the problem types, and in particular across each of the conflict-problem types; (b) the types of strategies that might account for the observed decision patterns if individuals do not demonstrate equal proficiency for each of the problem types; and, (c) if changes in the type of decision strategy used on problems of this type can be linked to age.

Chapter Two: Study One

Early studies of decision making in non-reoccurring, concurrent choice situations tended to focus on isolated decisions rather than a range of selections. One of the major findings reported in these early studies was that individuals tended to avoid making risky selections on problems that involved a gain, and tended to make risky selections on problems that involved a loss. However, many of the deviations from expected value predictions that were originally reported were based on data obtained when a single question was presented and where the expected value of the two alternatives was equated (see for example, Kahneman & Tversky, 1979, 1984; Tversky & Kahneman, 1981).

Recent studies have used larger problem sets such as 6 problems (Chang, Nichols & Schultz, 1987; Diamond, 1988), 10 problems (Fischhoff, 1983; Schneider & Lopes, 1986), and in one instance 34 problems (Hershey & Schoemaker, 1980), but in these five studies the problems have also equated the expected values of the tested alternatives, and all the problems have included one alternative which would be received with certainty. Under these circumstances it is not clear that the results obtained can be used to show that individuals make decisions that are inconsistent with the assumptions of expected value theory. According to expected value theory, when an individual must decide between receiving $x for certain, or receiving $2x with a probability of 0.5, he or she should be indifferent as to which alternative is received; both alternatives should be rated as being equally attractive. However, in the studies cited indifference was not an option; a decision was required. Under these circumstances, the tendency of individuals to avoid the risky alternative for gain problems and to select the risky alternative for loss problems may be a procedural artifact. If both the available alternatives are rated as equally attractive, but one or the other must be selected, the decision problem must be resolved in some way. At least two potential strategies exist: (a) an individual who considers the probability of occurrence to be more important than the amount at stake in reaching a decision will select the certain alternative in a gain situations, and the risky alternative in a loss situation; (b) an individual who considers the amount at stake to be the more important dimension would make the opposite selections, selecting the alternative with the larger amount at stake for gains (the risky alternative), and the alternative with the smaller amount at stake for losses (the certain alternative). This means that selections on conflict-equivalence problems may simply reflect the relative importance of each of the problem dimensions. Thus the most commonly reported decision strategy in previous studies of decision making (risk-aversion for gains coupled with risk-seeking for losses) may result from the fact that, if a selection must be made between alternatives individuals judge to be equivalent, the majority of individuals may decide on the basis of probability of occurrence. The importance of the probability of occurrence in the decision process has been noted in a number of studies; for example, Hershey and Schoemaker (1980) reported: "For subjects who said they focused on one dimension only, the probability factor (p) appears [to be] most important (p. 415)."

To understand the decision-making process more fully, and to determine the conditions under which expected value theory fails to predict observed behavior adequately, it is necessary to present individuals with decision problems in which the expected values of the alternatives are not equated. However, little decision-making research has been conducted in which the objective expected values of the available alternatives were not equated.

In one study, Budescu and Weiss (1987) presented subjects with 17 questions in which the expected values of the alternatives were not equated.

However, the composition of the pairs Budescu and Weiss (1987) selected confounded probability of occurrence and amount at stake. In each pair they presented, the larger monetary amount was always paired with the smaller probability of occurrence, and for the specific values they selected this resulted in a situation where the alternative with the larger monetary amount (and hence the smaller probability of occurrence) always had the lower expected value. This means that all 17 problems were conflict-probability problems (see Figure 1).

To select the alternative with the larger expected value, the individual would have to select: (a) the alternative with the larger probability of occurrence in each gain question, and (b) the alternative with the smaller probability of occurrence in each loss question. Therefore, if selections were made solely on the basis of probability of occurrence, the resulting decision pattern would be consistent with predictions based on expected value theory, and also with one of the central assumptions of prospect theory: the assumption that individuals tend to make risk-averse selections for gains and risk-seeking selections for losses (Kahneman & Tversky, 1979). The confounding of probability with amount in the Budescu and Weiss (1987) study means that it is not possible to use their data to show definitive support for prospect theory over expected value theory, or vice versa (either both theories would be supported, or neither would be supported), nor is it possible to use their data to conclude that individuals combine problem dimensions in the manner suggested by economic models of decision making.

The following study was designed to provide a clearer indication of whether the process individuals use to decide between alternatives in non-reoccurring, concurrent choice situations is adequately described by one of the economic models of decision making. The expected values of the alternatives in the problem set used in this study are not equated, and both conflict-amount and conflict-probability problems are used.

Method

Subjects. Four hundred and forty-five undergraduate students, enrolled in an introductory psychology course at the University of Alberta, took part in the study. The students completed the questionnaires during a regularly scheduled class period, and they received course credit for their participation.

Stimuli. The problems used in this study all involve amounts no greater than $50. Dollar values in this range were selected to determine if the results from Kahneman and Tversky's original studies (Kahneman & Tversky, 1979, 1984; Tversky & Kahneman, 1981) would be replicated when the amounts under consideration were ones the decision maker might realistically expect to encounter on a regular basis.

The original problem set under consideration contained a low set of values ($1.00, $2.50, and $5.00), and a high set of values that was ten times the value of the low set ($10.00, $25.00, and $50.00). Because all possible combinations of these values would yield 72 decision problems (36 gain problems and 36 loss problems) at a single probability level, a subset of these original values was selected, and the selected values were crossed with three probability levels; one was low (.125), one was intermediate (.375), and one was high (.875). The dominated problems were then removed from this problem set to arrive at the final set of 84 problems used in the study.

The problems used in this study were printed on 8-1/2" x 11" sheets of paper with four items per page (printed on one side of the page). These sheets were made up into booklets of 25 pages each. Each of the booklets contained the same set of 84 different decision problems along with 12 filler items. The 84 decision problems consisted of 42 gain questions, and 42 loss questions. In the gain questions both alternatives in the problem presented an amount which would be won; in the loss questions both alternatives in the problem presented an amount which would be lost. The composition of the decision problems is given in Table 1. Each problem consisted of two circles; one was completely shaded, and the other was partially shaded. Proportional representations, rather than explicitly stated numeric probabilities, were used to indicate the probability of occurrence so that the general procedure could later be adapted to a developmental assessment study.

Under each of the circles was a monetary amount. For the gain questions the amount was preceded by a "+" sign, and for the loss questions the amount was preceded by a "-" sign. The 12 filler items simply stated "For this item please fill in "C" on your answer sheet." These filler items were included to provide a means of determining if any of the subjects lost their place while completing the task. See Figure 2 for a sample page showing examples of the problems and the filler item.

The problems were numbered from 1 to 84, and a random sequence of 84 numbers was generated and used to order the problems. This initial ordering was designated ordering A and was counterbalanced by ordering B in which the signs for each of the questions were reversed. Using the sample page in Figure 2 as a referent: Group A would have seen this page; Group B would have seen the same questions but as a gain, a filler item, a loss, and a loss, respectively. An additional counterbalancing was undertaken in which Groups A and B were separated into Groups A1, A2, B1, and B2. In the booklets for Groups A2 and B2, the problem ordering was the same as that used for Groups A1 and B1, but the positions of the two alternatives in each questions were transposed, left to right.

Table 1

Composition of the Decision Problems Used in Study 1

Certain Amt	Probability	x	Uncertain Amt	=	Expected Value
1.00	0.125	x	5.00	=	0.63
1.00	0.375	x	5.00	=	1.88
1.00	0.875	x	5.00	=	4.38
1.00	0.125	x	10.00	=	1.25
1.00	0.375	x	10.00	=	3.75
1.00	0.875	x	10.00	=	8.75
1.00	0.125	x	25.00	=	3.13
1.00	0.375	x	25.00	=	9.38
1.00	0.875	x	25.00	=	21.88
1.00	0.125	x	50.00	=	6.25
1.00	0.375	x	50.00	=	18.75
1.00	0.875	x	50.00	=	43.75
2.50	0.125	x	5.00	=	0.63
2.50	0.375	x	5.00	=	1.88
2.50	0.875	x	5.00	=	4.38
2.50	0.125	x	10.00	=	1.25
2.50	0.375	x	10.00	=	3.75
2.50	0.875	x	10.00	=	8.75
2.50	0.125	x	25.00	=	3.13
2.50	0.375	x	25.00	=	9.38
2.50	0.875	x	25.00	=	21.88
2.50	0.125	x	50.00	=	6.25
2.50	0.375	x	50.00	=	18.75
2.50	0.875	x	50.00	=	43.75
5.00	0.125	x	10.00	=	1.25
5.00	0.375	x	10.00	=	3.75
5.00	0.875	x	10.00	=	8.75
5.00	0.125	x	25.00	=	3.13
5.00	0.375	x	25.00	=	9.38
5.00	0.875	x	25.00	=	21.88
5.00	0.125	x	50.00	=	6.25
5.00	0.375	x	50.00	=	18.75
5.00	0.875	x	50.00	=	43.75
10.00	0.125	x	25.00	=	3.13
10.00	0.375	x	25.00	=	9.38
10.00	0.875	x	25.00	=	21.88
10.00	0.125	x	50.00	=	6.25
10.00	0.375	x	50.00	=	18.75
10.00	0.875	x	50.00	=	43.75
25.00	0.125	x	50.00	=	6.25
25.00	0.375	x	50.00	=	18.75
25.00	0.875	x	50.00	=	43.75

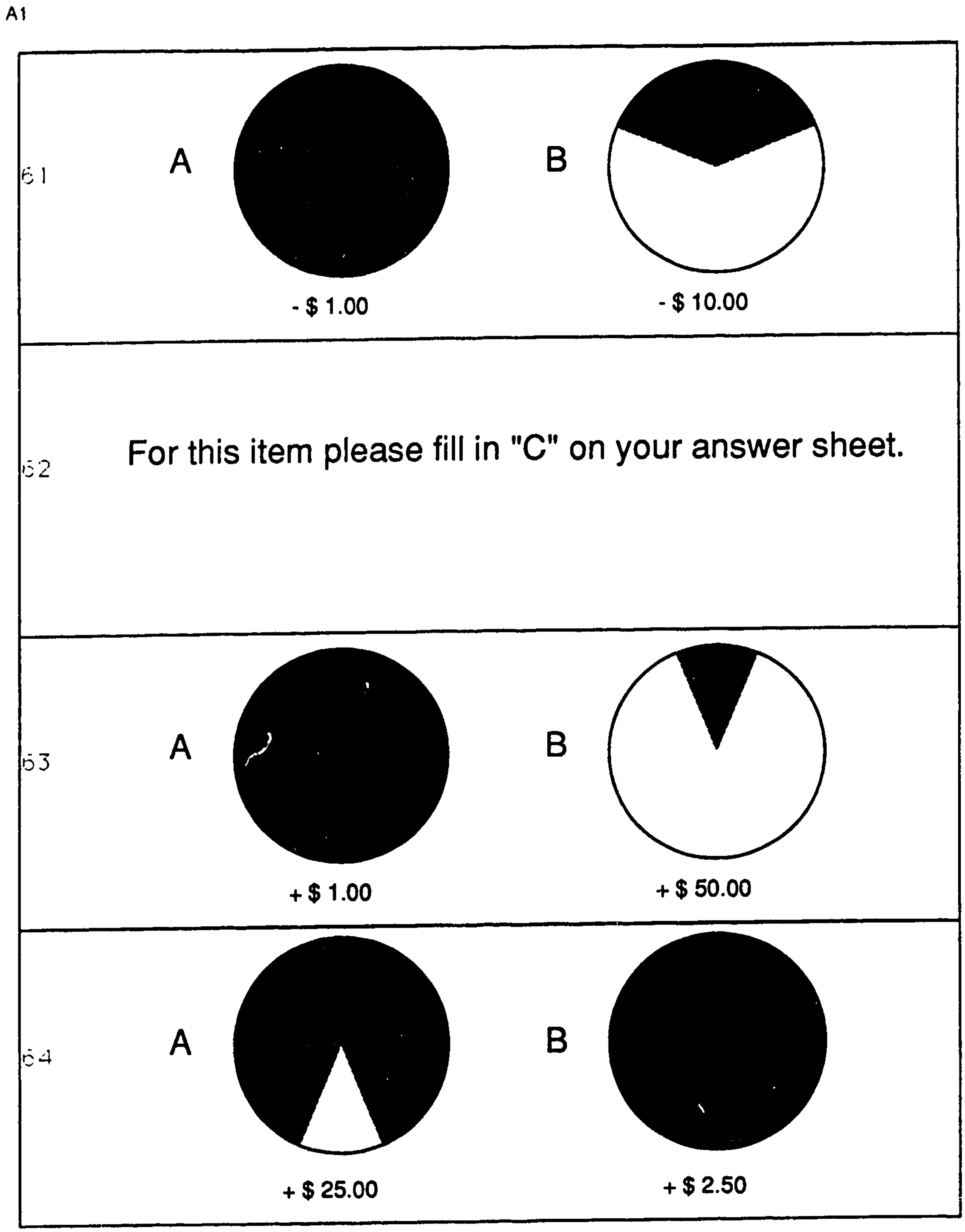


Figure 2. Sample page from testing materials used in Study 1 (Reproduced at 85% of original size).

Procedure. The subjects read the instructions in Figure 3 and responded by marking their selections for each of the problems on a machine-scored, multiple-choice answer sheet. Subjects were given as much time as they required to complete the questionnaire; each of the subjects completed the task in less than 20 minutes.

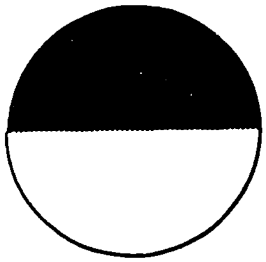
Results and Discussion

Subjects who failed to mark alternative C for the filler items (n = 9), subjects who marked alternative C for non-filler items (n = 20), and subjects who marked two answers for a single question (n = 2) were considered to have made errors in completing the questionnaire. The data from these individuals were omitted. In addition, five subjects failed to respond to at least one of the questions. The data from these individuals were also omitted. In total, data from 409 subjects were analyzed. Of these 409 subjects, 101 were from Group A1, 107 were from Group A2, 99 were from Group B1, and 102 were from Group B2.

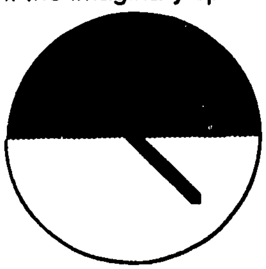
To check for differences which may have arisen from the use of the different forms, the response sheets were scored according to predictions generated on the basis of expected value theory. Selections that corresponded to expected value predictions were marked correct, and selections that were opposite to expected value predictions (SOPs) were marked incorrect. The mean and standard deviation, stated as the percentage of selections corresponding to expected value predictions, for the four groups were as follows: 77.69, s = 8.59 (Group A1); 76.80, s = 11.18 (Group A2); 78.78, s = 8.37 (Group B1); 78.07, s = 9.21 (Group B2). A one-way analysis of variance (ANOVA) indicated there were no significant differences between the four group means, $F(3, 405) = 0.78$, $p > .05$; therefore the data were aggregated for the main analyses.

Initially, the responses from all the subjects were aggregated by question, and the group data were compared to predictions generated on the basis of

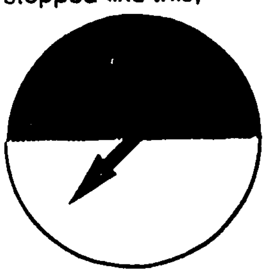
Each of the items in the attached booklet consists of a pair of partially shaded circles. Each of the circles has a monetary amount below it, describing either a win (indicated by a plus sign) or a loss (indicated by a minus sign). Imagine that these circles are discs with spinners attached to the center. You are to play a game in which you choose one of the two spinners. After you choose, the spinner is spun once. If it stops pointing to the shaded portion of the circle, you would win or lose the amount indicated under that circle. For example, suppose you chose the circle below:



If the imaginary spinner were to stop like this,



you would win (+) or lose (-) the amount indicated below the circle. On the other hand, if it stopped like this,



you would win or lose nothing.

In each case there are two circles to choose from. You are to choose the circle you would most like to play from each of the pairs, and then indicate your choice by darkening the appropriate spot on the answer sheet provided.

Before you open your booklet to the first question, please fill your I.D. number on the answer sheet and enter the following under the "SPECIAL CODE" section:

891101

Figure 3. Instruction sheet from Study 1 (Reproduced at 85% of original size).

expected value theory (see Tables 2a and 2b). For 40 of the 42 gain problems there was a significant difference between the proportion of individuals who selected the risky alternative and the proportion who selected the certain alternative. In each case, the majority selected in accordance with predictions generated on the basis of expected value theory.

For the 42 loss problems only 36 had a significant difference between the proportion of individuals who selected the risky alternative and the proportion who selected the certain alternative, and for 3 of these questions, the majority selected opposite to expected value predictions. Each of these three questions was a conflict-amount question where the probability of paying out the amount associated with the risky alternative was .125.

These deviations from expected value predictions, at the group level of analysis, appear to arise from a decision process which incorporates a subjective reformulation similar to the one by prospect theory, rather than the one proposed by expected utility theory. Specifically, prospect theory suggests that when individuals are assessing problems that involve a loss, some selections on conflict-amount problems may be opposite to expected value predictions (i.e., risk-seeking selections may occur), while selections on conflict-probability problems will be consistent with expected value predictions (i.e., risk-averse selections won't occur). In contrast, expected utility theory suggests that when individuals are assessing problems that involve a loss, some selections on conflict-probability problems may be opposite to expected value predictions (i.e., risk-averse selections may occur), while selections on conflict-amount problem will be consistent with expected value predictions (i.e., risk-seeking selections won't occur).

Because these questions involved non-equated alternatives, they differed in a fundamental way from the questions used in earlier studies (e.g. Chang,

Table 2a

Responses Aggregated by Question for Study 1 (Gains)

Certain Amount	Probability	x	Uncertain Amt	=	EV	% Choosing According to EV Predictions	Significant at $\alpha = .05$
1.00	0.125	x	5.00	=	0.63	60	*
1.00	0.375	x	5.00	=	1.88	83	*
1.00	0.875	x	5.00	=	4.38	95	*
1.00	0.125	x	10.00	=	1.25	56	*
1.00	0.375	x	10.00	=	3.75	90	*
1.00	0.875	x	10.00	=	8.75	96	*
1.00	0.125	x	25.00	=	3.13	75	*
1.00	0.375	x	25.00	=	9.38	90	*
1.00	0.875	x	25.00	=	21.88	95	*
1.00	0.125	x	50.00	=	6.25	80	*
1.00	0.375	x	50.00	=	18.75	93	*
1.00	0.875	x	50.00	=	43.75	93	*
2.50	0.125	x	5.00	=	0.63	84	*
2.50	0.375	x	5.00	=	1.88	46	
2.50	0.875	x	5.00	=	4.38	92	*
2.50	0.125	x	10.00	=	1.25	67	*
2.50	0.375	x	10.00	=	3.75	76	*
2.50	0.875	x	10.00	=	8.75	94	*
2.50	0.125	x	25.00	=	3.13	60	*
2.50	0.375	x	25.00	=	9.38	88	*
2.50	0.875	x	25.00	=	21.88	96	*
2.50	0.125	x	50.00	=	6.25	68	*
2.50	0.375	x	50.00	=	18.75	92	*
2.50	0.875	x	50.00	=	43.75	95	*
5.00	0.125	x	10.00	=	1.25	89	*
5.00	0.375	x	10.00	=	3.75	62	*
5.00	0.875	x	10.00	=	8.75	88	*
5.00	0.125	x	25.00	=	3.13	68	*
5.00	0.375	x	25.00	=	9.38	73	*
5.00	0.875	x	25.00	=	21.88	96	*
5.00	0.125	x	50.00	=	6.25	51	
5.00	0.375	x	50.00	=	18.75	85	*
5.00	0.875	x	50.00	=	43.75	94	*
10.00	0.125	x	25.00	=	3.13	90	*
10.00	0.375	x	25.00	=	9.38	67	*
10.00	0.875	x	25.00	=	21.88	92	*
10.00	0.125	x	50.00	=	6.25	83	*
10.00	0.375	x	50.00	=	18.75	57	*
10.00	0.875	x	50.00	=	43.75	93	*
25.00	0.125	x	50.00	=	6.25	89	*
25.00	0.375	x	50.00	=	18.75	79	*
25.00	0.875	x	50.00	=	43.75	88	*

Table 2b

Responses Aggregated by Question for Study 1 (Losses)

Certain Amount	Probability	x	Uncertain Amt	=	EV	% Choosing According to EV Predictions	Significant at α = .05
-1.00	0.125	x	-5.00	=	-0.63	81	*
-1.00	0.375	x	-5.00	=	-1.88	50	
-1.00	0.875	x	-5.00	=	-4.38	88	*
-1.00	0.125	x	-10.00	=	-1.25	33	* a
-1.00	0.375	x	-10.00	=	-3.75	68	*
-1.00	0.875	x	-10.00	=	-8.75	93	*
-1.00	0.125	x	-25.00	=	-3.13	52	
-1.00	0.375	x	-25.00	=	-9.38	81	*
-1.00	0.875	x	-25.00	=	-21.88	92	*
-1.00	0.125	x	-50.00	=	-6.25	63	*
-1.00	0.375	x	-50.00	=	-18.75	88	*
-1.00	0.875	x	-50.00	=	-43.75	90	*
-2.50	0.125	x	-5.00	=	-0.63	89	*
-2.50	0.375	x	-5.00	=	-1.88	85	*
-2.50	0.875	x	-5.00	=	-4.38	73	*
-2.50	0.125	x	-10.00	=	-1.25	84	*
-2.50	0.375	x	-10.00	=	-3.75	50	
-2.50	0.875	x	-10.00	=	-8.75	89	*
-2.50	0.125	x	-25.00	=	-3.13	36	* a
-2.50	0.375	x	-25.00	=	-9.38	74	*
-2.50	0.875	x	-25.00	=	-21.88	94	*
-2.50	0.125	x	-50.00	=	-6.25	47	
-2.50	0.375	x	-50.00	=	-18.75	84	*
-2.50	0.875	x	-50.00	=	-43.75	95	*
-5.00	0.125	x	-10.00	=	-1.25	90	*
-5.00	0.375	x	-10.00	=	-3.75	82	*
-5.00	0.875	x	-10.00	=	-8.75	76	*
-5.00	0.125	x	-25.00	=	-3.13	80	*
-5.00	0.375	x	-25.00	=	-9.38	51	
-5.00	0.875	x	-25.00	=	-21.88	91	*
-5.00	0.125	x	-50.00	=	-6.25	33	* a
-5.00	0.375	x	-50.00	=	-18.75	74	*
-5.00	0.875	x	-50.00	=	-43.75	93	*
-10.00	0.125	x	-25.00	=	-3.13	91	*
-10.00	0.375	x	-25.00	=	-9.38	81	*
-10.00	0.875	x	-25.00	=	-21.88	83	*
-10.00	0.125	x	-50.00	=	-6.25	86	*
-10.00	0.375	x	-50.00	=	-18.75	48	
-10.00	0.875	x	-50.00	=	-43.75	91	*
-25.00	0.125	x	-50.00	=	-6.25	91	*
-25.00	0.375	x	-50.00	=	-18.75	85	*
-25.00	0.875	x	-50.00	=	-43.75	73	*

[a] Significant difference in opposite direction to expected value predictions.

Nichols & Schultz, 1987; Fischoff, 1983; Hershey & Schoemaker, 1980). It was anticipated that as the differences in the expected value between the two alternatives increased, the proportion of individuals who selected the alternative with the greater expected value would also increase. A multinomial logit analysis modeling this prediction confirmed this was the case. As the difference in expected values between the alternatives increased, the proportion of subjects who selected the alternative with the higher expected return also increased , t (163) = 16.875, $p < .05$. This effect remained significant when problems with a difference in expected value greater than $5.00 were excluded from the analysis, t (79) = 9.05, $p < .05$.

To determine the types of individual decision patterns that produced the overall group pattern, a second analysis was carried out. In this analysis the pattern of selections for the subset of problems which had a difference of less than $5.00 in the expected values of the two alternatives was categorized for each subject. This subset of problems was selected because it included the three loss problems where a significant proportion of those tested made SOPs, and it also included the two gain problems and five of the six loss problems where there were no significant differences between the proportion of subjects who selected according to predictions based on expected value theory, and the proportion who selected opposite to predictions. There were 12 conflict-amount problems and 9 conflict-probability problems in this subset.

For this second analysis an individual was classified as a consistent/predicted responder for the conflict-amount problem set if he or she selected the alternative with the most to gain (or the least to lose) for at least 11 of the 12 problems. If an individual selected the alternative with the least to gain (or the most to lose) for at least 11 of the 12 conflict-amount problems he or she was classified as a consistent/opposite responder for that problem set. For the conflict-probability problem set, an individual was classified as a consistent/predicted responder if he or she selected the gain alternative which was most likely to occur (or the loss alternative which was least likely to occur) for at least 8 of the 9 problems. If an individual selected the gain alternative which was least likely to occur (or the loss alternative which was most likely to occur) for at least 8 of the 9 conflict-probability problems, he or she was classified as a consistent/opposite responder for that problem set. Finally, an individual was classified as a mixed responder for either the conflict-amount or conflict-probability problems sets if his or her selections were consistent with expected value predictions on at least two of the problems in the set, and opposite to expected value predictions on at least two of the other problems in the set.

Using this classification system there were nine decision patterns which could emerge: (a) consistent/predicted selections for both conflict-amount and conflict-probability questions; (b) consistent/predicted selections for conflict-amount questions and consistent/opposite selections for conflict-probability questions; (c) consistent/opposite selections for conflict-amount questions and consistent/predicted selections for conflict-probability questions; (d) mixed responses for both conflict-amount and conflict-probability questions; (e) consistent/predicted selections for conflict-amount questions and mixed responses for conflict-probability questions; (f) mixed responses for conflict-amount questions and consistent/predicted selections for conflict-probability problems; (g) consistent/opposite selections for both conflict-amount and conflict-probability questions; (h) consistent/opposite selections for conflict-amount questions and mixed responses for conflict-probability questions; and (i) mixed responses for conflict-amount questions and consistent/opposite selections for conflict-probability questions. Because it was possible for the decision pattern for gains to differ from the decision pattern for losses, there were a total of 81 possible decision patterns. However, the last three patterns (g, h, and i) did not occur for any of the subjects for either gain questions or loss questions. This left 36 possible decision patterns. The number of individuals whose decision patterns corresponded to each of these 36 possibilities is given in Table 3.

Because both conflict-amount and conflict-probability questions were used in this study, the decision patterns shown in Table 3 can be linked to specific decision strategies. Three possible decision strategies, and the decision patterns each of these strategies would produce, are:

1. Amount/Probability. This is a two-dimensional strategy where both the amount at stake and the probability of occurrence are considered in making the final decision. The individual will select the alternative which maximizes their gains, or minimizes their losses (cf. Expected Value Theory; Expected Utility Theory, Bernoulli, 1738; Subjective Expected Utility Theory, Edwards, 1954c; Prospect Theory, Kahneman & Tversky, 1979).

2. Pure amount. This is a one-dimensional strategy where the amount at stake in each of the alternatives determines the final decision. The individual will select the alternative which provides the highest return, or the smallest loss (cf. Minimax Heuristic, Thorngate, 1980).

3. Pure probability. This is a one-dimensional strategy where the probability of occurrence for each of the alternatives determines the final decision. The individual will select the alternative which provides the greatest chance of winning, or the smallest chance of losing (cf. Most Likely Heuristic, Thorngate, 1980).

The economic models of decision making all suggest a two-dimensional, multiplicative strategy underlies decision making in non-reoccurring, concurrent

Table 3

Tabulation of Decision Patterns From Study 1

Gain Problem Selections, Relative to Expected Value Predictions

Loss Problem Selections, Relative to Expected Value Predictions

Conflict-Amount / Conflict-Probability	Consistent/Predicted / Consistent/Predicted	Consistent/Predicted / Consistent/Opposite	Consistent/Opposite / Consistent/Predicted	Mixed / Mixed	Consistent/Predicted / Mixed	Mixed / Consistent/Predicted
Consistent/Predicted / Consistent/Predicted	4	0	0	1	6	9
Consistent/Predicted / Consistent/Opposite	0	4	1	2	0	1
Consistent/Opposite / Consistent/Predicted	0	5	0	4	6	2
Mixed / Mixed	5	1	2	33	24	15
Consistent/Predicted / Mixed	1	1	1	8	12	6
Mixed / Consistent/Predicted	14	5	0	70	74	92

Note. The first pattern listed for each row (column) is the selection pattern for conflict-amount problems, and the second pattern listed for each row (column) is the selection pattern for conflict-probability problems.

choice situations. However, expected value theory, expected utility theory, subjective expected utility theory, and prospect theory each suggest different initial subjective formulations of the decision problem on the part of decision makers. As a result, each model leads to some unique predictions regarding the decision patterns which should emerge on conflict-amount and conflict-probability problems for questions involving gains and losses. Specifically, the following predictions can be derived (refer to Table A-1): (a) for both gain and loss questions, individuals deciding according to the process implied by expected value theory will select the alternative with the highest expected value on both conflict-amount and conflict-probability problems, and as a result they will make consistent/predicted selections for all problem types; (b) individuals deciding according to the process implied by expected utility theory may make selections opposite to expected value predictions on conflict-amount gain problems, but they will be consistent/predicted responders on conflict-probability gain problems; for loss problems these individuals may make some selections opposite to expected value predictions on conflict-probability problems, but they will be consistent/predicted responders on conflict-amount problems; (c) when the probability of occurrence for each alternative exceeds approximately .12, individuals deciding according to the process implied by prospect theory may make selections opposite to expected value predictions on conflict-amount problems for both gain and loss questions, but they will be consistent/predicted responders on conflict-probability problems for both gain and loss questions; (d) finally, when the probability of occurrence for each alternative exceeds approximately .20, individuals deciding according to the process implied by subjective expected utility theory may show either decision pattern #2 (expected utility theory), or decision pattern #3 (prospect theory).

There may also be individuals who attempt to execute a two-dimensional strategy of the type suggested by expected value theory, but who lack the skills necessary to combine the problem dimensions in a reliable and consistent manner. As a result, even though these individuals use both problem dimensions in making a final decision, they may make some selections which do not maximize their gains (or minimize their their losses). Individuals in this category will tend to be mixed responders on both conflict-amount and conflict-probability problems, for both gain and loss questions.

In addition, some individuals may rely on decision strategies other than those suggested by the economic models of decision making. For example, neither of the one-dimensional strategies described above is suggested by economically-based theories of decision making; however, these one-dimensional strategies still represent discernible decision strategies and, even though these strategies may be inefficient from an economic analysis, they should not be ignored. Individuals relying on a one-dimensional strategy will also show distinctive response patterns.

Specifically, an individual using a pure amount strategy will select the larger amount to be won in a gain situation, and the smaller amount to be lost in a loss situation. This means that on conflict-amount problems they will be consistent/predicted responders, and on conflict-probability they will be consistent/opposite responders. This decision pattern could also be interpreted as a tendency to make risk-seeking selections for gains (selecting the alternative with the smaller probability of occurrence, even though it has the lower expected value), and risk-averse selections for losses (selecting the alternative with the higher probability of occurrence even though it represents a higher expected loss).

An individual using a pure probability strategy will select the higher probability of winning in a gain situation, and the lower probability of losing in a loss situation. This means that on conflict-probability problems they will be consistent/predicted responders, and on conflict-amount problems they will be consistent/opposite responders. This decision pattern may also be interpreted as being indicative of a tendency to make risk-averse selections for gains (selecting the higher probability alternative even though it has the lower expected value), and risk-seeking selections for losses (selecting the lower probability alternative even though it represents a higher expected loss). This is similar to the decision pattern which Kahneman and Tversky (1979) suggest will be the most prevalent in non-reoccurring, concurrent choice situations; however, they theorize that this type of decision pattern occurs, not because a pure probability strategy is being used, but because individuals discount the probabilities and the amounts which are given in decision problems, and then combine the discounted values using a two-dimensional, multiplicative strategy.

Referring to Table 3, several points of interest emerge. First, 5.9% of those tested made selections consistent with expected value predictions for gain problems, and 4.9% made selections consistent with expected value predictions for loss problems. In addition, 28.9% of those tested gave mixed responses on both types of problems for gain questions, and 19.6% gave mixed responses on both types of problems for loss questions. Predicted/consistent selections on both types of problems indicate the effective use of a two-dimensional strategy, and mixed responses on both types of problems indicate the less effective use of a two-dimensional strategy.

Second, expected utility theory, subjective expected utility theory and prospect theory all lead to the prediction that individuals will make consistent/predicted selections on conflict-probability gain problems, due to the subjective discounting these models incorporate into the valuation stage of the decision process. This means that consistent/opposite responders, or mixed responders on conflict-probability gain problems are making selections inconsistent with the predictions generated by all three of these decision making models. In this study 62.6% of the subjects were either consistent/opposite or mixed responders on conflict-probability gain questions.

For the loss problems the situation is somewhat more complex. Expected utility theory leads to the prediction that individuals will make consistent/predicted selections on conflict-amount problems, and prospect theory leads to the prediction that individuals will make consistent/predicted selections on conflict-probability problems. This means that consistent/opposite responders or mixed responders on conflict-amount loss problems are making selections inconsistent with expected utility theory, and consistent/opposite responders or mixed responders on conflict-probability loss problems are making selections inconsistent with prospect theory. In this study 86.1% of the subjects made loss selections that were inconsistent with predictions based on expected utility theory, and 28.7% made loss selections inconsistent with predictions based on prospect theory; 19.6% made loss selections inconsistent with both these theories.

Third, a small but significant percentage of those tested made selections which were consistent with the use of a one-dimensional strategy. For gain questions 3.9% of the subjects made selections consistent with the use of a pure amount strategy (always selecting the larger amount at stake, even on conflict-probability problems), and 1.0% made selections consistent with the use of a pure probability strategy (always selecting the alternative with the greater probability of occurrence, even on conflict-amount problems. For loss questions 2.0% of the subjects made selections consistent with the use of a pure amount strategy, and 4.2% made selections consistent with the use of a pure probability strategy.

Finally, in this study only 35.5% of those tested showed the same decision pattern for gain questions and for loss questions. This indicates that: (a) individuals may use different basic strategies to make gain and loss decisions; or (b) individuals may use the same basic strategy for both types of questions, but they may not be equally effective at executing the strategy on both types of questions. One interesting finding is the fact that 1.2% of the subjects who took part in this study made selections consistent with the use of a pure amount strategy on gain problems, while making selections consistent with the use of a pure probability strategy on loss problems. A strategy of this type will result in a situation where all decisions which are inconsistent with predictions based on expected value theory involve risk-seeking selections (selecting the alternative with the lower probability of occurrence when it has a smaller expected value). This result confirms an earlier result reported by Schneider and Lopes (1986). They found approximately 1% of the subjects they pre-screened made risk-seeking selections for gains and Schneider and Lopes suggested that the difference between the subjects who made risk-averse selections and those who made risk-seeking selections could be partially explained if the two groups focused on different dimensions of the problem when making a decision. The results from this study indicate that the dimension controlling the decision process may not only differ between individuals within a problem domain (gains or losses), but also that the dimension controlling the decision process may differ within an individual across the problem domains. Schneider and Lopes concluded: "[T]he evidence suggests that prospect theory will not be able to completely describe preferences under risk. This may indicate that the process leading to these preferences is different from that embodied in prospect theory"

(Schneider & Lopes, 1986, p. 546).

Conclusions

In this study there was strong evidence that economically based models of decision making that incorporate subjective discounting of probability of occurrence and/or amount at stake fail to adequately describe decision-making in non-reoccurring, concurrent choice situations. In this study the majority of the subjects (62.6%)made selections on gain questions that were inconsistent with predictions based on any of the economic models of decision making. For loss questions this proportion was reduced considerably, but still over one quarter of the subjects (28.7%)had decision patterns that indicated subjective discounting was not being consistently applied to the available alternatives.

Therefore, it appears that the process which underlies decision making in non-reoccurring, concurrent choice situations may differ from the process suggested by the revised economic models. But in this study, although the problems used were similar to those used in previous studies of decision making in non-reoccurring, concurrent choice situations (e.g., Budescu & Weiss, 1987; Hershey & Schoemaker, 1980; Kahneman & Tversky, 1979, 1984), there are at least two factors that might affect individuals decisions on problems of this type. First, individual utility functions may differ, and individuals who have different monetary utility functions may evaluate the same problems in very different ways (cf. von Neumann & Morgenstern, 1947). Second, there were no consequences for any of the decision problems, and as a result individuals may have been less concerned with making optimal decisions on each one of the 84 problems. Study 2 was undertaken to determine if similar decision patterns would emerge on a set of problems that had non-monetary stakes, and where actual gains and losses could be incurred.

Chapter Three: Study Two

In Study 1, a set of one- and two-dimensional decision strategies was proposed, and it was shown how use of these strategies could produce some of the decision patterns in Table 3, specifically: (a) individuals who successfully execute a two-dimensional strategy of the type suggested by expected value theory will be consistent/predicted responders on both conflict-amount and conflict-probability problems; (b) individuals who attempt to execute a two-dimensional strategy of the type suggested by expected value theory, but whose accuracy is less than 100% will tend to be mixed responders on both conflict-amount and conflict-probability problems; (c) individuals who decide solely on the basis of amount at stake will be consistent/predicted responders on conflict-amount problems and consistent/opposite responders on conflict-probability problems; (d) individuals who decide solely on the basis of probability of occurrence will be consistent/predicted responders on conflict-probability problems and consistent/opposite responders on conflict-amount problems.

In Study 1 it was also shown that individuals who were mixed responders on both conflict-amount and conflict-probability problems, for either gain or loss questions, were making selections inconsistent with economic models of decision making that incorporate subjective reformulations involving the discounting of the amount at stake, the probability of occurrence, or both. Finally, nearly two-thirds of the individuals tested in Study 1 had different decision patterns for questions involving gains and questions involving losses. This result suggests that individuals may use different decision strategies on gain questions and on loss questions, or that individuals may be less efficient at using the same decision strategy across the two types of problems.

Study 2 was designed to determine if similar decision patterns would be found in non-reoccurring, concurrent choice situations where: (a) differences in utility for the amount at stake were controlled, (b) decisions were not abstract, but could result in real gains and losses, and (c) the specified objective was to maximize the amount obtained within an experimental session.

Stimuli similar to those in Study 1 were used. However, earlier studies have raised the concern that individual utility functions may differ when monetary amounts are at stake, and differences in the marginal utility for monetary amounts may affect the decision outcome (see, for example, Bernoulli, 1738; Mosteller & Nogee, 1951) To reduce the impact of differences in utility for the amount at stake in this study, monetary amounts were replaced with tokens. In addition, to make the decisions less abstract, twelve of the questions each subject evaluated during the main part of the experiment were played out at the end of the experimental session. The selected items were played in the manner indicated during the main part of the experiment, and each subject increased or decreased the number of tokens they had according to the outcome of these twelve items. To ensure maximization within the session was the common objective, subjects were told at the start of the session that the tokens they accumulated would be exchanged for McDonald's™ gift certificates at the end of the study, and that the more tokens they obtained, the more gift certificates they would receive. The actual rate of exchange was not disclosed until the session was completed.

Method

Subjects. Thirty male and female undergraduate students enrolled in an introductory psychology class at the University of Alberta took part in the study. The students signed up for individual sessions, and they received course credit for their participation, in addition to any winnings received in the course of the experiment.

Stimuli. The decision problems used in this study were displayed sequentially on a Macintosh computer screen. There were four sections to each experimental session, and in each section 30 different decision problems were presented. Each problem was presented twice for a total of 240 decision problems (4 sections x 30 pairs x 2 presentations). In two of the sections both alternatives presented amounts to be won, and in the other two sections both alternatives presented amounts to be lost. The composition of the decision problems is given in Table 4.

In each decision problem there were two circles, one of which was completely shaded, and the other which was partially shaded; under each of the circles was a number of tokens. For the gain questions the tokens had a "+" sign on them, and for the loss questions the tokens had a "-" on them (see Figure 4 for examples of the decision problems used).

To reduce the likelihood of errors that might have resulted from subjects misinterpreting loss problems as gain problems, and vice versa, the problems were divided into four subsets. Two of the subsets contained only gain questions, and two contained only loss questions. In one subset from gains and one subset from losses the number of tokens under the risky alternative was held constant at 6 tokens and the probability of receiving or losing the 6 tokens varied. Probabilities used were: 1/12, 3/12, 5/12, 7/12, 9/12, and 11/12. This set of problems will be referred to as risk problems because for the risky alternative only the probability of occurrence changed from one question to the next. In the other subset from gains and losses the number of tokens under the risky alternative varied but the probability of winning or losing those tokens was held constant at 6/12. The number of tokens used were: 1, 3, 5, 7, 9, and 11. This set of problems will be referred to as worth problems because only the amount at stake changed from one question to the next. Equivalent worth and

Table 4

Composition of the Decision Problems Used in Study 2

Tokens with Certain Alternative	Risk Factor[a] for Risky Alternative	Problem Type[b] in Risk Problem Set	Problem Type in Worth Problem Set
1	1	C/P	P
1	3	C/A	C/A
1	5	C/A	C/A
1	7	C/A	C/A
1	9	C/A	C/A
1	11	C/A	C/A
2	1	C/P	N/C
2	3	C/P	C/P
2	5	C/A	C/A
2	7	C/A	C/A
2	9	C/A	C/A
2	11	C/A	C/A
3	1	C/P	N/C
3	3	C/P	P
3	5	C/P	C/P
3	7	C/A	C/A
3	9	C/A	C/A
3	11	C/A	C/A
4	1	C/P	N/C
4	3	C/P	N/C
4	5	C/P	C/P
4	7	C/P	C/P
4	9	C/A	C/A
4	11	C/A	C/A
5	1	C/P	N/C
5	3	C/P	N/C
5	5	C/P	P
5	7	C/P	C/P
5	9	C/P	C/P
5	11	C/A	C/A

[a] Risk factor refers to the risky alternative. It represents the number of shaded twelfths in the risk problem set, and the number of tokens in the worth problem set. Multiplying this factor by 0.5 gives the expected value of the risky alternative.

[b] Problem types: C/A = conflict-amount; C/P = conflict-probability; N/C = no-conflict; P = probability

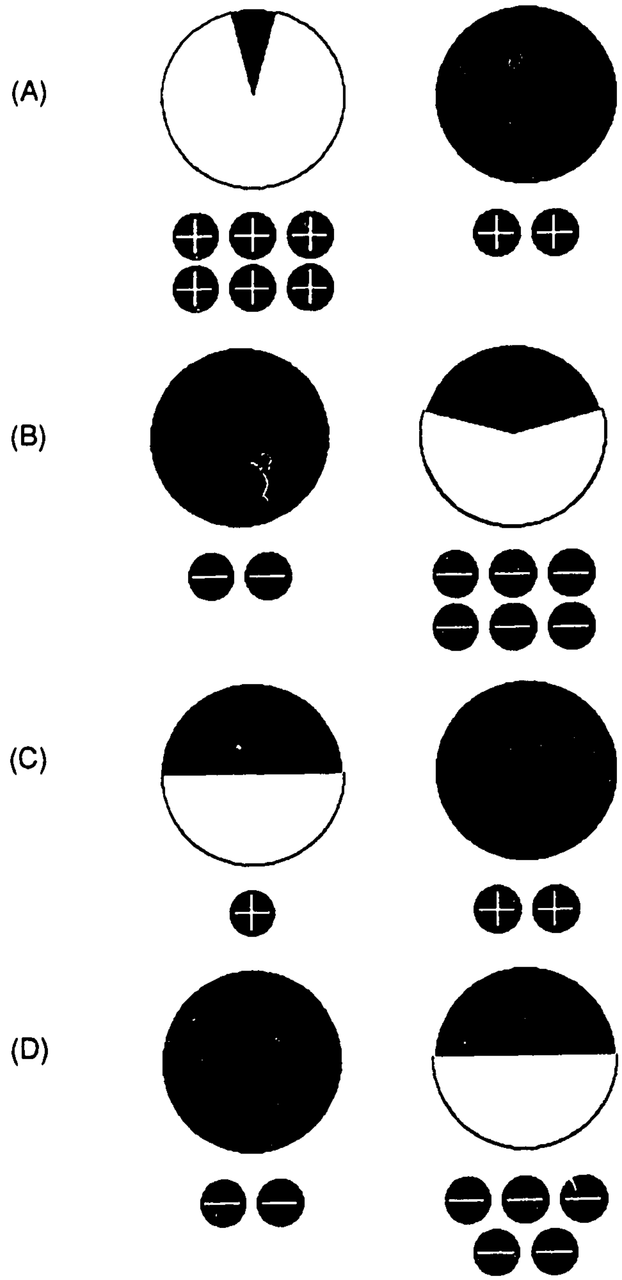


Figure 4. Examples of the decision problems from Study 2. (Reproduced at 60% of original size).

All examples have a difference of 1/2 token between the expected values of the alternatives. The examples represent the following problem types:

(A) a conflict-probability question from the risk-gain problem set
(B) a conflict-amount question from the risk-loss problem set
(C) a no-conflict question from the worth-gain problem set
(D) a conflict-amount question from the worth-loss problem set

risk problem sets were developed to allow testing of the functional form of the value and risk functions proposed by Kahneman and Tversky (1979).

The problems within each subset were blocked into sets of 6 in which the certain alternative was the same for all six items; the items within each block were placed in a randomized order. Each of the subsets contained a total of 10 blocks of 6 problems each. A random sequence of 10 numbers was generated and used to order these blocks of problems. Each subject saw the same ordering, and each subject completed the four subsets in the following sequence: gain questions, loss questions, loss questions, gain questions. This sequencing was selected to minimize the likelihood of subjects terminating the session prior to the completion of both sets of loss questions. For half the subjects the risk problems were presented first, followed by the worth problems; for the remaining subjects the worth problems were presented first, followed by the risk problems.

For the risk problem set each subject answered a total of 60 conflict-amount problems and 60 conflict-probability problems; for the worth problem set there were a total of 12 probability problems, 24 no-conflict problems, 60 conflict-amount problems, and 24 conflict-probability problems. To illustrate why these differences between the two problem sets arose refer to Table 4, line 7. When this item is presented as a gain (loss) risk problem, the individual must decide between: (a) receiving (losing) two tokens with certainty, and (b) receiving (losing) 6 tokens with a probability of 1/12. This is a conflict-probability problem; the more probable (less probable) alternative has the higher expected value. In contrast, when the same item was presented as a gain (loss) worth problem the individual must decide between: (a) receiving (losing) two tokens with certainty, and (b) receiving (losing) 1 token with a probability of 6/12. This is a no-conflict problem; the more probable (less probable) alternative also offers more tokens (less tokens), and therefore dominates the less probable (more probable) alternative.

Procedure. Each subject was given a copy of the instruction sheet shown in Figure 5, and the instructions were read aloud by the experimenter. The instructions were similar to those from Study 1 with the exception that 12 of the items would be played out at the end of the session. After the instructions had been read there was a brief warm-up to familiarize the subject with the computer. During this warm-up 12 stimuli, similar to those used in the main part of the study, were presented and the subject indicated which alternative was preferred by pressing one of two keys marked R (for the alternative on the right-hand side of the screen) and L (for the alternative on the left-hand side of the screen). Each pair of alternatives remained on the screen until a selection was made.

Following the warm-up each subject was given four tokens to start with. The main part of the experiment was run in four consecutive blocks. Before each block the experimenter indicated: (a) whether the following block of questions contained gain or loss questions, and (b) which element would remain unchanged from question to question. The subjects were under no time constraint; no subject took longer than 40 minutes to complete the entire session.

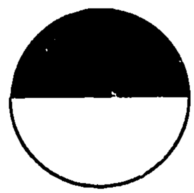
After all the questions had been answered, each subject played out 12 of the questions. The same questions were played out for all the subjects, but the subjects did not know in advance which questions would be selected. The tokens which the subjects won in this section were traded for McDonald's™ gift certificates at the end of the session. The rate of exchange was approximately 8 tokens for a $1 gift certificate, but this rate of exchange was not revealed to the subjects until the very end of the session. The median amount won was $2; the

For this study, in addition to the research credit you receive for your participation, you will have the opportunity to earn tokens which will be redeemed for McDonald's™ coupons at the end of the session. At all times your continued participation is strictly voluntary. If at any point you decide you do not wish to continue with the session, you will still receive course credit for your participation; you will also be able to cash in any tokens you have earned to that point.

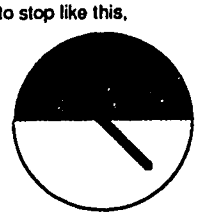
There will be a short warm-up so you can become familiar with the task. After you complete this warm-up you will receive four tokens to start with. We will then ask you to complete the main task in which you will be making selections between alternatives which involve the gain or loss of additional tokens. The entire session should take a total of approximately one hour to complete.

Each of the items you will be evaluating consists of a pair of partially shaded circles. Each of the circles has a number of tokens below it, describing either a win (indicated by a plus sign) or a loss (indicated by a minus sign).

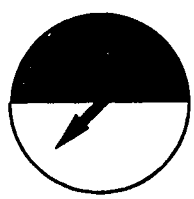
Imagine that each of these circles is a disc with a spinner attached to the center. For each item you are to choose one of the two circles. When you make your choice, imagine the spinner attached to the circle you selected is to be spun once. If the spinner stops pointing to the shaded portion of the circle, you would win or lose the amount indicated under that circle. For example, suppose you chose the circle below:



If the imaginary spinner were to stop like this,



you would win (+) or lose (-) the number of tokens indicated below the circle. On the other hand, if it stopped like this,



you would win or lose nothing.

In each case there will be two circles to choose from. You are to choose the circle you would most like to play from each of the pairs, and then indicate your choice by pressing the key corresponding to the position of the circle you select. You can take as long as you require to respond, each pair of items will remain on the computer screen until you indicate which of the two alternatives you prefer.

After you have evaluated all the items, twelve of the items will be chosen. These items will be played out at the end of the session, in the manner you indicate in your selections. Six of these items will involve gains and six will involve losses. You will increase or decrease the number of tokens you have by the amount indicated when these twelve items are played out. The total number of coupons you receive will depend on the number of tokens you have to trade-in at the end of the session.

Figure 5. Instruction sheet from Study 2 (Reproduced at 60% of original size).

lowest amount was $1 and the highest amount was $4.

Results and Discussion

A preliminary analysis to determine the functional form of individual value and risk functions indicated that these functions were highly irregular. Prospect theory would lead to the prediction that preferences should show some degree of consistency (Kahneman & Tversky, 1979). For example, if an individual chose to receive one token for certain, over an opportunity to receive 3 tokens with a probability of 0.5, he or she should also choose to receive 1 token for certain if the number of tokens associated with the risky alternative decreases. However, in this study 17 of the 29 subjects showed deviations from this consistent ordering within the worth-gain set, and 27 of the 29 subjects showed inconsistencies within the worth-loss set. In the same way, if an individual chose to receive one token for certain, over an opportunity to receive 3 tokens with a probability of 0.5, he or she should also choose to receive 1 token for certain if the probability of receiving the risky tokens is decreased. However, within the risk-gain set 19 of the 29 individuals showed inconsistency, and within the risk-loss set 24 of the 29 individuals made inconsistent selections. This result indicates that the individual functions were either nonmonotonic functions of probability level or token quantity, or that the functions were quite variable at the individual level. Consequently, to delineate these functional forms fully and accurately a more sensitive procedure, such as a titration procedure, would be required. For the present data, it seemed more fruitful to pursue a different type of analysis.

Therefore, the responses were grouped by problem type and the overall percentage of selections opposite to expected value predictions (SOPs) was calculated for each problem type. On average subjects made SOPs on 36.0% of the conflict-amount problems, 12.9% of the conflict-probability problems, 4.2% of the probability problems, and 5.0% of the no-conflict problems. This analysis uncovered one subject who selected the dominated alternative on 11 of the 12 probability problems and 22 of the 24 no-conflict problems. The data from this subject were removed from the main analysis, and will be discussed separately.

With this subject's data removed, the average number of SOPs for the remaining 29 subjects was as follows: 34.4% of the conflict-amount problems, 11.1% of the conflict-probability problems, 1.7% of the probability problems, and 2.0% of the no-conflict problems. The difference between the percentage of SOPs for conflict-amount and for conflict-probability problems is significant (z = 3.82, $p < .05$).

The discovery of one subject who selected the dominated alternative on 91.7% of the dominated problems highlights the importance of presenting individuals with a variety of problem types. If these dominated problems had not been included and the questionnaire had consisted of only a single type of conflict problem, this subject's responses could have been categorized in two extremely different ways. First, on conflict-probability problems this subject's selections were consistent with risk-seeking for gains and risk-aversion for losses. For this problem subset, in each case the alternative with the lower probability of occurrence and the larger amount at stake was selected for gains and rejected for losses. In other words, this subject made consistent/opposite selections on both gain and loss conflict-probability questions. Second, on conflict-amount problems this subject's selections were consistent with risk-averse selections for gains and risk-neutral selections for losses. For this problem subset all the gain problems and 98% of the loss problems were solved by selecting the alternative with the smaller amount at stake. In other words, this subject made consistent/opposite selections on conflict-amount gain questions and consistent/predicted selections on conflict-amount loss questions.

However, because dominated problems were included in the problem set, and because selections were also opposite to predictions derived from expected value theory for the majority of these problems, it was evident that this subject's responses were anomalous. Several post-hoc explanations can be offered to explain the observed response pattern: (a) the instructions may have led the subject to reverse left and right in responding; (b) the subject may have misunderstood the rules for the task, and responded on the basis that nothing would occur if the spinners stopped on black, or (c) the subject may have set out to answer each question by selecting opposite to expected value predictions. Regardless of the reasons for the resulting decision pattern, if the study had not included dominated problems, data from this subject would have been erroneously included in the main analysis.

The decision patterns from the remaining subjects were categorized using a criterion similar to the one set out Study 1: a subject was classified as a consistent/predicted responder for a particular problem type if he or she selected in accordance with expected value predictions for all, or for all but one of the problems; a subject was classified as a consistent/opposite responder for a particular problem type if he or she selected opposite to expected value predictions for all, or for all but one of the problems; an individual was classified as a mixed responder for a particular problem type if he or she selected in accordance with expected value predictions on at least two of the questions and opposite to expected value predictions on at least two of the questions.

When subjects' decision patterns were classified in this way, only one subject made consistent/predicted selections on conflict-probability problems for both gain and loss questions. This subject made consistent/opposite selections on conflict-amount loss problems; however, for conflict-amount gain questions this same subject was a mixed responder. Eleven subjects made consistent/predicted selections on conflict-probability problems when evaluating gain problems, while giving mixed responses on conflict-amount gain problems; these eleven subjects were all classified as mixed responders for both conflict-probability and conflict-amount problems which involved a loss. One subject had the opposite pattern and made consistent/predicted selections on conflict-probability problems when evaluating loss problems, while giving mixed responses on conflict-amount problems; this subject was a mixed responder for both conflict-probability and conflict-amount problems which involved a gain. The remaining 16 subjects gave mixed responses on both types of conflict problems for gain questions and for loss questions.

These results are similar to those obtained in Study 1; the majority of individuals made SOPs on both conflict-amount and conflict-probability problems. Errors on both types of problems are consistent with the use of a two-dimensional, multiplicative decision strategy which is executed with less than 100% accuracy. In addition, errors on both types of problems are inconsistent with economic strategies that involve subjective discounting of the problem dimensions before the decision is made. Unlike Study 1, there was no evidence of selections consistent with the use of a pure one-dimensional strategy across both problem domains in any of the subjects. This may be attributable, in part, to the fact that the problems were no longer abstract, but could result in real gains and losses. As a result, individuals who might rely on simpler, one-dimensional strategies when problems have no real consequences, may execute more complex, two-dimensional strategies when non-abstract decision problems are being evaluated.

To determine if individual decision patterns for those subjects who were mixed responders on both conflict-amount and conflict-probability problems followed the group pattern of significantly more SOPs on conflict-amount problems than on conflict-probability problems, individual z-statistics were calculated for each problem subset. These individual z-statistics were combined using the Stouffer Combined Test (Wolf, 1986, p. 20). In three of the conditions: risk-gains, worth-gains, and risk-losses, when the proportion of SOPs on conflict-amount problems was compared to the proportion of SOPs on conflict-probability problems at the individual level, SOPs on conflict-amount problems were more likely. For the loss condition in the worth problem set this effect disappeared, and the proportion of SOPs on both types of problems did not differ significantly. For the gain subset of the risk problems 28 of the 29 subjects made more SOPs on conflict-amount problems than on conflict-probability problems; the difference between the proportion of SOPs on the two problem types was significant, $z = 16.06$, $p < .05$. For the loss subset of the risk problems 22 of the 29 subjects made more SOPs on conflict-amount than on conflict-problems, but the difference between the proportion of SOPs on the two problem types was still significant, $z = 8.85$, $p < .05$. For the gain subset of the worth problems 26 of the 29 subjects made more SOPs on conflict-amount problems than on conflict-probability problems, and the difference between the proportion of SOPs on the two problem types was significant, $z = 11.29$, $p < .05$. For the loss subset of the worth problems only 14 of the 29 subjects made more SOPs on conflict-amount problems than on conflict-probability problems. For this problem set the difference between the proportion of SOPs on the two problem types was not significant, $z = 0.08$, $p > .05$.

SOPs on conflict-amount problems are consistent with the pattern of selections commonly found in decision-making studies: selecting the more probable alternative in gain situations, coupled with avoiding the more probable alternative in loss situations. The finding of a higher proportion of SOPs on conflict-amount problems suggests that consideration of the probability of occurrence may tend to override consideration of the amount at stake in two-dimensional decision problems. If this is the case, it would be expected that in a non-reoccurring, concurrent choice situation individuals would select the alternative which offers the higher probability of winning, or the lower probability of losing, even on conflict-amount problems.

However, in the worth-loss problem set fewer selections appeared to be made on the basis of probability of occurrence. The non-significant finding for the loss subset of the worth problems, relative to the loss subset of the risk problems, may have resulted: (a) because the overall number of SOPs was reduced, and as a result conflict-amount SOPs were less likely to occur; or (b) because the number of SOPs on conflict-probability problems increased. Testing indicated both these factors contributed to the change. On worth-loss questions, where the probabilities for both alternatives were held constant and only the amounts changed from one question to the next, SOPs on conflict-amount problems decreased and SOPs on conflict-probability problems increased, relative to the risk-loss questions. It may be that when the probability of occurrence for each of the alternatives is constant from one problem to the next (at least for loss questions) individuals shift their attention from the probability of losing to the amount that could be lost. As a result they would tend to make fewer SOPs on conflict-amount problems, and more SOPs on conflict-probability problems, by selecting the alternative which has the smaller amount at stake. This type of selection on loss problems did not appear as a common strategy in Study 1. One reason an amount focus may have emerged for loss problems in the worth problem set of this study is that subjects were aware that some of the problems would be played out at the end of the session, and as a result they may have been less willing to gamble on incurring the larger loss associated with the risky alternative.

Further evidence of a difference in the decision-making strategies for gain questions and loss questions was evident when the total number of SOPs on loss questions was compared to the total number of SOPs on gain questions. There were significantly fewer SOPs on loss questions ($z = 5.61$, $p < .05$). Overall subjects made 6.3% more SOPs on gain questions than on loss questions.

Finally, a one-way, repeated-measures ANOVA was done to determine whether there were significant differences in the decision times for the various problem types (average response times are given in Appendix B). A decision-making model which allows for strategies of differing complexity would lead to the prediction that average decision times on two-alternative problems may differ. Specifically, response times on problems where the final selection is opposite to predictions derived from expected value theory may be faster than response times on problems where the final selection is consistent with predictions derived from expected value theory if SOPs result from the use of strategies that are simpler than those suggested by economic models of decision making, _and_ if these simpler strategies take less time to execute.

Overall, the average decision time for each problem, across all subjects and across all 240 questions, was 2.92 seconds; however, there were significant differences in decision times between the various problem subsets, $F(3, 87) = 17.44$, $p < .05$. To isolate these differences, two Scheffé contrasts were conducted. The average decision time was longer for risk problems (3.10 seconds) than for worth problems (2.74 seconds), $F(3,87) = 18.37$, $p < .05$. The average decision time was also longer for loss problems (3.16 seconds) than for gain problems (2.68 seconds), $F(3,87) = 33.14$, $p < .05$.

It may be that risk problems had longer decision times than worth problems because the risk problems were somewhat more complex. In the risk problem set the probability of the risky alternative, and the number of tokens associated with the certain alternative, varied from one problem to the next. Consequently, a cross-dimensional comparison was required which may have resulted in longer decision times. In the worth problem set the probabilities for both alternatives remained the same for all the problems, and only the number of tokens was varied. Solving worth problems can be accomplished without a cross-dimensional comparison, and this may result in faster solution times than for risk problems.

The lower overall rates of SOPs on loss problems may have resulted from the longer decision times for these problems, relative to the gain problems. Subjects may have spent more time considering their decision when a loss was possible. In the gain questions, it was not possible to lose any tokens, and this may have led to faster decision times, and higher rates of SOPs.

Conclusions

The subjects in this study were able to evaluate non-dominated decision problems quickly; the average decision time across all subjects and questions was just under three seconds. They were able to make decisions involving complex probabilities without the aid of a calculator; the probabilities used were 1/12, 3/12, 5/12, 7/12, 9/12 and 11/12. They were able to make these decisions using only visual representations of the probabilities; explicit numeric probabilities were not provided. They also showed a high degree of accuracy; when the two alternatives in a problem differed in expected value by only 1/2 token, selections on 79.8% of the conflict-amount problems and 95.3% of the conflict-probability problems were consistent with predictions based on expected value theory. This level of accuracy indicates that expected value theory may provide an adequate first approximation of non-reoccurring, concurrent choice behavior (cf. Payne, 1973).

In Study 1, at least 34.7% of those tested made selections consistent with the use of a two-dimensional, multiplicative decision strategy for gain questions, and at least 24.4% of those tested made selections consistent with the use of a two-dimensional, multiplicative decision strategy for loss problems; 4.9% had decision patterns consistent with the use of a one-dimensional strategy on gain questions, and 6.1% had decision patterns consistent with the use of a one-dimensional strategy on loss questions; the remainder could not be accurately categorized because only two types of problems were used (conflict-amount and conflict-probability). In the current study, non-abstract problems were provided, and the two-dimensional multiplicative decision strategy described in Chapter 2 appears to provide a better description of the observed decision patterns than the pure one-dimensional strategies. The majority of those tested (58.6%) made selections consistent with the use of a two-dimensional, multiplicative strategy for gain questions, and all but two subjects (93.1%) made selections consistent with the use of a two-dimensional, multiplicative strategy for loss questions. Only one subject had a decision pattern consistent with the use of a one-dimensional strategy on gain questions, and none of the subjects showed this type of decision pattern for loss questions. The fact that the majority of those tested made SOPs on both conflict-amount and conflict-probability problems indicates: (a) that both dimensions of the problem are considered in reaching a decision; and, (b) that the subjective discounting proposed in expected utility theory, subjective expected utility theory, and prospect theory does not accurately describe the decision process in non-reoccurring, concurrent choice situations. It appears that selections opposite to expected value predictions may arise because the two problem dimensions are not given equal importance when a decision is being made; probability of occurrence seems to dominate the amount at stake to some degree, as evidenced by the fact that more SOPs occur on conflict-amount problems than on conflict-probability problems. These findings are consistent with those of Hershey and Schoemaker (1980) who reported: "For subjects who said they focused on one dimension only, the probability factor (p) appears most important (p. 415)."

Based on the results from this study, and those from Study 1, a rule-based model of decision-making in non-reoccurring, concurrent choice situations is developed and evaluated in the next chapter. This model incorporates both the one-dimensional and two-dimensional strategies characterizing the performance revealed in Studies 1 and 2.

Chapter Four: Study Three

The structure of two-dimensional, non-reoccurring, concurrent choice problems parallels the structure of the classic balance scale problem which Piaget presented to children (see, for example, Inhelder & Piaget, 1958). Both problems involve two relevant dimensions which are important to successful problem solution: in the balance scale problem, the child must attend to the weight on either side of the fulcrum, and the distance of the weight from the fulcrum; in a non-reoccurring concurrent choice problem the individual must attend to the probability of occurrence for each alternative, and the amount at stake in each of the alternatives. Siegler (1976) developed a sequence of increasingly complex rules which he suggested reflected a child's acquisition of a more complete understanding of the balance scale problem.

It is possible to develop a similar model of increasingly complex rules which would reflect an increase in the understanding of non-reoccurring, concurrent choice problems. A model of this type is presented in Figure 6 (cf. Siegler, 1981, p. 6). In this model, an individual using Rule 1 would consider only one of the relevant problem dimensions (x) in reaching a decision. When the alternatives are unequal on the dimension being considered ($x_i \neq x_j$), the individual will select the alternative where the value of x is greater in a gain situation, and the alternative where the value of x is smaller in a loss situation. When the alternatives are equated on dimension x ($x_i = x_j$) the individual will consider the alternatives to be equivalent, and as a result the model predicts that the individual will make a selection based on some dimension other than probability of occurrence or amount at stake.

For an individual using Rule 2, a difference between the alternatives on dimension x ($x_i \neq x_j$) will still control the decision process, however when the alternatives are equated on dimension x ($x_i = x_j$), dimension y is taken into

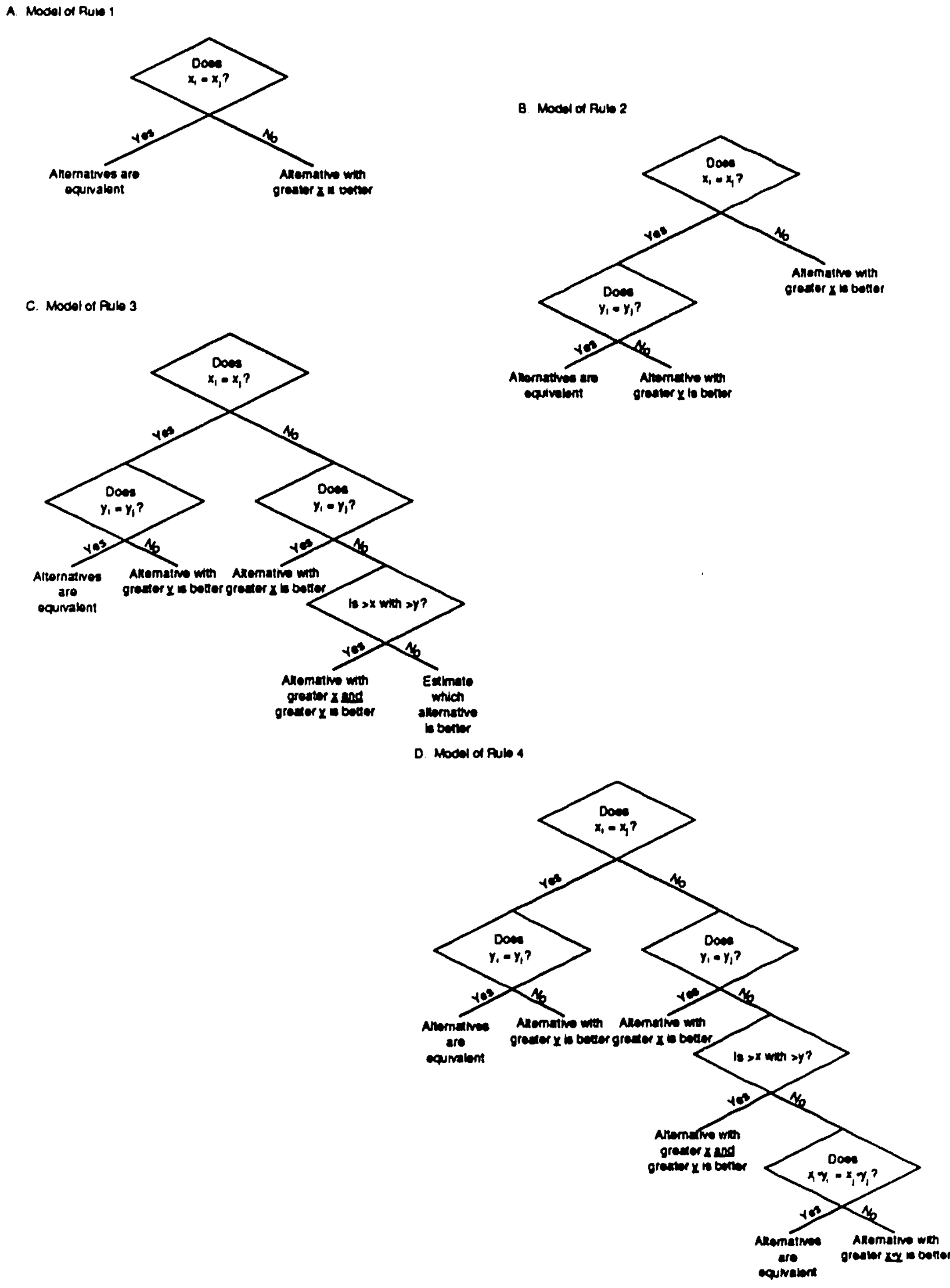


Figure 6. Rule-based model for decisions in non-reoccurring, concurrent choice situations. The decisions noted represent selections in gain situations; in loss situations the alternative with the smaller value of the comparison dimension would be selected.

consideration. When the alternatives are also equated on dimension $\underline{y}$ ($y_i = y_j$) the individual will know the alternatives are equivalent, and if a decision is required, the model predicts that the individual will make a selection based on some dimension other than probability of occurrence or amount at stake. When the alternatives are not equal on dimension $\underline{y}$ ($y_i \neq y_j$) the individual will select the alternative where the value of $\underline{y}$ is greater in a gain situation, and the alternative where the value of $\underline{y}$ is smaller in a loss situation.

When an individual progresses to Rule 3, both dimensions are considered in all instances. When the alternatives are equal on both dimensions the model predicts that the individual will make a selection based on some dimension other than probability of occurrence or amount at stake; when the alternatives are equal on only one dimension, the second dimension will determine the decision. When both dimensions are unequal, but one of the alternatives has both the greater probability of occurrence and the greater amount at stake, that alternative will be selected for gains, and avoided for losses. When both dimensions are unequal, and the alternative with the greater probability of occurrence has the smaller amount at stake, an individual using Rule 3 does not have a consistent, reliable method for combining the dimensions to arrive at a solution; however, he or she will attempt to combine the two dimensions, and estimate which alternative offers the better outcome. In some cases the alternative with the higher probability of occurrence will be selected for gains and avoided for losses; in other cases the alternative with the larger amount at stake will be selected for gains and avoided for losses.

Finally, Rule 4 represents a complete understanding of the decision task. When the two dimensions are in conflict, an individual using Rule 4 will compute the expected gain (or the expected loss) for each of the alternatives, and select the alternative which offers the greater expected value.

To determine if this represents a reasonable model of decision-making strategies, Siegler's (1976) rule-assessment methodology can be utilized. First, decision problems can be separated into the seven types described in Chapter 1 (shown in Figure 1). Individuals who utilize decision-making strategies corresponding to the different rules in Figure 6 would show different response patterns, relative to predictions based on expected value theory, across these seven problem types (Figure 7).

Individuals who decide only on the basis of the probability of occurrence (Rule 1P) will be consistent/predicted responders on probability problems, conflict-probability problems, and no-conflict problems. In addition, these individuals will be consistent/opposite responders on conflict-amount problems. On conflict-equivalence problems individuals using Rule 1P will select the alternative with the greater probability of occurrence in gain situations, and the alternative with the smaller probability of occurrence in loss situations. Finally, individuals using Rule 1P will view amount problems as equivalent to equality problems and in both these problem types, if required to select one of the alternatives, the model predicts that they will base their selection on some dimension other than probability of occurrence or amount at stake; this means that on amount problems these individuals will be mixed responders. Individuals who decide using Rule 2P will make similar selections on all but the amount problems; for these problems they will be consistent/predicted responders.

Individuals who decide only on the basis of the amount at stake (Rule 1A) will be consistent/predicted responders on amount problems, conflict-amount problems, and no-conflict problems. In addition, these individuals will be consistent/opposite responders on conflict-probability problems. On conflict-equivalence problems individuals using Rule 1A will select the

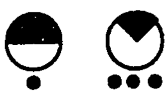
Problem Type	Rule 1P	2P	1A	2A	3	4
Equality [a] 	model makes no predictions	model makes no predictions	model makes no predictions	model makes no predictions	model makes no predictions	model makes no predictions
Amount 	mixed responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder
Probability 	consistent/ predicted responder	consistent/ predicted responder	mixed responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder
No Conflict 	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder	consistent/ predicted responder
Conflict-Amount 	consistent/ opposite responder	consistent/ opposite responder	consistent/ predicted responder	consistent/ predicted responder	mixed responder	consistent/ predicted responder
Conflict-Probability 	consistent/ predicted responder	consistent/ predicted responder	consistent/ opposite responder	consistent/ opposite responder	mixed responder	consistent/ predicted responder
Conflict-Equivalence [b] 	consistent/ predicted responder	consistent/ predicted responder	consistent/ opposite responder	consistent/ opposite responder	mixed responder	mixed responder

Figure 7. Predicted response patterns for each decision rule. Consistent/predicted responses indicate that selections correspond to predictions based on expected value theory; consistent/opposite responses indicate that selections are opposite to predictions based on expected value theory; mixed responses indicate that some selections correspond to, and some selections are opposite to, predictions based on expected value theory.

[a] There is no prediction for the choice pattern on equality problems, based on expected value theory

[b] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the response patterns in this row are based on prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

alternative with the greater amount at stake in gain situations, and the alternative with the smaller amount at stake in loss situations. Finally, individuals using Rule 1A will view probability problems as equivalent to equality problems and in both these problem types, if required to select one of the alternatives, the model predicts that they will base their selection on some dimension other than probability of occurrence or amount at stake; this means that on probability problems these individuals will be mixed responders. Individuals who decide using Rule 2A will make similar selections on all but the probability problems; for these problems they will be consistent/predicted responders.

Individuals who consider both dimensions in all cases, but who lack the capacity to combine the dimensions in a consistent manner (Rule 3) will be consistent/predicted responders on all dominated problems (amount, probability problems, and no-conflict), and the model predicts that on equality problems, if they are required to select one of the two alternatives, they will base their selection on some dimension other than probability of occurrence or amount at stake. On conflict problems, because these individuals lack the ability to combine the two dimensions in a consistent manner, they will be mixed responders.

Finally, those individuals who use Rule 4 will be able to respond correctly on all problem types. For equality problems the model predicts that, if they are required to select one of the two alternatives, they will base their selection on some dimension other than probability of occurrence or amount at stake. For conflict-equivalence problems these individuals also understand that the alternatives offer the same expected outcome. Because these individuals should be indifferent between the alternatives offered in conflict-equivalence problems, the model makes no predictions regarding how selections will be made, if a selection is required. For the remaining problem types, they will solve dominated problems (amount, probability, and no-conflict) on the basis of the determining dimension, and non-dominated problems (conflict-amount and conflict-probability) on the basis of expected value calculations.

These rules correspond roughly to the strategies outlined in Chapter 2. Individuals using Rules 1 and 2 would be relying on a one-dimensional strategy to solve decision problems; individuals using Rules 3 and 4 would be making use of a two-dimensional decision strategy. The difference between individuals who use Rule 3 and those who use Rule 4 could be considered primarily a quantitative one. Individuals in both groups utilize a two-dimensional strategy to analyze decision problems; they only differ in their ability to execute the two-dimensional strategy successfully. In contrast, the difference between individuals who use Rule 2 and those who use Rule 4 is primarily a qualitative one. Individuals in these two groups differ in the basic strategy they utilize to analyze decision problems, but not in their ability to execute the strategy they are using successfully.

To test these predictions a third study was conducted. In this study the stimuli were selected to include five gain problems and five loss problems from each of the non-equality problem types shown in Figure 1. The inclusion of all problem types was necessary to allow for differentiation between those decision patterns corresponding to Rule 1 and those corresponding to Rule 2. This would not possible if some types of dominated problems are excluded, because Rules 1 and 2 will generate similar decision patterns on five of the six non-equality problem sets.

Method

Subjects. Twenty-two undergraduate students enrolled in an introductory psychology class at the University of Alberta took part in the study. The average

age of the students was 19 years 8 months, with a standard deviation of 1 year 6 months (the median age was 19 years 2 months). The students signed up for individual sessions. In addition to any winnings received in the course of the experiment, the students received course credit for their participation.

Stimuli. The decision problems used in this study were displayed sequentially on a Macintosh computer screen. Sixty different decision problems were presented. For half the questions both alternatives presented amounts to be won, and for the other half both alternatives presented amounts to be lost. The composition of the decision problems is given in Table 5. Each problem was presented four times for a total of 240 questions (60 pairs x 4 presentations).

Each decision problem consisted of two circles; under each of the circles was a number of tokens. For the gain questions the tokens were black and had a white "+" sign on them; for the loss questions the tokens were white and had a black "-" sign on them (see Figure 8 for examples of the decision problems).

The problems were blocked into sets of 60, and the items within each block were presented to each subject in a different randomized order. Successive items were separated by a white screen which contained the instruction: "Please hit the "RETURN" key to see the next problem."

Procedure. Each subject was given a copy of the instruction sheet shown in Figure 9, and the instructions were read, out loud, by the experimenter. The instructions were the same as those in Study 2, and 12 of the items were played out at the end of the session. After the instructions had been read there was a brief warm-up to familiarize the subject with the computer. During this warm-up 12 stimuli similar to those used in the main part of the study were presented, and the subject indicated which alternative was preferred by pressing one of two keys marked R (for the alternative on the right-hand side of the screen) and

Table 5

Composition of the Decision Problems Used in Study 3

Number of Tokens for Alternative 1	Probability of Occurrence for Alternative 1	Number of Tokens for Alternative 2	Probability of Occurrence for Alternative 2	Problem[a] Type
1	1.00	2	1.00	A
1	1.00	3	1.00	A
1	0.75	2	0.75	A
2	1.00	3	1.00	A
2	0.50	3	0.50	A
2	1.00	2	0.50	P
2	0.75	2	0.50	P
3	0.50	3	0.25	P
4	0.75	4	0.50	P
4	0.75	4	0.25	P
2	1.00	1	0.75	N/C
2	0.75	1	0.50	N/C
2	0.50	1	0.25	N/C
3	0.75	2	0.50	N/C
3	0.50	2	0.25	N/C
1	1.00	2	0.75	C/A
1	1.00	4	0.75	C/A
1	1.00	4	0.50	C/A
1	0.75	3	0.50	C/A
2	1.00	4	0.75	C/A
2	1.00	4	0.25	C/P
2	0.75	3	0.25	C/P
2	0.75	4	0.25	C/P
3	1.00	4	0.50	C/P
3	1.00	4	0.25	C/P
1	1.00	2	0.50	C/E
1	0.75	3	0.25	C/E
1	0.50	2	0.25	C/E
2	0.75	3	0.50	C/E
2	0.50	4	0.25	C/E

[a] Problem types: A = amount; P = probability; N/C = no-conflict;

C/A = conflict-amount; C/P = conflict-probability; C/E = conflict-equivalence

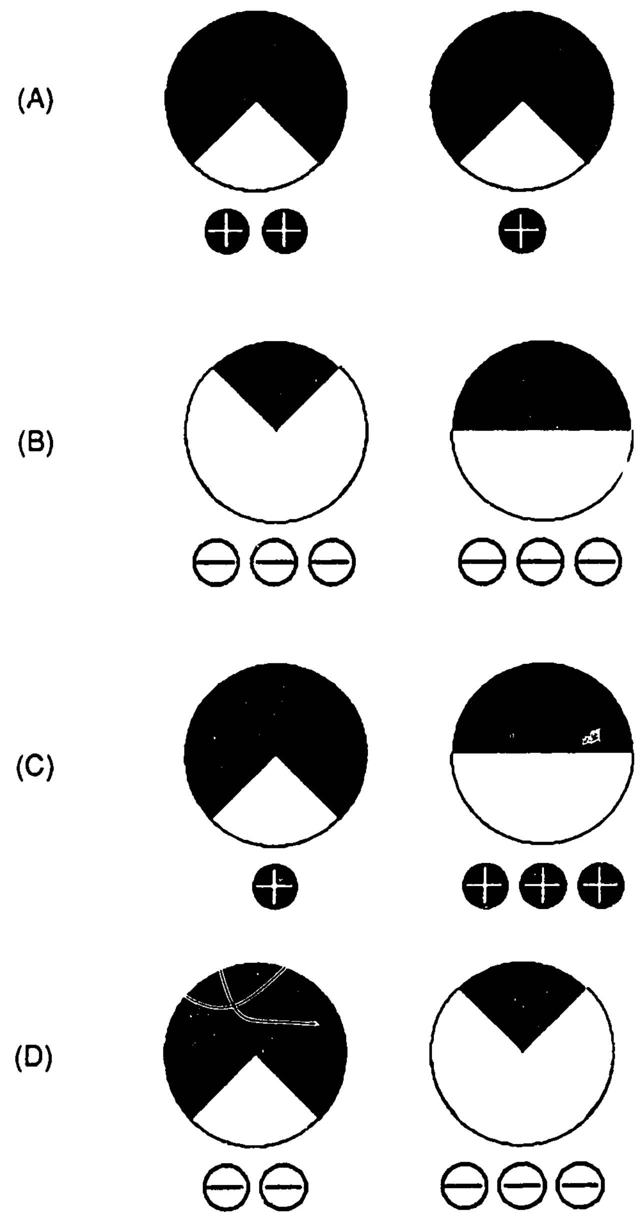


Figure 8. Examples of the decision problems from Study 3 (Reproduced at 60% of original size).

In each of the examples the absolute difference in expected value between the two alternatives is 0.75 tokens, and the relative difference in expected value between the two alternatives is 2 to1. The examples represent the following problem types:

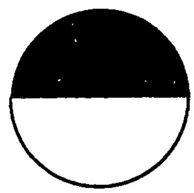
(A) an amount question from the gain problem set
(B) a probablity question from the loss problem set
(C) a conflict-amount question from the gain problem set
(D) a conflict-probability question from the loss problem set

For this study, in addition to the research credit you receive for your participation, you will have the opportunity to earn tokens which will be redeemed for McDonald's™ coupons at the end of the session. At all times your continued participation is strictly voluntary. If at any point you decide you do not wish to continue with the session, you will still receive course credit for your participation; you will also be able to cash in any tokens you have earned to that point.

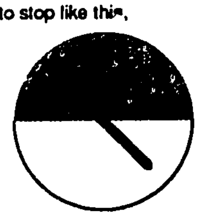
There will be a short warm-up so you can become familiar with the task. After you complete this warm-up you will receive four tokens to start with. We will then ask you to complete the main task in which you will be making selections between alternatives which involve the gain or loss of additional tokens. The entire session should take a total of approximately one hour to complete.

Each of the items you will be evaluating consists of a pair of partially shaded circles. Each of the circles has a number of tokens below it, describing either a win (indicated by a plus sign) or a loss (indicated by a minus sign).

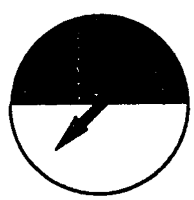
Imagine that each of these circles is a disc with a spinner attached to the center. For each item you are to choose one of the two circles. When you make your choice, imagine the spinner attached to the circle you selected is to be spun once. If the spinner stops pointing to the shaded portion of the circle, you would win or lose the amount indicated under that circle. For example, suppose you chose the circle below:



If the imaginary spinner were to stop like this,



you would win (+) or lose (-) the number of tokens indicated below the circle. On the other hand, if it stopped like this,



you would win or lose nothing.

In each case there will be two circles to choose from. You are to choose the circle you would most like to play from each of the pairs, and then indicate your choice by pressing the key corresponding to the position of the circle you select. You can take as long as you require to respond, each pair of items will remain on the computer screen until you indicate which of the two alternatives you prefer.

After you have evaluated all the items, twelve of the items will be chosen. These items will be played out at the end of the session, in the manner you indicate in your selections. Six of these items will involve gains and six will involve losses. You will increase or decrease the number of tokens you have by the amount indicated when these twelve items are played out. The total number of coupons you receive will depend on the number of tokens you have to trade-in at the end of the session.

Figure 9. Instruction sheet from Study 3 (Reproduced at 60% of original size).

L (for the alternative on the left-hand side of the screen). The stimuli used in the warm-up task consisted of one gain problem and one loss problem from each of the six problem types used in the main part of the study. Each pair of alternatives remained on the screen until a selection was made. Following the warm-up each subject was given four tokens to start with. For the main part of the experiment, the subjects were under no time constraint; no subject took longer than 40 minutes to complete the entire session.

After all the questions had been answered each subject played out twelve of the questions. The same questions were played out for all the subjects, but subjects did not know in advance which questions would be selected. The tokens which the subjects won in this section were traded for McDonald's™ gift certificates at the end of the session. The rate of exchange was approximately five tokens for a $1 gift certificate; this rate of exchange was not revealed to the subjects until the very end of the session. The median amount won by all subjects was $3; the lowest amount was $1 and the highest amount was $4.

Results and Discussion

Twenty-two subjects took part in the study; data from two subjects were not analyzed. One of these subjects showed evidence of a left/right confusion. Halfway through the main part of the study this subject asked for clarification whether L meant her left, or the computer's left. This raised doubts concerning how responses to earlier questions had been made, and therefore data from this subject were excluded. Data from a second subject were excluded because, when the 12 items were played out at the end of the session, the subject indicated he had not understood the task. Specifically, he stated that he thought the rules were reversed for loss questions; he thought he would lose tokens if the spinner stopped on the white portion of the circle.

The data from the remaining twenty subjects were sorted by problem type, and individual selections were evaluated relative to predictions based on expected value theory; each subject evaluated a total of 20 problems of each type (5 problems x 4 presentations) for gains and 20 problems of each type for losses. Tables 6a and 6b summarize the number of selections corresponding to expected value predictions, for each subject, by problem type.

For dominated problems (amount, probability and no-conflict) the average rate of selections opposite to expected value predictions (SOPs) was 1%. This compared with SOP rates of 1.85% on the probability and no-conflict problems in Study 2. With one exception, each subject made 1 SOP or no SOPs on each set of the dominated problems; one subject (#8) made two SOPs on the probability problem set for losses, as well as on the no-conflict problem set for losses.

Therefore, the overall base rate of SOPs on dominated problems was 2 or fewer, in a set of 20 problems. Because selections on dominated problems should be consistent with predictions based on expected value theory for all individuals except those who utilize Rule 1A or 1P, and because the objective in a rule-assessment analysis is to classify subjects according to their strategic understanding of the problem situation, the rate of SOPs on dominated problems was also used to evaluate performance on non-dominated problems. A subject was classified as a consistent/predicted responder for a particular problem type if he or she had 2 or fewer SOPs; a subject was classified as a consistent/opposite responder for a particular problem type if he or she had 18 or more SOPs; and an individual was classified as a mixed responder for a particular problem type if he or she had more than 2, but fewer than 18, SOPs. Because expected value theory does not generate predictions for decision patterns on conflict-equivalence problems, selections on problems of this type were evaluated relative to predictions based on prospect theory. Therefore, for

Table 6a

Decision Pattern Across Question Types for Study 3 (Gains)

Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
	Problem Type						
1	20	20	20	18	19	17	4
2	19	20	19	19	18	6	4
3	20	20	20	17	16	10	3
4	20	20	20	19	20	15	4
5	19	19	20	17	14	7	3
6	20	20	20	20	18	9	4
7	20	20	20	20	20	17	4
8	20	19	20	18	20	14	4
9	20	20	20	18	19	19	4
10	20	20	20	11	17	13	3
11	20	20	20	18	18	16	4
12	20	20	20	16	17	17	3
13	20	20	20	19	20	13	4
14	20	19	19	18	20	17	4
15	20	20	20	2	20	20	2P
16	20	20	20	20	20	13	4
17	20	20	19	20	20	17	4
18	19	20	20	14	17	11	3
19	20	19	19	13	17	17	3
20	20	20	20	18	19	9	4

Note. The number in each column represents the number of selections (out of 20) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 20) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

Table 6b

Decision Pattern Across Question Types for Study 3 (Losses)

	Problem Type						
Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	20	19	20	18	20	17	4
2	19	19	20	14	17	10	3
3	20	19	20	17	14	9	3
4	20	20	20	19	19	15	4
5	19	19	20	15	17	7	3
6	20	20	19	12	17	17	3
7	20	20	20	19	18	10	4
8	20	18	18	17	15	13	3
9	20	20	20	18	19	18	4
10	20	20	19	13	17	6	3
11	20	20	20	18	19	11	4
12	20	19	20	17	17	17	3
13	20	20	20	15	17	12	3
14	20	20	20	17	15	[illegible]	3
15	20	20	20	20	18	9	4
16	20	20	19	19	20	12	4
17	20	20	20	15	16	12	3
18	19	20	19	13	17	13	3
19	20	19	19	14	17	11	3
20	20	20	19	17	16	8	3

Note. The number in each column represents the number of selections (out of 20) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 20) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

conflict-equivalence problems: an individual was classified as a consistent/predicted responder if he or she selected the alternative which presented the greater chance of winning (or the smaller chance of losing) for 18 or more of the problems; an individual was classified as a consistent/opposite responder if he or she selected the alternative which presented the larger amount to be won (or the smaller amount to be lost) for 18 or more of the problems; and an individual was classified as a mixed responder if he or she selected the alternative which presented the greater chance of winning (or the smaller chance of losing) for more than 2, but fewer than 18 of the problems.

Each subject's decision pattern was then categorized using the following classification system: (a) subjects who were consistent/opposite responders on conflict-amount problems, and who were consistent/predicted responders on all the remaining problem types were categorized as using Rule 2P; (b) subjects who were consistent/opposite responders on conflict-probability problems and conflict-equivalence problems, and who were consistent/predicted responders on all the remaining problem types were categorized as using Rule 2A; (c) subjects who were consistent/predicted responders on all the dominated problems (amount, probability, and no-conflict), and who were mixed responders on all the non-dominated problems (conflict-amount, conflict-probability, and conflict-equivalence) were categorized as using Rule 3; (d) subjects who were mixed responders on conflict-equivalence problems, but who were consistent/predicted responders on the remaining problem types were categorized as using Rule 4; and (e) subjects who were consistent/predicted responders on all the problem types were categorized as using Rule 4*. Rule 4* corresponds to selections which are consistent with predictions based on expected value theory on problems where one of the alternatives has a higher expected value than the other, coupled with selections on conflict-equivalence problems which are consistent with predictions based on prospect theory.

In any classification system there exists the possibility of misclassification. In the current study concern was focused on the probability of overclassification, that is, the probability of categorizing an individual as making use of a higher-level rule when, in fact, he or she was relying on a lower level rule. The binomial probability of misclassifying an individual who was relying on a one-dimensional rule to solve the problems (Rule 2) as using a two-dimensional rule (Rule 3) was 4.3×10^{-4}. The binomial probability of misclassifying an individual who was using a two-dimensional strategy, but who was unable to execute it successfully (Rule 3) as successfully executing the strategy (Rule 4) was less than 1%. The probability of misclassification if the individual was able to execute the two-dimensional strategy successfully 50% of the time was 4×10^{-8}, and the probability of misclassification if the individual was able to execute the two-dimensional successfully 75% of the time was 8.3×10^{-3}. Therefore, the probability of overclassification was less than 1%.

In total, 12 of the twenty subjects were categorized as using Rule 4 for gain problems, 1 subject was categorized as using Rule 4*, 1 subject was categorized as using Rule 2P, and the remaining 6 subjects were categorized as using Rule 3. For loss problems only 6 of the 20 subjects were categorized as using Rule 4, 1 subject was categorized as using Rule 4*, and the remaining 13 subjects were categorized as using Rule 3.

One subject (#9) made selections on conflict-equivalence problems that were consistent with predictions based on prospect theory for both gain and loss questions, however overall support for the type of decision process implied by prospect theory is weak. The majority of subjects gave mixed responses on conflict-equivalence questions; this decision pattern is inconsistent with predictions based on prospect theory (and on other economic models of decision making which incorporate subjective discounting of the problem dimensions). Also, as in the previous studies a large percentage of the subjects were mixed responders on both conflict-amount and conflict-probability problems; nearly one-third (30%) had this type of decision pattern for gains, and nearly two-thirds (65%) had this type of decision pattern for losses.

In addition, there is some evidence to suggest that differences in decision patterns across gain and loss questions, such as those found in Study 1 and Study 2, may result from the use of quantitatively or qualitatively different decision strategies in each domain. Eight of the subjects were categorized as using different rules on gain problems than on loss problems. Seven subjects were categorized as using a higher rule on gain problems than on loss problems. These subjects all appeared to be able to execute a two-dimensional decision strategy successfully when evaluating gain problems (Rule 4), but they all appeared to be less successful in executing the same type of strategy when evaluating loss problems (Rule 3). In only one instance was a individual categorized as using a lower level strategy on gain problems than on loss problems (Subject #15). The use of a lower level strategy for gain problems in this instance may have resulted from the use of a back-up strategy (cf. Siegler & Jenkins, 1989). Siegler and Jenkins (1989) suggest that individuals who know higher level strategies may not always use them, especially if there is a speed/accuracy trade-off between the different strategies. In the present study none of the gain problems would ever result in a loss of tokens; the worst outcome would be for the individual to break even. Under these circumstances, where the differences in amount between the alternatives never exceeded 3 tokens, an individual might rely on a strategy which was easier to execute even though more complex strategies were available.

Conclusions

This study provides evidence that the proposed rule-based model of decision making may describe some of the decision strategies individuals use in non-reoccurring, concurrent choice situations. When the pattern of selections across a series of decision problems was analyzed, the majority of subjects showed evidence of using a two-dimensional strategy (Rule 3 or Rule 4) for both gain problems and loss problems. In addition, the classification system developed from the rule-based model was able to identify one individual whose selections on gain problems clearly indicated that a one-dimensional, probability strategy (Rule 2P) was used to decide between the available alternatives.

Therefore, the data from this study suggest that the majority of individuals make use of two-dimensional decision rules of the type suggested by expected value theory to decide between the available alternatives in non-reoccurring, concurrent choice situations. The data also suggest, however, that individuals do not engage in the types of subjective discounting which have been proposed by expected utility theory, subjective expected utility theory, and prospect theory. Instead, decisions that are non-optimal from an economic perspective may arise because individuals are unable to consistently and reliably combine the two relevant problem dimensions, or because individuals make use of simpler, one-dimensional strategies.

In addition to providing an alternate way of viewing the processes underlying adult decision making, conceptualizing of behavior in non-reoccurring, concurrent choice situations as rule-based behavior which utilizes progressively more complex rules may provide a means to link the development of decision-making skills with the large body of literature on adult decision-making. This linkage is important; developmentally we are "interested not only in identifying what...shifty dodges and hybrid evasions...adults resort to now and again but also in tracking their origins back to childhood cognitive operations" (Hoemann & Ross, 1982, p. 120). The next study was designed to provide a developmental assessment of the proposed rule-based model.

Chapter Five: Study Four

In the previous chapter a rule-based model of decision-making behavior in non-reoccurring, concurrent choice situations was developed and evaluated. This approach to the analysis of decision-making can be extended to trace the development of decision-making skills across individuals of different ages. The goal in a developmental study is to discover how we move from having no frame of reference with which to conceptualize probabilistic events, to having the ability to combine two problem dimensions to arrive at a decision. Siegler and Jenkins (1989, p. 4) argue that "a model that does not account for knowledge acquisition is a seriously incomplete model of cognition."

At present there is no unifying theory which takes into account the acquisition of decision-making skills. The rule-based model developed in the previous chapter provides a foundation for analyzing decision-making skills across individuals at different age levels. The intention in using a rule-based approach is to describe, in detail, the types of rules which might be operating at each stage of development, and also to provide insight into how one rule can be transformed into a more complex rule. The goal is to identify which components of the rules change (Chi & Rees, 1983).

For an individual to make a reasoned decision in a non-reoccurring, concurrent choice situation, he or she must first have some understanding of the nature of probabilistic outcomes. But how does an individual develop an understanding of risk and uncertainty? Piaget and Inhelder (1975) viewed a child's understanding of probabilistic outcomes as complementary to his or her understanding of cause and effect. They argued that without comprehension of caused events, the child can have no frame of reference for identifying events that are due to chance. Thus, Piaget and Inhelder concluded a child's concepts of chance and probability are derived concepts which emerge from the child's search for order and causality. They suggest that this understanding does not emerge until a child moves from preoperational patterns of thought to the level of concrete operations (Hoemann & Ross, 1982). Therefore, from a Piagetian viewpoint, achievement of the level of concrete operations is necessary for coherent assessment of decision problems. However, to select the best alternative in a non-reoccurring, concurrent choice situation, attainment of the concept of probabilistic outcomes is necessary, but not sufficient. The types of processes required to evaluate these problems also require the concepts and procedures of combinatorial analysis (Fischbein, 1975) which are not attained until the level of formal operations.

To determine if decision-making skills develop in a manner similar to that suggested from a Piagetian perspective, Study 3 was replicated using subjects from three age groups: 8-year-olds, 12-year-olds and 19-year-olds. It is hypothesized that children in the youngest age group may not understand that failing to combine the two problem dimensions can result in non-optimal decisions, and as a result the children in this group may rely on simpler, one-dimensional strategies to make their selections. In contrast, children in the middle age group should understand that combining the two problem dimensions is necessary to make an optimal decision and, as a result, the children in this group should attempt to execute more complex, two-dimensional strategies to make their selections. However, the children in this age group may lack the skills necessary to combine the two problem dimensions in a reliable and consistent way. Finally, those in the oldest age group should understand that combining the two problem dimensions is necessary in order to make an optimal decision, and these individuals should also have the necessary skills to combine the problem dimensions in a reliable and consistent way.

Method

Subjects. Data were collected from 75 subjects: twenty-five 8-year-olds and twenty-five 12-year-olds enrolled in regular classes in the Edmonton public school system, and 25 undergraduate students enrolled in an introductory psychology class at the University of Alberta. The mean age in the youngest group was 8 years 4 months, with a standard deviation of 2 months (median age = 8 years 4 months); the mean age in the middle group was 12 years 5 months, with a standard deviation of 3 months (median age = 12 years 5 months); the mean age in the oldest group was 19 years 10 months, with a standard deviation of 15 months (median age = 19 years 4 months). Eight additional subjects were tested, but no data were recorded for these subjects; the reasons for excluding these subjects are provided in the procedure section.

All the 12-year-olds and all but two of the 8-year-olds were tested individually, during regular school hours, in the school they normally attended. The remaining two 8-year-olds were tested individually, in their own homes, immediately after regular school classes had ended for the day. The university students signed up for individual sessions. These students received course credit for their participation in addition to any winnings received in the course of the experiment.

Stimuli. The 60 decision problems used in this study were the same as those used in Study 3 (see Table 5). For each problem a pair of plastic roulette spinners which had been painted black and white was set out, and plastic tokens were placed under each of the spinners (from the subject's perspective). For the gain questions the tokens were black and had a white "+" sign on them; for the loss questions the tokens were white and had a black "-" sign on them.

Procedure. Each subject had the task verbally explained to them using the script in Figure 10. (For the 8-year-olds and the 12-year-olds the second

In this study we're going to play a game where you can win tokens. The object is to win as many tokens as you can because after the game is over you can trade your tokens for McDonald's gift certificates, and the more tokens you have at the end of the game, the more coupons you get.

At all times your continued participation is strictly voluntary. If at any point you decide you do not wish to continue you will still receive course credit for your participation, and you will also be able to cash in any tokens you have earned up to that point.

In the game, I am going to be showing you some spinners just like this one. Part of the spinner is white and part of the spinner is black. When the spinner stops after it is spun, if the little arrow is pointing to the white part of the circle, nothing happens. But, if the little arrow stops pointing to the black part of the circle then something happens.

What happens depends on the color of the tokens under the spinner. If the tokens are black like this one, then you would win the tokens which were under that spinner. But, if the tokens are white like this one, then you have to give me back as many tokens as there are under the spinner.

So, if the tokens are black, stopping on the black part of the circle is good, because you want to win as many tokens as you can. But, if the tokens are white, stopping on the black part of the circle is not good, because you don't want to lose any tokens. Let's try a couple so you can see how it works.

[Try some problems with a single spinner and two tokens; have the participant tell you what would happen in each case. Continue until six problems in a row are answered correctly.]

Okay, you've got that figured out. So, let's start the game. During the game I am going to show you two different spinners at the same time, and I want you to tell me which one you would prefer to play, if you had to choose one of them, and why you prefer that one. I am going to mark your answer on a sheet of paper, and also record your answers on this tape recorder. After you have shown me which one you would pick for each of the problems, we are going to play out all the problems, just the way you said you would like to. When we play the problems out at the end, you get to take the tokens by the spinner whenever you win, but you have to give tokens back to me whenever you lose.

When we're done, you can trade all the tokens you have won for McDonald's gift certificates.

Figure 10. Instruction sheet from Study 4.

paragraph was omitted.) Midway through the instructions, each subject was shown a single spinner which was painted half black and half white. Two tokens were placed under this spinner. Initially the tokens were black, and the spinner was spun once so that it stopped on white, and once so that it stopped on black. The subject was asked to indicate what would happen in each case. The subject was to state whether: (a) he or she would win tokens, (b) he or she would lose tokens, or (c) nothing would happen. The tokens were then changed to white tokens and the process was repeated. The experimenter cycled through these four steps until the subject responded correctly on at least six successive items. All but one of the 19-year-old subjects met this criterion after 8 items had been presented, and all but seven of the younger subjects met this criterion after 16 items had been presented. Six 8-year-olds and one 12-year-old were not able to meet the criterion of correctly responding to 6 successive items after 48 items had been presented, and one 19-year-old was not able to meet the criterion of 6 successive correct responses after 12 items had been presented; data were not collected for these 8 subjects.

After the instructions had been given, data collection began. Each problem was presented twice. The first time the subject was asked to indicate which spinner, from the pair of spinners, he or she would prefer to play, "if you could only play one, but if you had to play one." Selections were recorded on the form shown in Figures 11a and 11b (the order of presentation was the same for all subjects). In addition, each subject was asked to state the reasons for his or her selection, immediately after each selection had been made. These responses were recorded on audiotape. When each problem had been presented once, data collection was complete; the remainder of the procedure was designed to make the initial selection process more meaningful.

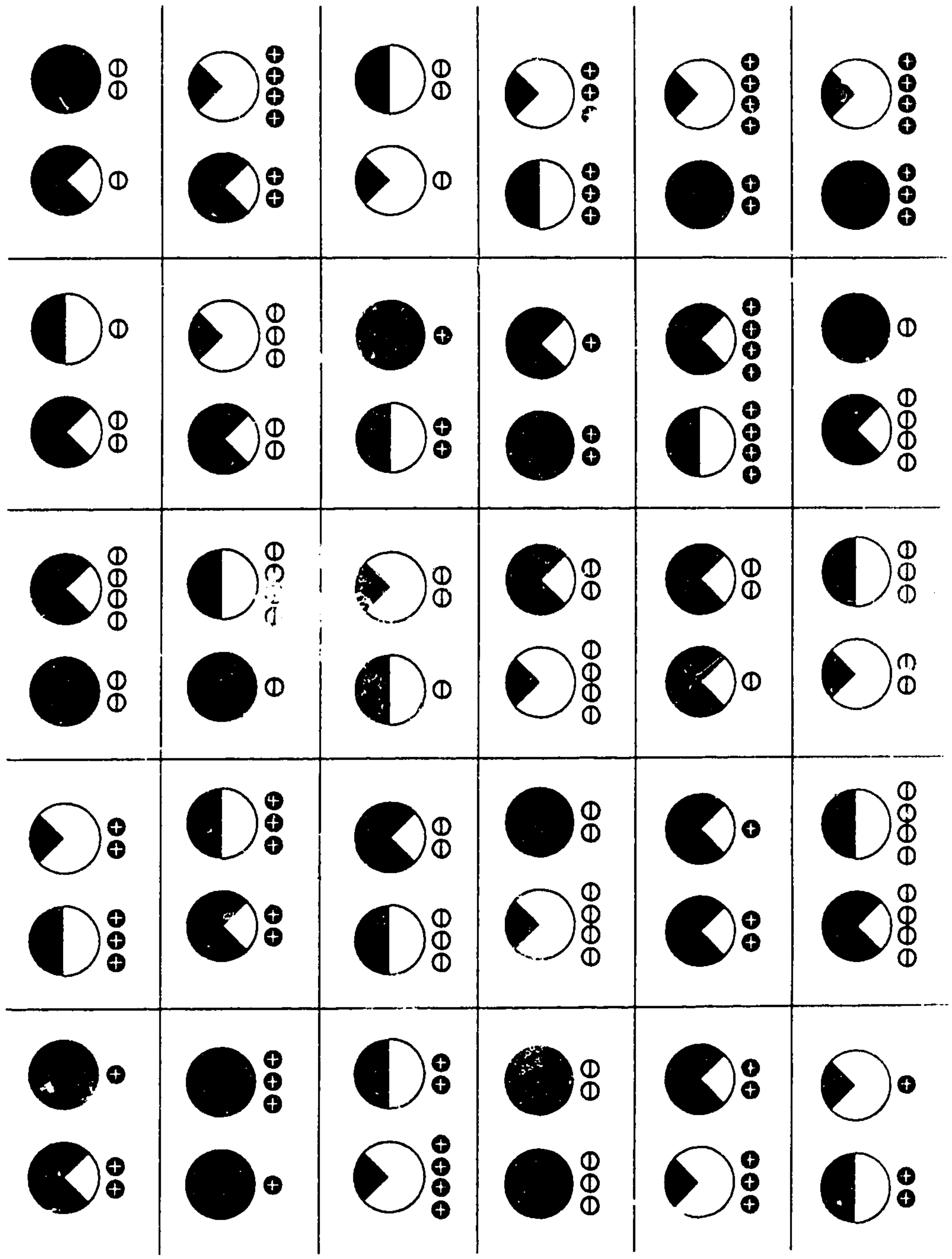


Figure 11a Page 1 of form used to record selections in Study 4 (reproduced at 75% of original size).

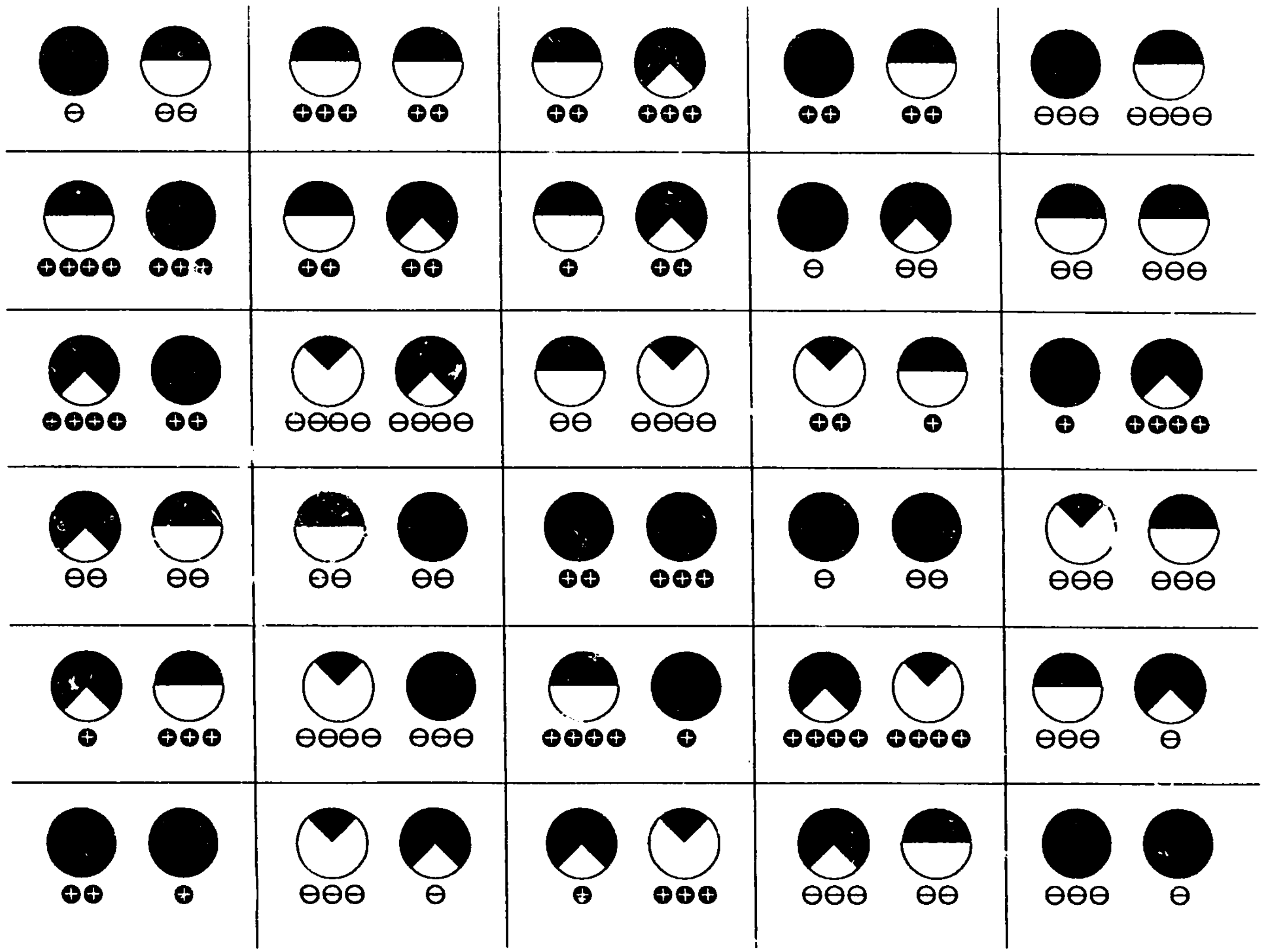


Figure 11b. Page 2 of form used to record selections in Study 4 (reproduced at 75% of original si...

Each problem was presented a second time, and each alternative which had been selected was played out. The subject accumulated or gave up tokens based on the outcome when the selected spinner was spun; the accumulated tokens were traded for McDonald's™ gift certificates at the end of the session. The rate of exchange was approximately 12 tokens for a $1 gift certificate; this rate of exchange was not revealed to the subjects until the very end of the session. The median amount won by the 8-year-old subjects was $1, the lowest amount was $1 and the highest amount was $3; the median amount won by both the 12-year-old and the 19 year-old subjects was $2, for both groups the lowest amount won was $1 and the highest amount won was $3.

Results and Discussion

The verbal protocols from each subject were scored first. Each subject's stated reasons for selecting a given alternative were scored as using reasoning based on either probability of occurrence, amount at stake, or both. For each question, if the reason provided contained statements such as: "there is more black," or "there is more chance of nothing happening," or "the spinners are the same," the subject was scored as using probability of occurrence as a factor in reaching his or her decision. If the reason provided contained statements such as: "there are more tokens," or "I'd have to give less back," or "the tokens are the same," the subject was scored as using the amount at stake as a factor in reaching his or her decision. The maximum number of statements that could be counted for an individual subject was 120 (60 questions x 2 factors considered). There was no minimum number of statements because in some cases subjects provided no reasons why they selected in the way they did (e.g. "I don't know why"); in other cases the reasons provided could not be classified. Some examples of non-classifiable statements include: "because I like that one," and "because that one is better."

The entire set of verbal protocols was scored by the main researcher, and a subset of five verbal protocols from each of the age groups was scored by a research assistant. The interrater reliability (r^2) on the protocols that were scored by both individuals was +0.986.

For each subject the proportion of probabilistic statements was determined by dividing the number of times probability was given as a reason into the total number of reasons given (see Appendix C). Probability was selected as the dimension for comparison because the results from Study 1 and Study 2 suggested that, for university-aged subjects, probability considerations may dominate amount considerations in the decision process. A one-way ANOVA on the proportion of probabilistic reasons, across age groups, was not significant, $F(3, 72) = 0.74$, $p > .05$. The average proportion of probabilistic statements for the 8-year-old group was 0.54 (s = 0.25), the average for the 12-year-old group was 0.64 (s = 0.16), and the average for the 19-year-old group was 0.54 (s = 0.09).

Next, each subject's performance was evaluated relative to predictions based on expected value theory. Because expected value theory does not generate predictions for decision patterns on conflict-equivalence problems, selections on problems of this type were evaluated relative to predictions based on prospect theory.

The decision pattern for each subject, for both gain and loss questions, was classified using a system similar to the one used in Study 3. (The results of this classification are given in Tables 7a through 7f.) The classification was done as an upward sift: an individual who had already been classified as using Rule 0 was not considered when the Rule 1 classification was done, an individual whc had already been classified as using Rule 1 was not considered when the Rule 2 classification was done, and so on. A set of criteria similar to the ones

Table 7a

Decision Pattern Across Problem Type for Study 4 (Gains: 8-year-olds)

Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	5	3	5	5	1	0	1A
2	5	3	5	5	0	1	1A
3	5	5	5	1	4	4	3
4	5	4	5	5	0	0	1A
5	5	5	5	5	0	1	2A
6	3	3	5	2	3	4	0
7	5	5	5	0	5	5	2P
8	5	5	5	2	3	4	3
9	5	2	5	5	0	0	1A
10	5	5	5	5	4	3	4
11	5	5	5	4	5	4	4
12	5	5	5	4	2	2	3
13	5	5	5	4	4	4	3
14	3	5	5	1	5	5	1P
15	5	5	5	0	5	5	2P
16	3	5	5	0	5	4	1P
17	5	5	5	1	5	5	2P
18	5	5	5	5	4	5	4
19	5	5	5	3	4	4	3
20	5	5	5	5	0	0	2A
21	5	5	5	4	2	1	3
22	4	4	4	2	5	3	0
23	5	5	5	4	0	0	2A
24	5	5	5	2	4	3	3
25	5	5	5	4	5	5	4

Note. The number in each column represents the number of selections (out of 5) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 5) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

Table 7b

Decision Pattern Across Problem Type for Study 4 (Losses: 8-year-olds)

Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	4	2	4	3	1	0	0
2	5	3	5	5	0	0	1A
3	3	5	5	1	5	5	1P
4	5	2	5	5	0	0	1A
5	5	5	5	4	1	1	3
6	5	4	3	4	2	0	0
7	5	5	5	1	4	3	3
8	4	1	3	5	0	0	0
9	0	4	0	0	5	5	1A*
10	5	5	5	0	5	5	2P
11	5	5	5	2	4	4	3
12	5	1	5	5	0	0	1A
13	5	5	5	1	4	4	3
14	4	5	5	0	5	5	1P
[illegible]	1	5	5	0	5	5	1P
[illegible]	4	5	5	0	5	5	1P
[illegible]	5	5	5	1	5	5	2P
18	5	5	5	4	2	4	3
19	5	5	5	3	4	4	3
20	5	1	5	5	0	0	1A
21	5	1	5	5	0	0	1A
22	5	5	5	4	5	1	4
23	5	5	5	5	0	0	2A
24	5	5	5	4	1	2	3
25	5	5	5	4	5	5	4

Note. The number in each column represents the number of selections (out of 5) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 5) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

Table 7c

Decision Pattern Across Problem Type for Study 4 (Gains: 12-year-olds)

	Problem Type						
Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	5	5	5	1	5	5	2P
2	5	5	5	4	3	2	3
3	5	5	5	4	0	0	2A
4	5	5	5	4	4	3	3
5	5	5	5	4	5	5	4
6	5	5	5	4	5	5	4
7	5	5	5	5	5	5	4
8	5	5	5	5	4	3	4
9	5	5	5	4	4	1	3
10	5	5	5	3	4	3	3
11	5	5	5	4	4	4	3
12	5	5	5	4	4	3	3
13	5	5	5	1	5	5	2P
14	5	5	5	5	4	5	4
15	5	5	5	4	5	5	4
16	5	5	5	4	5	4	4
17	5	5	5	2	4	4	3
18	5	5	5	5	5	4	4
19	5	5	5	4	5	3	4
20	5	5	5	4	4	4	3
21	5	5	5	4	4	3	3
22	5	5	5	4	5	2	4
23	5	5	5	1	5	5	2P
24	5	5	5	4	5	4	4
25	5	5	5	4	5	4	4

Note. The number in each column represents the number of selections (out of 5) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 5) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

Table 7d

Decision Pattern Across Problem Type for Study 4 (Losses: 12-year-olds)

Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	5	5	5	1	5	5	2P
2	5	5	5	4	2	3	3
3	5	5	5	5	1	0	2A
4	5	5	5	3	3	1	3
5	5	5	5	5	5	4	4
6	5	5	5	1	5	5	2P
7	5	5	5	4	5	4	4
8	5	5	5	5	4	3	4
9	5	5	5	4	2	1	3
10	5	5	5	2	4	4	3
11	5	5	5	0	5	5	2P
12	5	5	5	3	4	3	3
13	1	5	5	0	5	5	1P
14	3	5	5	0	5	5	1P
15	5	5	5	4	5	3	4
16	5	5	5	1	5	5	2P
17	5	5	5	1	3	2	3
18	5	5	5	5	5	5	4
19	5	5	5	4	5	4	4
20	5	5	5	5	5	5	4
21	1	5	5	0	5	5	1P
22	5	5	5	1	3	4	3
23	5	5	5	4	5	4	4
24	5	5	5	4	5	4	4
25	5	5	5	5	5	5	4

Note. The number in each column represents the number of selections (out of 5) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 5) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

Table 7e

Decision Pattern Across Problem Type for Study 4 (Gains: 19-year-olds)

	Problem Type						
Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	5	5	5	5	1	0	2A
2	5	5	5	4	5	4	4
3	5	5	5	4	5	5	4
4	5	5	5	5	5	3	4
5	5	5	5	4	5	4	4
6	5	5	5	5	1	0	2A
7	5	5	5	4	5	2	4
8	5	5	5	4	5	2	4
9	5	5	5	5	5	2	4
10	5	5	5	1	5	5	2P
11	5	5	5	1	5	5	2P
12	5	5	5	4	5	5	4
13	5	5	5	4	5	3	4
14	5	5	5	4	5	2	4
15	5	5	5	5	5	4	4
16	5	5	5	5	4	3	4
17	5	5	5	5	4	2	4
18	5	5	5	5	5	4	4
19	5	5	5	5	4	1	4
20	5	5	5	4	4	2	3
21	5	5	5	5	5	4	4
22	5	5	5	1	5	5	2P
23	5	5	5	5	1	0	2A
24	5	5	5	1	5	5	2P
25	5	5	5	5	5	4	4

Note. The number in each column represents the number of selections (out of 5) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 5) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

Table 7f

Decision Pattern Across Problem Type for Study 4 (Losses: 19-year-olds)

Subject #	Amount	Probability	No-Conflict	Conflict Amount	Conflict Probability	Conflict[a] Equivalence	Rule
1	5	5	5	1	5	5	2P
2	5	5	5	5	5	4	4
3	5	5	5	4	5	2	4
4	5	5	5	5	5	4	4
5	5	5	5	5	5	2	4
6	5	5	5	5	0	0	2A
7	5	5	5	5	4	3	4
8	5	5	5	4	5	5	4
9	5	5	5	4	5	3	4
10	5	5	5	0	5	4	2P
11	5	5	5	1	5	5	2P
12	5	5	5	5	5	4	4
13	5	5	5	1	5	5	2P
14	5	5	5	4	5	2	4
15	5	5	5	4	5	4	4
16	5	5	5	4	5	3	4
17	5	5	5	4	5	4	4
18	5	5	5	4	5	3	4
19	5	5	5	5	4	2	4
20	5	5	5	4	4	3	3
21	5	5	5	5	5	4	4
22	5	5	5	5	4	4	4
23	5	5	5	5	4	4	4
24	5	5	5	2	3	2	3
25	5	5	5	1	5	5	2P

Note. The number in each column represents the number of selections (out of 5) corresponding to predictions based on expected value theory.

[a] Because expected value theory does not generate predictions regarding selections on conflict-equivalence problems, the number in this column represents the number of selections (out of 5) corresponding to prospect theory predictions: selecting the more probable alternative for gains; selecting the less probable alternative for losses.

adopted in Study 3 were used to classify each subject's decision strategy. The specific criteria used were the following:

1. First, the decision pattern on dominated problems was considered. If an individual (a) made more than 1, but less than 4, selections opposite to predictions based on expected value theory (SOPs) on the no-conflict problems, or (b) made SOPs on both amount and probability problems, then he or she was considered to have used a decision strategy other than one based on probability or amount, or to have inconsistently used a probability strategy or an amount strategy in evaluating the problems. Because the selections these subjects made were inconsistent with those that would be expected if either a probability or an amount strategy were being used, these selection patterns were not classified. Instead, these subjects were designated as using Rule 0.

2. The remaining subjects made SOPs on only one of the dominated problem sets, with one exception: loss questions for 8-year-old subject #9. The pattern of selections on loss problems for this subject was consistent with a decision strategy of always selecting the alternative with the larger amount at stake, even though loss problems were being evaluated. Specifically, for the probability problem set this individual selected the alternative with the lower probability of occurrence on four of the five problems, but rejected the less probable alternative on the remaining problem; for the remaining 25 problems this individual selected the alternative with the larger amount at stake. Because this decision pattern is consistent with the use of an amount strategy that is executed opposite to predictions, this subject was classified as using Rule 1A* for loss questions.

3. The remaining subjects made SOPs on only one of the dominated problem sets. If an individual (a) made at least one SOP, but less than five SOPs on the probability set of the dominated problems, and (b) selected the

alternative with the higher probability of winning (or the lower probability of losing) for at least 13 of the 15 non-dominated problems, he or she was classified as using Rule 1P.

If an individual (a) made at least one SOP, but less than five SOPs on the amount set of the dominated problems, and (b) selected the alternative with the larger amount to be won (or the smaller amount to be lost) for at least 13 of the 15 non-dominated problems, he or she was classified as using Rule 1A.

4. The remaining subjects made no SOPs on any of the dominated problems; therefore only the decision pattern on the non-dominated problems was considered. If an individual selected the alternative with the higher probability of winning (or the lower probability of losing) for at least 13 of the 15 non-dominated problems, he or she was classified as using Rule 2P. If an individual selected the alternative with the larger amount to be won (or the smaller amount to be lost) for at least 13 of the 15 non-dominated problems, he or she was classified as using Rule 2A.

5. The remaining subjects: (a) selected the alternative with the higher probability of winning (or the lower probability of losing) for less than 13, but more than 2, of the non-dominated problems, and (b) selected the alternative with the larger amount to be won (or the smaller amount to be lost) for less than 13, but more than 2 of these problems. This type of a decision pattern on non-dominated problems is inconsistent with the patterns that would be expected if only a single problem dimension were being considered. Therefore the remaining subjects were all classified as using a two-dimensional decision strategy. If an individual made SOPs on both conflict-amount and conflict-probability problems, he or she was classified as using Rule 3. If an individual selected the alternative with the higher expected value for at least 9 of the 10 conflict-amount and conflict-probability problems, he or she was

classified as using Rule 4.

As in the previous study, the concern was with overclassification, categorizing a subject as using a rule higher than the one actually being used. In this study, all the subjects who were classified as using Rule 1, as opposed to Rule 0, made no SOPs on two of three dominated problems sets: there were no SOPs on the no-conflict and probability problem sets for those classified as using Rule 1P, and there were no SOPs on the no-conflict and amount problem sets for those classified as using Rule 1A. The binomial probability of having this type of decision pattern on dominated problems, if selections are actually evenly distributed between the two alternatives is .001; therefore the probability of incorrectly classifying an individual who was indifferent between the alternatives for dominated problems as using Rule 1 was 1/10 of 1%.

Next, all the subjects who were classified as using Rule 2, as opposed to Rule 1 made no SOPs on any of the dominated problems. Compared with the subjects classified as using Rule 1 these subjects made 5 out of 5 selections consistent with predictions on one additional problem set: the amount problem set for those classified as using Rule 2P, and the probability problem set for those classified as using Rule 2A. In both cases these are problems which individuals who rely on Rules 1P and 1A, respectively, should evaluate as offering equivalent selections, and therefore Rule 1 users should have no preference for either of the offered alternatives on these problem sets. The binomial probability of making no SOPs, if selections are evenly distributed across the two alternatives is .0312. Therefore, there is just over a 3% chance of misclassifying an individual who is using Rule 1 as using Rule 2.

All the subjects who were classified as using Rule 3, as opposed to Rule 2, made 3 or more selections on non-dominated problems that were inconsistent with the decision pattern expected if only a single problem dimension were being considered. The binomial probability of a decision pattern of this type occurring if an individual is relying on a one-dimensional strategy, and is able to execute the strategy correctly 95% of the time, is .0362. Therefore, the probability of misclassifying an individual who is using Rule 2 (a one-dimensional strategy) as using Rule 3 (a two-dimensional strategy) is just over 3%.

Finally, the difference between individuals who use Rule 3 and Rule 4 is conceptualized as a quantitative one. Individuals using both these rules are executing a two-dimensional decision strategy, but they differ in their ability to combine the dimensions in a consistent manner. If the individual using Rule 3 is 50% accurate in his or her estimates, responses should be equally distributed across the two alternatives on non-dominated problems. In other words, he or she would be expected to make SOPs 50% of the time. All the subjects who were classified as using Rule 4, as opposed to Rule 3, selected the alternative which had the higher expected value on at least 9 of the 10 conflict-amount and conflict-probability problems. The binomial probability of a decision pattern of this type occurring when SOPs are expected at the rate of 50% is .011. Therefore, in this study the probability of misclassifying a subject as using Rule 4 (successfully executing a two-dimensional strategy), when he or she makes accurate on only half the problems, is just over 1%.

However, the probability of overclassification increases as the accuracy of the estimates made by individuals using Rule 3 increases. The binomial probability of selecting the alternative with the higher expected value on at least 9 of the 10 conflict-amount and conflict-probability problems, when the accuracy of the estimates is 60% is just under 5% (.049), and when the accuracy of the estimates is 75% the probability of this decision pattern occurring is nearly 25% (.244). Therefore, it may be that some individuals were classified as using Rule

4, when they were not using the multiplicative strategy suggested by the model to make their decisions.

In addition to making predictions about the type of decision pattern which will be generated by each of the proposed rules, the rule-based model makes specific assumptions regarding the cognitive processes which underlie non-reoccurring, concurrent decision behavior. Specifically the model suggests: (a) individuals using Rule 1 will focus exclusively on one problem dimension, and will consider the offered alternatives to be equivalent if they do not differ on that dimension; (b) individuals using Rule 2 will focus on one problem dimension, but will consider the second dimension when the offered alternatives are equal on the dominant dimension; (c) individuals using Rules 3 and 4 will consider both dimensions in arriving at a decision. If these are valid assumptions regarding the underlying cognitive processes, the reasons subjects provided for their selections should provide converging evidence for the rule classification system. Specifically, if individuals consider only a single problem dimension in reaching a decision, the verbal justifications they provide to explain their selections should reflect this dimensional focus. If individuals consider both dimensions of the problem in reaching a decision, the verbal justifications they provide to explain their selections should include both problem dimensions. Therefore, the scores from the verbal protocols were recalculated. For those subjects who had been classified as using either Rule 1A or Rule 2A the proportion of amount statements were calculated, instead of the proportion of probability statements. For those subjects who had been classified as using either Rule 1P or Rule 2P the proportion of probability statements were calculated. These statements will be referred to as focus-consistent reasons to indicate they are consistent with the dimensional focus determined through an analysis of the decision patterns. For subjects who had been classified as using Rule 3 and Rule 4 either dimension could have been selected because both dimensions should be given equal consideration. Probability was used, rather than amount, to ensure subsequent comparisons were as conservative as possible (of the subjects classified as using Rule 3 or Rule 4 only 4 out of 49 provided more amount reasons than probability reasons on gain problems, and only 8 out of 45 provided more amount reasons than probability reasons on loss problems).

The predicted pattern of the reasons provided for a subject's selections is as follows: (a) individuals who are using Rule 1 should provide a significantly higher proportion of focus-consistent reasons than those using Rule 2, because Rule 1 individuals presumably do not consider the second problem dimension in making a decision; (b) individuals who are using Rule 2 should provide a significantly higher proportion of focus-consistent reasons than those using Rule 3, because Rule 2 individuals only consider the second problem dimension when the focused dimension does not provide a definitive solution to the problem; (c) individuals who are using Rule 3 should not differ significantly from those using Rule 4 in the proportion of probability and amount reasons they provide, because these groups consider both dimensions on each problem, and only differ in their ability to execute a two-dimensional strategy successfully; and, (d) for those individuals who use either Rule 3 or Rule 4 the proportion of probability reasons provided should not differ significantly from the proportion of amount reasons, because both dimensions should be considered equally often in making a decision.

Because each of the groups contained a different number of subjects, these predictions were tested in a series of Mann-Whitney U tests. The proportion of focus-consistent reasons was significantly higher in those individuals classified as using Rule 1 than in those classified as using Rule 2 for both gains (.846

versus .709), $U(9, 17) = 35$, $p < .05$ and losses (.845 versus .744), $U(11, 14) = 43$, $p < .05$. The proportion of focus-consistent reasons given by subjects classified as using Rule 2 was also significantly higher than the the proportion of probability reasons given by subjects classified as using Rule 3 for both gains (.709 versus .601), $U(17, 17) = 89.5$, $p < .05$ and losses (.744 versus .568), $U(14, 17) = 39.5$, $p < .05$. The proportion of probability reasons did not differ significantly between those subjects classified as using Rule 3 and those classified as using Rule 4 for either gains (.601 versus .589), $U(17, 32) = 253.5$, $p > .05$ or losses (.568 versus .569), $U(17, 28) = 224.5$, $p > .05$. Therefore, the first three predictions were supported. However, the average proportion of probability reasons provided by those individuals who were classified as using Rule 3 or Rule 4 was significantly higher than 50% for both gains (59.3%, s = 1.3%), $t(48) = 7.25$, $p < .05$ and losses (56.8% s = 1.4%), $t(44) = 4.85$, $p < .05$. This result indicates that the probability of occurrence may be given more consideration than the amount at stake when a two-dimensional strategy is used to decide between the available alternatives.

The analysis of the reasons individuals gave to explain their decisions suggests that the subjects classified as using Rules 1 and 2, on the basis of their overall decision pattern, had a qualitatively different understanding of the problem situation from that of the subjects classified as using Rules 3 and 4. In contrast, it appears that the subjects classified as using Rules 3 and 4, on the basis of their overall decision pattern, shared the same qualitative understanding of the relevant problem dimensions, but differed quantitatively in their ability to successfully execute a two-dimensional strategy. These differences in understanding, and in the ability to execute the different strategies, were evident in the verbal protocols subjects provided.

The verbal protocols from the subjects who were classified as using Rule 1 suggested that these individuals were only encoding part of the information that was available to them in each of the problems. For example, one 8-year-old (whose choices were consistent with the use of Rule 1P) gave the following response when given a choice between receiving two tokens for certain or receiving three tokens for certain: "This one [indicating the alternative with two tokens] because they both look the same." Later, when this same subject was given a choice between receiving two tokens for certain or receiving one token for certain she gave a similar response: "This one [indicating the alternative with two tokens] because they're both the same." Similar responses were also given by 12-year-old subjects whose overall decision pattern for loss questions corresponded to the use of Rule 1P. One 12-year-old, when asked to choose between a 75% chance of losing one token and a 75% chance of losing two tokens responded: "I'd pick this one [indicating the alternative with two tokens], it doesn't matter." When the same question was presented to another 12-year-old a similar response was provided: "This one [indicating the alternative with two tokens], just a guess 'cause they're both the same." These responses suggest that subjects who were classified as using the simplest rule in making their decisions failed to encode the second dimension relevant to the problem solution.

A number of other studies have found young children solve a variety of tasks using only unidimensional rules. In predicting balance scale problems most 5-year-olds consistently select the side with the most weight (Siegler, 1976); in conservation of quantity the same children select the taller container as holding more fluid, and they select the longer piece of clay as having more clay (Siegler, 1983). Siegler and Richards (1979) found similar unidimensional rule use for concepts such as time, speed and distance, and Strauss and Stavy (1982) uncovered similar reasoning for time, sweetness and temperature.

The verbal protocols from subjects who were classified as using Rule 2 indicated serial, one-dimensional processing of the problem parameters. For example, one 8-year-old (whose responses were consistent with using Rule 2A) provided the following reasons for selecting a 50% chance to receive three tokens over a 25% chance to receive three tokens: "Well, I can't pick by tokens 'cause there's equal numbers, so I have to pick by color. I'll pick this one [indicating the alternative with a 50% of winning] because it has more black on it." This type of reasoning is consistent with the assumption that individuals using Rule 2 will make selections on the basis of a single dimension, unless that dimension provides no definitive solution; when this occurs selections will be made on the basis of the second dimension.

In contrast to the one-dimensional reasoning evident in the responses from subjects classified as using Rule 1 or Rule 2, two-dimensional reasoning on non-dominated problems was often evident in the verbal responses given by subjects who had decision patterns consistent with the use of Rules 3 and 4. For example, the following responses were given by a 19-year-old and a 12-year-old subject for a problem which required a choice between a 75% chance of receiving two tokens and a 100% chance of receiving one token. The 19-year-old chose the alternative with the better pay-off even though it was less likely to occur giving the following reasons: "I'd play the one on the...the one on the right. Well, because I know your chances of winning here are, you're going to win for sure, but with this one you can win two tokens, two tokens instead of one, and your chances are...pretty good, at least 75%, and I'll gamble on it." In contrast, the 12-year-old selected the sure thing giving the following reasons: "I would pick this one because...umm...not only you can't lose, but you can win, and this one [the one with two tokens] I wouldn't pick because...umm...sometimes it might go on the white one, and nothing would happen, but still this one you can win more."

Next, the use of different rules across the three age groups was tabulated for gains (Figure 12a) and for losses (Figure 12b). Several comparisons were made between and within the different age groups to determine the prevalence of different strategies, and the effectiveness of those strategies. Initially two comparisons were made between the groups for each of the data sets using the Kolmogorov-Smirnov two-sample test (Siegel, 1956). Because two comparisons were carried out within a single data set, Bonferroni's inequality was used to adjust the alpha level for the individual tests; the adjusted alpha level was set to .05/2 = .025 (Hays, 1981, p. 435). The adjusted level provides .05 protection for tests involving gains, and an equal level for tests involving losses.

Rule usage for the 8-year-old subjects was compared to that of the 12-year-old subjects for both gains and losses. It was found that 8-year-olds consistently made use of lower level rules than the 12-year-olds for both gains ($D = 10$, $p < .025$) and losses ($D = 10$, $p < .025$). However, when rule usage for the 12-year-old subjects was compared to that of the 19-year-old subjects for gains and losses, the differences between these two groups was not significant for either gains ($D = 5$, $p > .025$), or for losses ($D = 8$, $p > .025$).

The Fisher exact probability test (Siegel, 1956) was used to isolate the nature of the differences between the 8-year-olds and the 12-year-olds. The Fisher exact probability test can be used to determine the exact probability of observing a particular set of frequencies "when the scores from two independent random samples all fall into one or the other of two mutually exclusive classes" (Siegel, 1956, p. 96). The proportion of 8-year-olds who made use of two-dimensional strategies (Rules 3 or 4) versus those who made use of lower level strategies (Rules 0, 1, or 2) was compared to proportion of

12-year-olds who made use of these different strategies. The proportions differed significantly between the two groups for both gains ($p = .004$) and losses ($p = .023$). In both cases the younger subjects made significantly less use of two-dimensional rules than the older subjects did. However, within those subjects who were classified as using a two dimensional strategy, the proportion who used Rule 3 versus Rule 4 did not differ significantly between these two groups for either gains ($p = .229$) or for losses ($p = .138$).

Although the Kolmogorov-Smirnov test had indicated that the 12-year-olds and the 19-year-olds did not consistently differ in their rule usage, because all the 19-year-old subjects fell into one of three categories, there was some concern that the test might not have been sensitive enough to pick up important differences in strategy usage by these two groups. "In the use of the Kolmogorov-Smirnov test...it is well to use as many intervals as are feasible. When too few intervals are used, information may be wasted" (Siegel, 1956, p. 128).

To determine if there were systematic differences between the two older groups which the Kolmogorov-Smirnov test had missed, two proportional comparisons were made using the Fisher exact probability test. The initial comparison was consistent with the results of the Kolmogorov-Smirnov test. The proportion of subjects who made use of a one-dimensional strategy (Rules 1 or 2) versus a two-dimensional strategy (Rules 3 or 4) did not differ significantly between these two groups for gains ($p = .248$), or for losses ($p = .377$). However, within those subjects classified as using a two-dimensional strategy, the proportion of subjects using Rule 3 was significantly higher in the 12-year-old group than in the 19-year-old group for both gains ($p = .009$) and for losses ($p = .018$). This indicates that, although the 12-year-olds frequently use of a two-dimensional strategy in non-reoccurring concurrent choice settings,

	Rule 0	Rule 1	Rule 2	Rule 3	Rule 4
8-year-olds	2	6	6	7	4
12-year-olds	0	0	4	9	12
19-year-olds	0	0	7	1	17

Figure 12a. Tabulation of rule use by age group in Study 4 (gains). Each cell contains the frequency count of individuals in each age group who were classified as using a particular rule.

	Rule 0	Rule 1	Rule 2	Rule 3	Rule 4
8-year-olds	**3**	**10**	**3**	**7**	**2**
12-year-olds	**0**	**3**	**5**	**8**	**9**
19-year-olds	**0**	**0**	**6**	**2**	**17**

<u>Figure 12b</u>. Tabulation of rule use by age group in Study 4 (losses). Each cell contains the frequency count of individuals in each age group who were classified as using a particular rule.

they may be less efficient than the 19-year-olds in executing this type of strategy.

Finally, rule usage for gain and loss problems was tabulated (Figure 13). When different rules were used in each domain, the rule used for loss problems tended to be a lower rule than the one used on gain problems (sign test 19/27, p = .03). This result suggests that the understanding of gain and loss problems may show horizontal décalage. Horizontal décalage is the term Piaget used to describe non-synchronous cognitive development with respect to tasks having equivalent problem structures. This horizontal décalage may occur in two different ways: (a) individuals may attempt the same basic type of strategy (one-dimensional or two-dimensional), for both types of problems, but they may be less effective in executing the strategy on loss problems, or (b) individuals may use different basic types of strategies when evaluating gain and loss questions (i.e., a two-dimensional strategy for gains and a one-dimensional strategy for losses).

To understand why different strategies might be used in evaluating gain and loss problems, it is necessary to look at the differences in information-processing demands for each of these problem types. First, consider individuals who are successful at executing a two-dimensional strategy (Rule 4) for questions involving gains. For these individuals to select the better alternative on loss problems they must have: (a) the ability to compare two negative quantities, and (b) the understanding that the alternative which offers the smaller loss is better. These additional skills may develop later than the ability to combine the two problem dimensions in a reliable and consistent manner. As a result, even though these individuals are able to combine the two problem dimensions effectively, the selection pattern on loss problems may correspond to the pattern predicted based on a Rule 3

Rule for Gain Problems

Rule for Loss Problems

	Rule 0	Rule 1	Rule 2	Rule 3	Rule 4
Rule 0	1	1	0	1	0
Rule 1	0	5	3	4	1
Rule 2	0	0	8	1	5
Rule 3	0	0	4	10	3
Rule 4	1	0	2	1	24

Figure 13. Tabulation of rule use for gain and loss questions (Study 4). Each cell contains the frequency count of individuals who were classified as using that particular rule.

understanding of decision problems.

A similar effect may also occur for individuals who are able to successfully execute a serial, one-dimensional strategy for questions involving gains (Rule 2). When loss questions are evaluated, the observed selection pattern may correspond to the pattern predicted based on a Rule 1 understanding of decision problems.

Alternatively, individuals who consider both problem dimensions for gain problems, and who are able combine these dimensions in some way (Rule 3 or Rule 4), may lack the ability to carry out similar types of evaluations when negative quantities are involved. As a result, some individuals may rely on fall-back strategies (cf. Siegler, 1983) for loss questions. Rather than attempting to combine the problem dimensions, these individuals may process the dimensions serially. As a result, their selection patterns for questions involving gains and losses will be consistent with the use of qualitatively different strategies.

Conclusions

This study provided further evidence that the proposed rule-based model may provide an accurate description of decision making in non-reoccurring, concurrent choice situations. The decision patterns of 70 of the 75 subjects were consistent with patterns predicted on the basis of the rule-based model, for both gain and loss problems. For one subject (8-year-old subject #9) the decision pattern for loss problems was not predicted on the basis of the model. However, a further analysis of this subject's pattern of selections indicated that an amount strategy was being used on loss problems, but that the larger loss, rather than the smaller loss, was being selected. The data from this subject show the importance of including dominated problems in the problem set. For the non-dominated problems the decision pattern for this subject was identical to the decision pattern for individuals who used either Rule 1P or 2P; only when the decision pattern for dominated problems was analyzed was it apparent that an amount strategy was being used, and executed opposite to predictions. Four other 8-year-olds made SOPs on no-conflict problems, but their decision patterns on the remaining problems were inconsistent with patterns which would be anticipated if either relevant problem dimension was consistently being used to make selections.

The verbal protocols collected in this study provided converging evidence for the classification scheme; however the reasons provided by those subjects classified as using either Rule 3 or Rule 4 contained a significantly higher proportion of probability-based statements than amount-based statements. This finding is consistent with findings from earlier studies which used only conflict-equivalence problems (see for example, Kahneman & Tversky, 1979, 1984; Tversky & Kahneman, 1981). In these studies the majority of the subjects solved both gain and loss problems on the basis of probability of occurrence.

This study also provided an indication of the way in which decision-making skills develop. The strategies used by the youngest children differed qualitatively from the strategies used by those children in the middle age group, a significantly higher proportion of the 8-year-olds relied on a one-dimensional strategy. However, the two younger age groups did not differ quantitatively in their ability to execute a two-dimensional strategy when this type of strategy was used.

The strategies used by the children in the middle age group did not differ qualitatively from the strategies evident in the subjects in the oldest age group, both groups relied predominantly on a two-dimensional strategy for both gain and loss problems. However, the ability to execute a two-dimensional strategy successfully did differ between these two groups, with the 12-year-olds being significantly less successful than the 19-year-olds.

Finally, this study showed that the strategies used to evaluate gain problems may differ from the strategies used to evaluate loss problems; this occurred in just over 1/3 of those tested. When different strategies are used in the two domains, strategies used on loss problems tend to show less sophistication than those used on gain problems, in the majority of cases.

Chapter Six: General Discussion

One of the most striking findings which emerged from these four studies was the lack of empirical support for decision-making models which suggest individuals subjectively discount the probability of occurrence and/or the amount at stake before combining the problem dimensions. The most recently developed economic model of decision making in non-reoccurring, concurrent choice situations is prospect theory (Kahneman & Tversky, 1979). One of the basic assumptions of prospect theory is that decision makers subjectively discount both probabilities and amounts when they evaluate decision problems (see Appendix A). This assumption means that the alternative with the lower expected value on conflict-probability problems should be particularly unattractive, and as a result individuals should not make selections opposite to predictions based on expected value theory (SOPs) on these types of problem; the only SOPs which should be expected will occur on conflict-amount problems.

However, in the series of studies reported here the following results were obtained: (a) in Study 1 nearly two thirds of the subjects (62.6%) made SOPs on conflict-probability gain problems, and over one quarter (28.6%) made SOPs on conflict-probability loss problems; (b) in Study 2 the majority of subjects (58.6%) made SOPs on conflict-probability gain problems, and and nearly all (93.1%) made SOPs on conflict-probability loss problems; (c) in Study 3 almost one third of the subjects (30.0%) made SOPs on conflict-probability gain problems, and nearly two thirds (65.0%) made SOPs on conflict-probability loss problems. These results indicate that decisions that are inconsistent with the basic assumptions of prospect theory are common in non-reoccurring, concurrent choice situations. Also, in Study 3 only one subject made choices on conflict-equivalence problems that were consistent with predictions derived from prospect theory. This is a further indication that the relevant problem dimensions are not being discounted in the manner suggested by prospect theory.

In addition to the evidence that the decision-making process differs from the process suggested by prospect theory, these studies also provided evidence that the decision-making process may differ within subjects, for gain and loss problems. In Study 1, nearly two thirds of the subjects (64.5%) had different patterns of selections for gain and loss questions; in Study 2 just less than half the subjects (44.8%) had different selections patterns for gains and losses; and, in Study 3 over one third of the subjects (40%) had different selections patterns on these two types of questions.

Therefore, the results from these three studies suggest two things: (a) strategies other than those suggested by economically-based theories may guide decision behavior in non-reoccurring concurrent choice problems, and (b) individual decision strategies may differ on gain and loss problems. Based on these results, an alternative model of decision making in non-reoccurring, concurrent choice situations was developed. This model assumes that decision strategies of differing complexity may exist, and the simplest of these strategies may be one-dimensional rather than two-dimensional. In the model these differing decision strategies are cast as a series of decision rules. These rules differ in complexity and, in addition to describing different possible decision strategies in adult decision makers, it was hypothesized that the proposed rules might correspond to an increase in the conceptual understanding of non-reoccurring, concurrent choice problems across individuals of different ages.

The rule-based model was evaluated in a cross-sectional study across three age groups, and evidence was found for a developmental sequence in the emergence of decision-making skills. Specifically, it was found that the choices made by the subjects in the youngest age group differed primarily in a qualitative way from the choices made by the subjects in the two older age groups. For gain problems less than half the 8-year-olds (44%) made selections consistent with the use of a two-dimensional strategy, and for loss problems just over one third of the 8-year-olds (36%) appeared to consider both problem dimensions in making their selections. In contrast, over three quarters of the 12-year-olds (84%) made selections consistent with the use of a two-dimensional strategy for gains, and over two thirds (68%) did so for losses. The proportion of 12-year-olds using a two-dimensional strategy is comparable to the proportion of 19-year-olds who made selections consistent with the use of a two-dimensional strategy (72% for gains and 76% for losses). However, the 12-year-olds appeared to differ from the 19-year-olds in their ability to execute the two-dimensional strategy successfully. Of the 12-year-olds who used a two-dimensional strategy, just over half were able to combine the dimensions correctly on gain problems (57%), and a similar proportion were able to do so for loss problems (53%). In contrast, nearly all the 19-year-olds who used a two-dimensional strategy on gain problems executed the strategy successfully (94%), and over three quarters of those who used a two-dimensional strategy on loss problems executed it successfully (89%).

The age-related differences appear to be related to differences in both the strategic understanding the problem situation, and in the ability to execute the chosen strategy successfully. The youngest subjects appeared to have a qualitatively different understanding of the problem situation than the two older groups. In contrast, the two older groups appeared to share the same qualitative understanding of the problem situation; the difference between the two older groups appeared to arise from differences in the ability to execute a two-dimensional strategy successfully.

Therefore, the proposed rule-based model of decision making serves two important functions. First, it describes the decision-making process more completely than current economic models, and takes into account strategies which are less complex than those proposed by economic theories of decision making. Second, it provides a basis for understanding the acquisition of decision-making skills.

At the simplest level, decisions may be made by considering only a single problem dimension, and comparing the available alternatives on this dimension. For example, the subjects who were classified as using Rule 1 on the basis of their error patterns often provided reasons for their choices that indicated the second dimension of the problem might not have been encoded. "If children do not notice variables, it is difficult to see how they could have an intent to use a strategy that incorporates those variables" (Dean & Mollaison, 1986, p. 47). However, it is also possible that these younger children encoded both dimensions, but only utilized part of the information they had available in making a choice. Even if "children notice variables, [it] does not necessarily mean that they understand their relevance for solution" (Dean & Mollaison, 1986, p. 47).

Case (1984) suggests that differences in the ability to utilize more of the available information across age groups results from an increase in operational efficiency. Specifically, less of the available processing space is needed for basic operations such as encoding, and as a result more processing space is available for complex operations. For the two-dimensional problems used in this study this type of explanation would suggest that, even if both dimensions of the problem are encoded, the youngest children will lack the cognitive capacity to combine the dimensions in an efficient way. This type of explanation also suggests that more efficient strategies couldn't be taught to the youngest children because they don't have the resources available to execute complex strategies.

In contrast, Siegler (1983) suggests the use of unidimensional rules does not result from capacity limitations; instead these rules represent a global problem-solving strategy:

> Five-year-olds may utilize a fall-back rule of the following form: If you lack direct information about how to solve a problem on which you are to make a quantitative comparison, it is best to compare the values of the single, seemingly most important dimension and to choose the object with the greater value on that dimension as having more of whatever dimension is being asked about.
>
> Conceptualizing young children's unidimensional approaches as reflecting fall-back rules, as opposed to capacity limitations, suggests reasons why such approaches are observed in some but not all situations. (p. 270)

An explanation of this type suggests that more efficient strategies could be taught to the youngest children. At this point it is not clear whether the one-dimensional strategies result from capacity limitations, or whether they result from a lack of familiarity in dealing with the problem dimensions.

Once the importance of the second problem dimension is understood, this second dimension is incorporated into the basic decision strategy. First, the two dimensions are processed serially (Rule 2), and then they are considered in parallel, and tradeoffs are made between the problem dimensions to estimate which alternative offers the greater expected gain, or the smaller expected loss (Rule 3). If decision-making skills develop in this way, the accuracy of the estimates made by individuals using Rule 3 should be related to the differences in the problem dimensions. When there is a large difference between the alternatives in the probability of occurrence, and a small difference in the amount at stake, probability should control the decision process. Conversely, when there is a large difference between the alternatives in the amount at stake, and a small difference in the probability of occurrence, the amount at stake should control the decision process. When there is a large difference between the alternatives on both dimensions, or when there is a small difference on both dimensions, the accuracy of the estimates will be reduced, and it may be that selections will reverse on repeated presentations of the same problem.

Finally, as individuals gain experience with decision-making situations, and in making tradeoffs between the problem dimensions, the accuracy of the estimates should increase to the point that the final decision rule approximates the decision strategy proposed by expected value theory. Non-optimal decisions which arise at this point may occur because both problem dimensions are not considered equally important in making an optimal decisions. When subjects at this level gave reasons for their selections, the probability of occurrence was mentioned significantly more often than the amount at stake. This type of explanation also accounts for the results from earlier studies which used conflict-equivalence problems to evaluate decision-making in non-reoccurring, concurrent choice situations. Previous studies (e.g., Kahneman & Tversky, 1979, 1984; Tversky & Kahneman, 1981) have found that individuals tend to select the more probable alternative on conflict-equivalence gain problems, and the less probable alternative on conflict-equivalence loss problems.

In addition, within individuals there is evidence of a phenomenon analogous to horizontal décalage, in the ability to solve gain and loss problems. In all the studies a significant proportion of the subjects had different decision patterns on gain and loss problems. When decision patterns were categorized on the basis of the underlying decision rule, the majority of individuals who used different levels of rules in the two domains, used a lower level rule to solve loss problems.

Scardamalia (1977) showed that when the information-processing demands of a task were increased, but the logical structure was not altered, subjects would fail at tasks they had previously been able to solve successfully. She concluded that the failure was due to problems in execution of a strategy, not in understanding the problem because the competence required to successfully complete the task didn't change as the information-processing demands were increased: "[H]orizontal décalages will result when subjects have an appropriate strategy available but the task to be solved exceeds their available capacity by at least one unit."

This offers one possible explanation for within-subject differences in rule use. The problems involving the evaluation of losses may have higher information-processing demands than the problems which involve gains. Not only must the problems dimensions be processed, but it is also necessary to compare negative quantities when the final selections are made. Comparing negative, rather than positive quantities, may increase the information processing demands of the decision task, and as a result individuals: (a) may be less successful at executing the same strategy on loss problems, or (b) may fall back on less complex, and hence less demanding decision strategies.

Although a developmental progression through the various rules was evident across the age groups tested in the fourth study, some issues remain unresolved. At this point it is not clear whether an amount-based versus a probability-based focus in decision problems is an individual difference variable, or whether amount-based decisions precede, and are replaced by probability-based decisions. In order to assess this aspect of the development of decision-making skills a longitudinal study is required In addition, longitudinal testing is required to: (a) determine if decision strategies develop in the manner outlined, and (b) to delineate how decision-making strategies for gain and loss problems develop, within individuals. However, despite these unanswered questions, the evidence provided by this series of studies suggests that the process underlying decision making in non-reoccurring, concurrent choice situations may be more accurately described by a rule-based model, than by current economic models of decision making.

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Appendix A: Development of Expectancy-based Theories of Decision Making

Empirical research in this area has typically focused on testing formal theories of the processes believed to underlie decision making. The goal of the formal theories has been to specify, in advance, what the optimal decision would be in a given situation, or what would constitute a rational choice. Each of the theories is predicated on the belief that individuals make rational, optimal decisions, within the confines of certain cognitive constraints. The theories differ in the nature of the cognitive constraints they postulate. However, each of the theories defines rationality in a similar way, and observed decisions can be compared to predictions generated on the basis of each of the theoretical formulations. This allows researchers to determine whether or not the observed decisions were optimal, or rational, within the confines of each theory. The theories have evolved over time, with simpler theories forming the basis for more complex theories as stable, systematic violations of basic axioms were shown to exist.

Expected Value Theory

One of the earliest formulations of decision making is expected value theory, which was developed from basic probability theory. The expected value of an alternative with probabilistic consequences is determined by summing across all the values of the possible outcomes, each weighted by its own probability of occurrence:

$$EV = \Sigma(p_i)(V_i)$$

It was assumed that when an individual faced a choice between two probabilistic alternatives, he or she would decide in a manner which maximized the expected value. To illustrate, suppose an individual with current assets of $100.00 is faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will receive $25.00, and if the coin turns up "tails" the individual will receive nothing. However, if the individual prefers, he or she can accept a $10.00 payment and the coin toss will not take place. In this example the expected value of the individual's final assets if he or she chooses the risky alternative is .5($125.00) + .5($100.00) = $112.50, and the expected value of the final assets if the certain alternative is chosen is 1.0($110.00) = $110.00. Therefore, an individual deciding on the basis of expected value theory will accept the risky alternative, because this is the alternative which will maximize his or her expected assets.

However, suppose the same individual is now faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will pay out $25.00, and if the coin turns up "tails" the individual will pay out nothing. However, if the individual prefers, he or she can pay out $10.00 and the coin toss will not take place. In this example the expected value of the risky alternative is .5($75.00) + .5($100.00) = $87.50, and the expected value of the certain alternative is 1.0($90.00) = $90.00. Therefore, an individual deciding on the basis of expected value theory will reject the risky alternative, and instead decide to pay out the certain amount; the certain alternative will minimize his or her expected loss, therefore maximizing expected value.

In the event that the risky alternative and the certain alternative have the same expected value, the individual will be indifferent between the alternatives; in all other instances he or she will choose in a manner which maximizes gains, or minimizes losses. The predicted behavior, when an individual must decide between a certain alternative and a risky alternative, based on expected value theory, is presented graphically in Figure A-1.

The expected value of the certain alternative is shown on the vertical axis and the expected value of the risky alternative is shown on the horizontal axis. In all cases, when the expected value of the risky alternative is less than the

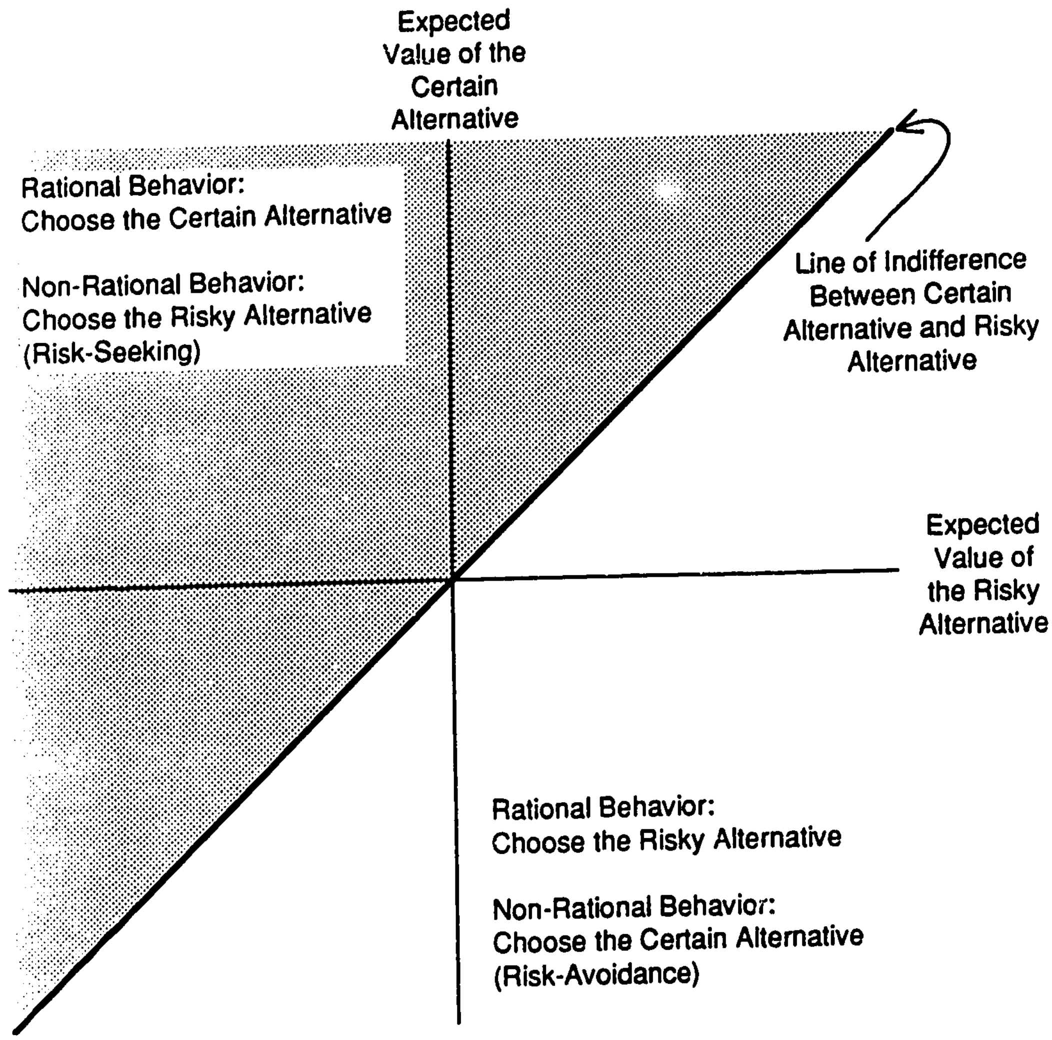


Figure A-1. Predicted decision behavior based on expected value theory.

expected value of the certain alternative (the area above the diagonal indifference line) the rational decision is to select the certain alternative; when the expected value of the risky alternative is greater than the expected value of the certain alternative (the area below the diagonal indifference line) the rational decision is to select the risky alternative.

However, Bernoulli (1738) showed expected value theory could not explain a phenomenon known as the St. Petersburg paradox. The St. Petersburg paradox occurs when an individual is asked to bet on a fair coin, which has a 50% probability of coming up "heads" on each independent toss. The coin is tossed repeatedly, and the individual receives 2^n dollars if the first head occurs on trial $\underline{n}$. In this situation the expected value of the risky alternative sums to an infinite number. Therefore, according to expected value theory, an individual should be willing to pay any amount to play; Bernoulli found few people were willing to pay even the equivalent of $100 to play.

Expected Utility Theory

This led Bernoulli (1738) to speculate that the determination of worth is not based on objective values (V), but instead on subjective values (U), which he termed "utilities." He suggested that rather than maximizing expected value, individuals were maximizing expected utility. The expected utility of an alternative with probabilistic consequences is determined by summing across all the utilities of the possible outcomes, each weighted by its own probability of occurrence:

$$EU = \Sigma(p_i)(U_i)$$

Specifically, Bernoulli (1738) suggested the utility resulting from an incremental change in wealth would be inversely proportional to the quantity of goods previously possessed. This inverse relationship is now referred to as "the law of diminishing marginal utility." According to economic theory, the more of any commodity an individual possesses, be it money or a consumer good, the less satisfaction is derived from each additional unit. Even though the individual's total satisfaction may continue to increase, the incremental increase in satisfaction becomes progressively smaller (Crane, 1980). Hence, a change in assets from $90 to $100 would have more impact than a change in assets from $100 to $110 (Figure A-2).

If individuals do, in fact, substitute total utilities for the objective values presented in a decision problem, and if the marginal utility of money is a continually decreasing function, the pattern of individual choices will not correspond to that predicted on the basis of expected value theory. Specifically, when an individual must decide between a certain alternative and a risky alternative which have equal objective expected values, he or she will not be indifferent between the alternatives, as would be predicted on the basis of expected value theory. Instead, in all cases, the individual will select the certain alternative.

The rationale for deciding in this manner in a gain situation is based on the fact each incremental increase in wealth will be viewed as being worth proportionately less than the previous incremental increase: $\mu(2y) < 2[\mu(y)]$, where $\mu(y)$ is the total utility an individual derives from monetary assets which have an objective value equal to $\underline{y}$. In a decision situation which offers a choice between (a) obtaining asset position $\underline{x}$ for certain, or (b) accepting a chance at obtaining asset position $\underline{y}$ with probability $\underline{p}$, and remaining at the current asset position $\underline{z}$ with probability 1-$\underline{p}$, where $(1-p)(z) + p(y) = 1.0(x)$, and $z < x < y$, the total expected utility of the risky alternative will always be less than the total expected utility of the certain alternative.

To illustrate, suppose an individual with current assets of $100.00 is faced with the following situation: A fair coin is to be tossed, if the coin turns up

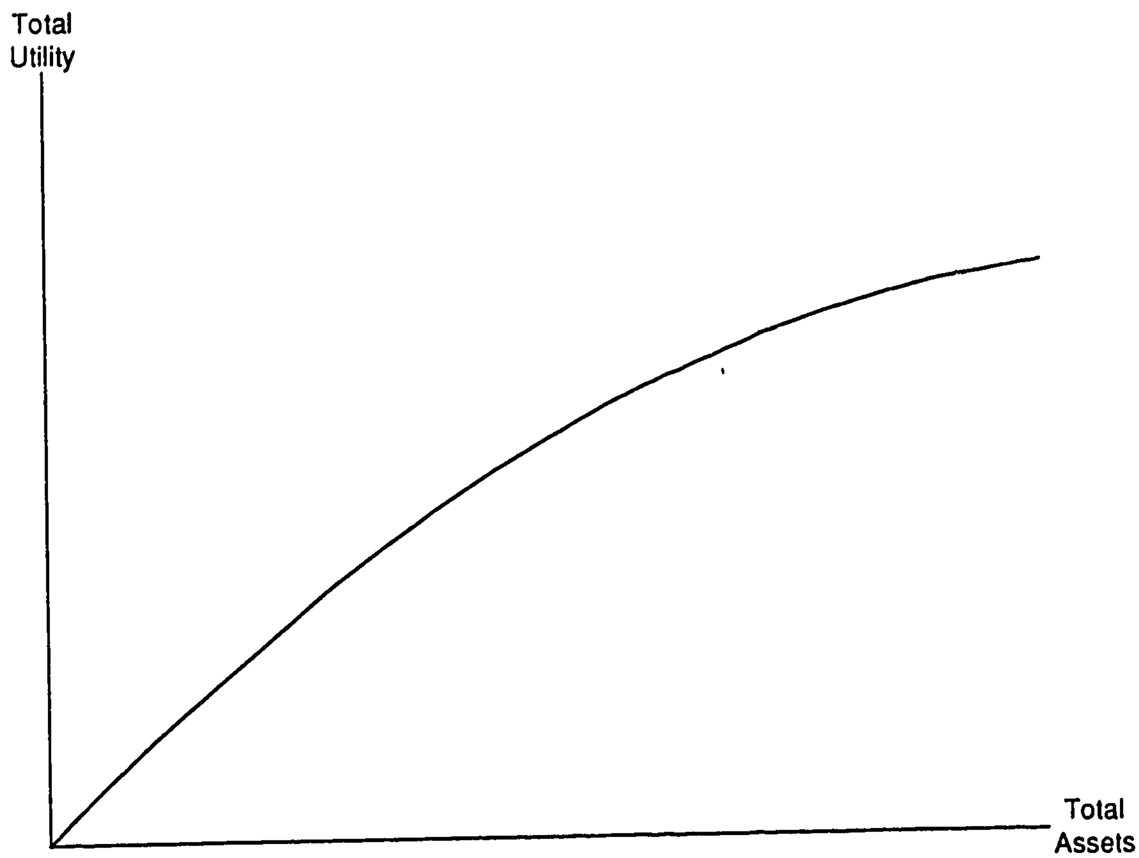


Figure A-2. Typical utility function.

"heads" the individual will receive $20.00, and if the coin turns up "tails" the individual will receive nothing. However, if the individual prefers, he or she can accept a $10.00 payment and the coin toss will not take place. In this example the total expected value of the risky alternative is .5($120.00) + .5($100.00) = $110.00, and the total expected value of the certain alternative is 1.0($110.00) = $110.00. Therefore, the individual should be indifferent between the two alternatives.

But, if the marginal utility derived from a gain of $20.00 is not equal to twice the marginal utility derived from a gain of $10.00, and the individual decides based on total expected utilities instead of total expected values, a different outcome will be predicted. In this case, according to law of diminishing marginal utility, we should deflate each of the objective values. In addition, the amount of the deflation will become progressively larger as the objective values increase.

When the individual is evaluating the gain situation, a deflation of this type might result in a total expected utility for the risky alternative of .5(.945)($120.00) + .5(.955)($100.00) = $104.45, and a total expected utility for the certain alternative of 1.0(.950)($110.00) = $104.50. The actual value selected for the deflation isn't critical, as long as the marginal utility derived from an increase of $20.00 is less than twice the marginal utility derived from an increase of $10.00. Therefore, by postulating a continuously decreasing marginal utility function, and by postulating that the individual will base his or her decisions on total expected utilities rather than on total expected values, expected utility theory leads to the following prediction: When two alternatives have equal expected values, an individual will always choose the certain alternative over the risky alternative in a gain situation.

It can be shown that an individual will also select the certain alternative when he or she must decide between alternatives with equal expected values in a loss situation. The rationale for also selecting the certain alternative in a loss situation is based on the fact that each incremental decrease in wealth is viewed as being proportionately larger than the previous decrease (i.e., more negative): $\mu(-2y) < 2[\mu(-y)]$. In a decision situation which offers a choice between (a) obtaining asset position -_x_ for certain, or (b) accepting a chance at obtaining asset position -_y_ with probability _p_, and remaining at the current asset position _z_ with probability 1-_p_, where $(1-p)(z) + p(-y) = 1.0(-x)$, and $z > x > y$, the total expected utility of the risky alternative will always be less than the expected utility of the certain alternative.

To illustrate, suppose an individual with current assets of $100.00 is faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will pay out $20.00, and if the coin turns up "tails" the individual will pay out nothing. However, if the individual prefers, he or she can pay out $10.00 and the coin toss will not take place. In this case the expected value of the risky alternative is .5($80.00) + .5($100.00) = $90.00, and the expected value of the certain alternative is 1.0($90.00) = $90.00. Therefore, on the basis of expected value theory, the individual should be indifferent between the two alternatives.

But, if the negative marginal utility derived from paying out $20.00 is more than twice the negative marginal utility derived from paying out $10.00, and the individual decides based on total utilities instead of total objective values, a different outcome will be predicted. In this case, according to law of diminishing marginal utility, we should again deflate each of the objective values. In addition, the amount of the deflation will become progressively smaller as the objective values decrease. When the individual is evaluating a loss situation, a deflation of this type might result in a total expected utility for the risky alternative of .5(.965)($80.00) + .5(.955)($100.00) = $86.35, and an expected utility for the certain alternative of 1.0(.960)($10.00) = $86.40.

Again, the actual value selected for the deflation isn't critical. As long as the negative marginal utility derived from paying out $20.00 is more than twice the negative marginal utility derived from paying out $10.00, expected utility theory leads to the following prediction: When two alternatives have equal expected values, an individual will always choose the certain alternative over the risky alternative in a loss situation.

The change in predicted behavior, when an individual must decide between a certain alternative and a risky alternative, based on expected utility theory is presented graphically in Figure A-3. The boundaries dividing the graph into two areas have been adjusted to account for the substitution of total utilities for stated objective values. These utilities are postulated to be lower than the associated objective values in all cases, and to decrease as objective values are increased.

As a result, the indifference line in the area of gains is now concave, indicating in instances where the objective expected values are equal, the rational decision based on expected utilities will be to select the certain alternative. In addition, as one moves farther away from the origin, the proportional net gain offered by the risky alternative must be larger before it will be selected. In the loss quadrant of the graph the indifference line is also concave, indicating in instances where the objective expected values are equal, the rational decision based on expected utilities will be to select the certain alternative. In addition, as one moves farther away from the origin, the proportional decrease in net loss offered by the risky alternative must be larger before it will be selected.

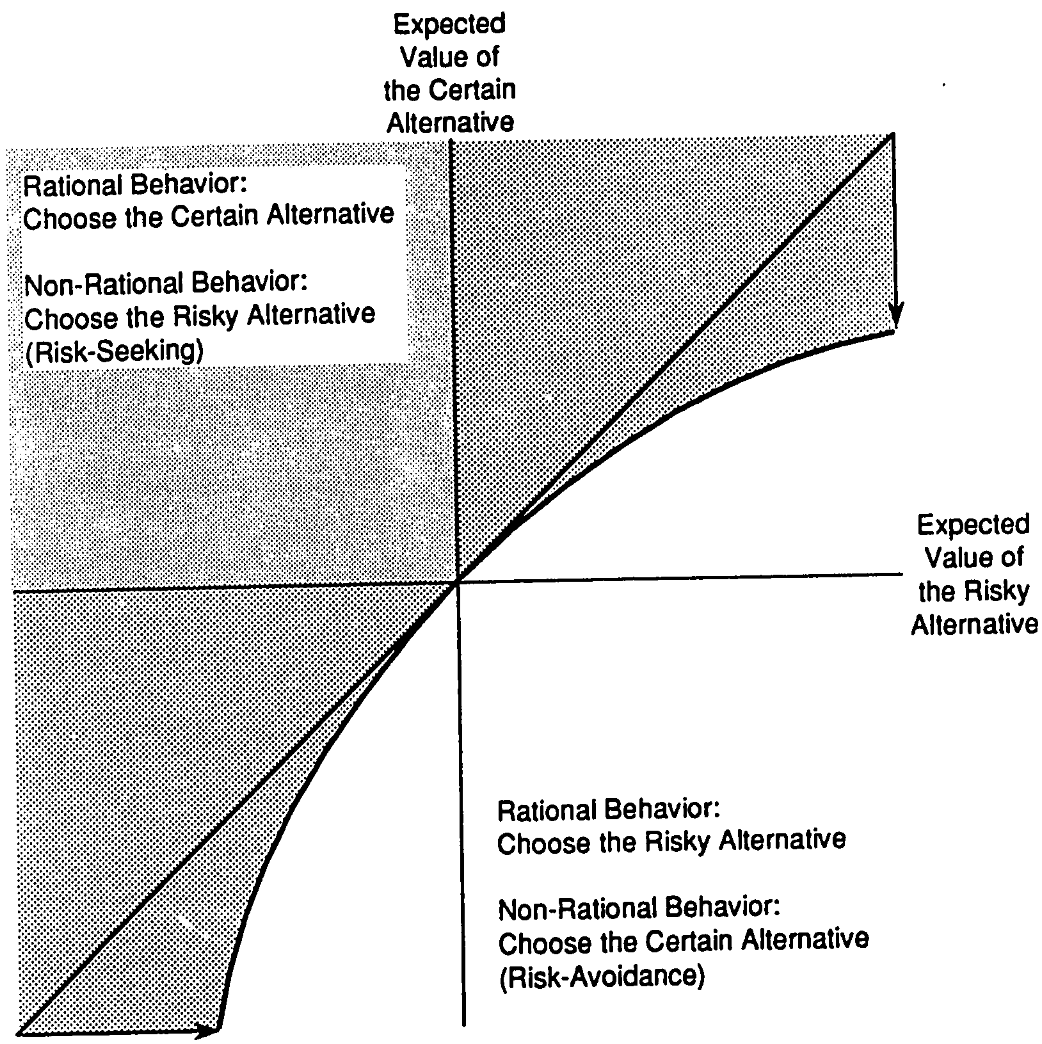


Figure A-3. Predicted decision behavior based on expected utility theory. Arrows (⟶) indicate increase in the area where the rational decision is to choose the certain alternative, relative to predictions based on expected value theory.

An individual who selects the certain alternative over the risky alternative, when each alternative has the same expected value is described as "risk-averse." Therefore, one behavioral prediction which arises from the substitution of total utilities for objectively presented values in decision making is: Individuals will consistently make risk-averse decisions when presented with two alternatives which have the same objective expected value, if one of the alternatives is to be received with certainty, and the other alternative has a probability of occurrence which is less than one.

Two hundred years after Bernoulli first suggested decisions were based on utility rather than value, von Neumann and Morgenstern (1947) developed a set of axioms to describe rational decisions, based on expected utility theory. Their basic axioms are:

1. Preferences between alternatives can be ordered.

2. Preferences are transitive; if alternative *A* is preferred to alternative *B*, and alternative *B* is preferred to alternative *C*, then alternative *A* will also be preferred to alternative *C*.

3. A person prefers a sure thing, *A*, to a gamble that could give him or her *A* at best, and might give him or her a less valued consequence *B*, and a person prefers a gamble that could give him or her *A* at worst, and possibly could give him or her the preferable consequence *B*, to the sure thing *A*.

4. In a choice between a sure thing and a gamble involving consequences more and less desirable, a value of *p* exists such that the sure thing is preferred, and a value of *p* exists such that the gamble is preferred.

5. The order in which the components of a gamble are listed does not affect preference.

6. The form of a gamble, "normal" or "compound," has no effect on preference.

These axioms imply that although one may not be able to predict isolated decisions on the basis of expected utility theory, one can make predictions about the pattern of decisions. The overall pattern should represent a consistent ordering, even though isolated decisions may appear non-rational when evaluated according to expected value predictions.

To illustrate, suppose an individual is offered the following choice: (a) receive $10.00 for certain, or (b) accept a 60% chance of receiving $20.00 and a 40% chance of receiving nothing. If the individual refuses the risky alternative in this situation, one can predict they will also refuse the risky alternative if the dollar value of this alternative is reduced to less than $20.00. On the other hand, if the individual accepts the risky alternative, one can predict they will also accept the risky alternative if the dollar value of this alternative is increased beyond $20.00.

In addition, suppose an individual is offered the following choice: (a) pay out $10.00 for certain, or (b) accept a 40% chance of paying out $20.00 and a 60% chance of paying out nothing. If the individual refuses the risky alternative in this situation, one can predict they will also refuse the risky alternative if the dollar value of this alternative is increased beyond $20.00. On the other hand, if the individual accepts the risky alternative, one can predict they will also accept the risky alternative if the dollar value of this alternative is reduced to less than $20.00. Therefore, even though isolated decisions may appear non-rational on the basis of expected value theory, the general decision pattern will still be a consistent one if the individual is choosing in a rational manner.

One of the underlying assumptions of expected utility theory is that the utility associated with a particular amount of money will be constant for an individual within a given situation. However, utilities may differ between individuals, and the utility for a given amount of money may also change for a single individual over time. In order to determine an individual's utility function at any given time, it is necessary to present him or her with several series of decisions. Each of these series would require choices between a given certain alternative and a risky alternative in which the probability of occurrence is held constant, and the dollar values are systematically varied. The definition of an individual's utility function would require the isolation of at least three stable points of indifference. If utility decreases in a non-linear manner, a minimum of three points will be needed to fit the function. In addition, utilities can only be calculated at points of indifference. These points of indifference would correspond to cross-over points where an individual shifted from accepting the risky alternative to refusing the risky alternative within a given series of choices containing the same certain alternative, and where the probability of the risky alternative occurring was held constant.

Expected utility theory was able to address some of the paradoxes in decision making which had been uncovered by the early 18th century. But expected utility theory could not explain why an individual would accept a fair bet which involved a small probability of winning a large sum of money. Based on expected utility theory, these types of bets should be especially unattractive.

Subjective Expected Utility Theory

Edwards (1953; 1954a; 1954b; 1954c) attempted to explain why these unattractive types of bets might be selected. His studies indicated subjects were particularly prone to overestimation of probabilities on bets involving long-shots.

These results confirm findings from an earlier study by Preston and Baratta (1948) who postulated that subjects utilized an s-shaped probability function, rather than utilizing the objective probabilities in risk situations. Specifically, they found subjects tended to overestimate low odds and underestimate high odds, with an indifference point, where subjective probabilities equaled objective probabilities, at about 0.2. Similar results were later reported by Griffith (1949), Attneave (1953), and Sprowls (1953). Edwards argued that if it was reasonable to substitute subjective values (utilities) for objective values, it was equally reasonable to substitute subjective probability estimates (p^*) for objective probabilities (p). This led to the formulation of subjective expected utility, which also suggested individuals faced with a risky decision arrive at the worth of an expected outcome through probabilistic reasoning. The subjective expected utility of an alternative with probabilistic consequences is determined by summing across all the utilities of the possible outcomes, each weighted by its own subjective probability of occurrence:

$$SEU = \Sigma(p_i^*)(U_i)$$

These subjective expected utilities are then compared, and the alternative which maximizes gains, or which minimizes losses, is chosen. The rules and operations governing subjective probabilities are the same as those governing objective probabilities (Harnett, 1982, p. 57). Therefore, the probabilities for complementary events will sum to one: $(p^*) + (1-p^*) = 1.0$. This axiom means individuals who overestimate the probability of an event occurring must also underestimate the probability of its non-occurrence, and individuals who underestimate the probability of an event occurring must also overestimate the probability of its non-occurrence.

Incorporating subjective probability estimates into the original expected value theory will result in a pivoting of the indifference line shown in Figure A-1. When subjective probability estimates are lower than the corresponding objective probabilities ($p > .20$ according to Preston & Baratta, 1948), the slope of the indifference line will be less than one (Figure A-4a); when subjective probability estimates exceed objective probabilities ($p < .20$ according to

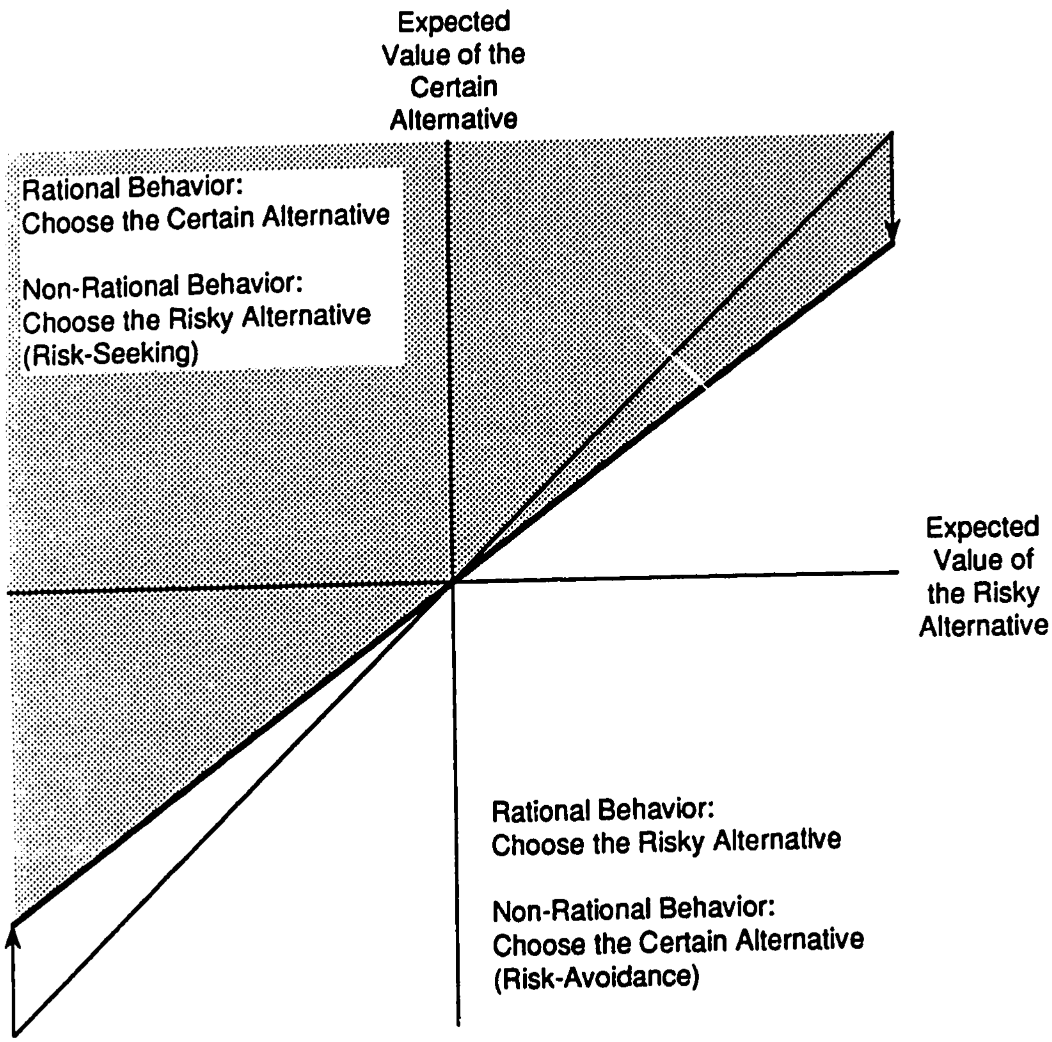


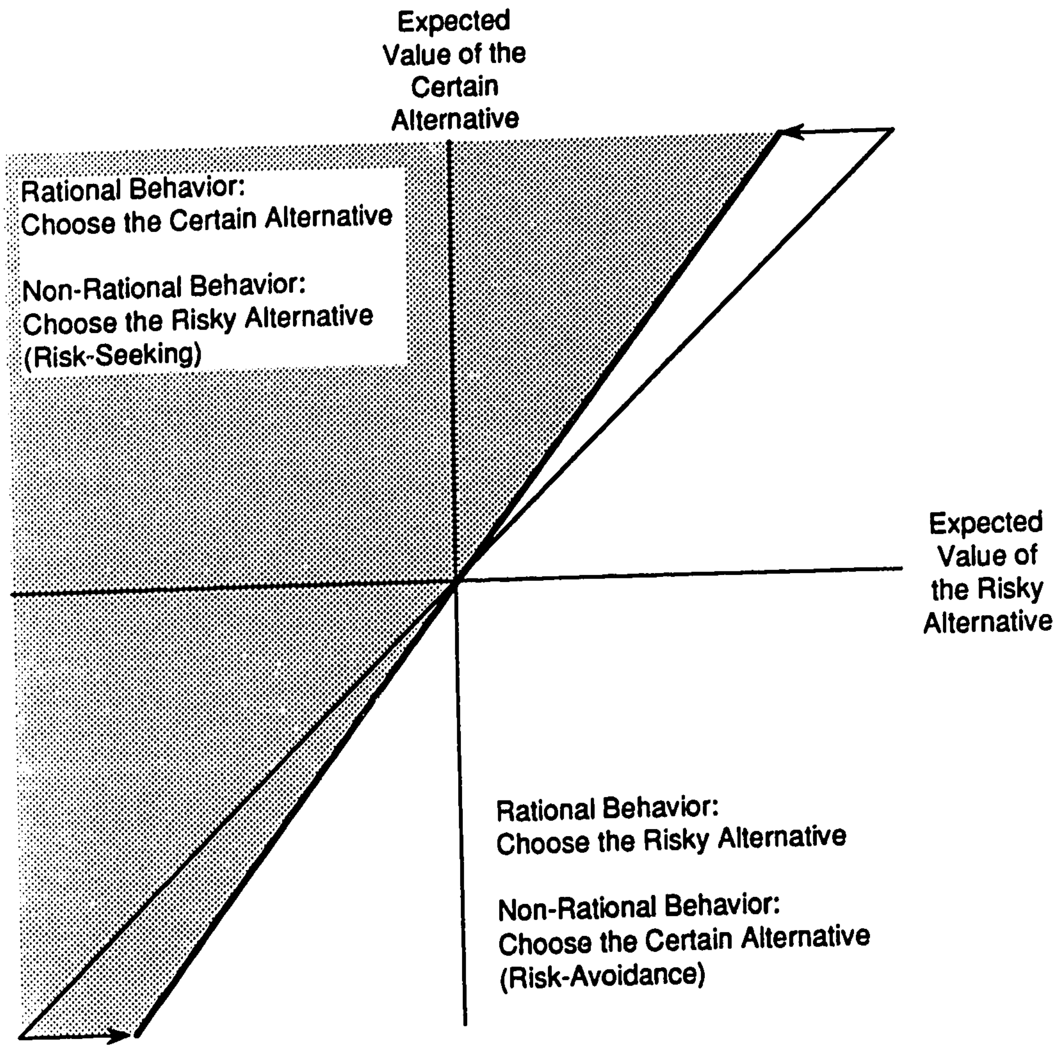
Figure A-4a. Predicted decision behavior when objective probabilities are underweighted. Arrows (——➤) indicate the direction of change in the line of indifference, relative to expected value theory.

Preston & Baratta, 1948), the slope of the indifference line will be greater than one (Figure A-4b).

This means, for situations involving objective probabilities greater than approximately .20, an individual who utilizes objective values and subjective probability estimates when deciding between a certain alternative and a probabilistic alternative of equal objective expected value, will show some evidence of risk-aversion for gains and risk-seeking for losses. Conversely, for situations involving objective probabilities less than approximately .20, an individual who utilizes objective values and subjective probability estimates when deciding between a certain alternative and a probabilistic alternative of equal objective expected value, will show some evidence of risk-seeking for gains and risk-aversion for losses.

However, subjective expected utility theory also incorporated the marginal utility function originally postulated by expected utility theory. If individuals do substitute subjective probability estimates and utilities, for the objective measures in a decision problem, the pattern of individual choices will not correspond to that predicted on the basis of either of the previous theories. Specifically, when an individual must decide between a certain alternative and a risky alternative which have equal expected values, he or she will not be indifferent between the alternatives, however the individual may not be uniformly risk-averse. When subjective probability estimates underweight objective probabilities there may be evidence of risk-seeking for losses, and when subjective probability estimates overweight objective probabilities there may be evidence of risk-seeking for gains.

To illustrate, we will reconsider the example presented in the previous section. For illustrative purposes, the objective probability of .5 will first be underweighted, and then overweighted. This is not strictly in accordance with



<u>Figure A-4b</u>. Predicted decision behavior when objective probabilities are overweighted. Arrows (⟶) indicate the direction of change in the line of indifference, relative to expected value theory.

the assumptions of subjective expected utility theory, but utilizing the same objective probability provides a clearer example of how the use of subjective probability estimates can influence decision making.

Suppose an individual with current assets of $100.00 is faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will receive $20.00, and if the coin turns up "tails" the individual will receive nothing. However, if the individual prefers, he or she can accept a $10.00 payment and the coin toss will not take place. First, we must deflate the objective values to allow for the use of utilities. Second, we must also deflate the objective probability associated with the risky alternative, to allow for the underweighting of high probabilities postulated by Edwards.

A deflation of this type might result in a total subjective expected utility for the risky alternative of .4(.945)($120.00) + .6(.955)($100.00) = $102.66, and a total expected utility for the certain alternative of 1.0(.950)($110.00) = $104.50. The actual value selected for the deflation isn't critical. Because the substitution of total utilities for objective values would result in risk aversion in this instance, underweighting of the objective probability associated with the risky alternative simply increases the perceived difference between the risky alternative and the certain alternative; the decision remains the same, avoid the risky alternative in this situation.

Suppose, instead of receiving money, an individual with current assets of $100.00 is faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will pay out $20.00, and if the coin turns up "tails" the individual will pay out nothing. However, if the individual prefers, he or she can pay out $10.00 and the coin toss will not take place. In this case we must also deflate both the objective values (to allow for the substitution of utilities) and the objective probabilities (to allow for subjective probability estimates which underweight the objective probabilities). A deflation of this type might result in a total subjective expected utility for the risky alternative of .4(.965)($80.00) + .6(.955)($100.00) = $88.18, and an expected utility for the certain alternative of 1.0(.960)($10.00) = $86.40. In this case, the amount of underweighting which occurs will affect the final decision. Underweighting of probabilities in a loss situation tends to negate the deflationary effect due the decreasing utility associated with large sums, and may result in the acceptance of risky alternatives which would be rejected if either expected value or expected utility calculations formed the basis of the decision process.

Now, suppose an individual with current assets of $100.00 is faced with the same two situations, but this time we will treat the objective probability associated with the risky alternative as if it were low (approximately $p < .20$) and allow for a subjective probability estimate which is higher than the stated value. How will this affect the decision outcome? When the individual is evaluating the gain situation, an overweighting of this type might result in a total subjective expected utility for the risky alternative of .6(.945)($120.00) + .4(.955)($100.00) = $106.24, and a total expected utility for the certain alternative of 1.0(.950)($110.00) = $104.50. In this case, the amount of overweighting which occurs will affect the final decision. Overweighting of probabilities in a gain situation tends to negate the deflationary effect due the decreasing utility associated with large sums, and may result in the acceptance of risky alternatives which would be rejected if either expected value or expected utility calculations formed the basis of the decision process.

However, when the individual is evaluating a loss situation, an overweighting of this type might result in a total subjective expected utility for the risky alternative of .6(.965)($80.00) + .4(.955)($100.00) = $84.52, and an expected utility for the certain alternative of 1.0(.960)($10.00) = $86.40. The actual value selected for the overweighting isn't critical in this instance. Because the substitution of total utilities for objective values would result in risk aversion, overweighting of objective probabilities simply increases the perceived difference between the risky alternative and the certain alternative, but the decision remains the same, avoid the risky alternative in this situation.

The change in decision-making behavior predicted by the integration of these two theoretical assumptions into a single theory of decision making is presented graphically in Figures A-5a and A-5b. The incorporation of subjective probability estimates into a rational decision theory will result in a series of decision functions; there is no longer a unique indifference line.

When the risky alternative has a high probability of occurrence (Figure A-5a), the indifference line from the expected utility theory will be pulled down above the origin, so that it lies even closer to the abscissa. In addition, the indifference line from the expected utility theory will be pulled up below the origin, so that it also lies closer to the abscissa, and at some points the indifference line may lie above the diagonal. At the points where the indifference line lies above the diagonal, the individual will select the risky alternative over the certain alternative, even though both outcomes have the same objective expected value. This type of behavior is described as risk-seeking.

When the risky alternative has a low probability of occurrence (Figure A-5b), the indifference line from the expected utility theory will be pulled upwards above the origin, so that at some points it may actually lie above the diagonal. And the indifference line from the expected utility theory will be pulled downwards below the origin, so that it lies even farther from the abscissa.

Therefore, two behavioral predictions which arise from the substitution of subjective probability estimates for objective probabilities in decision making

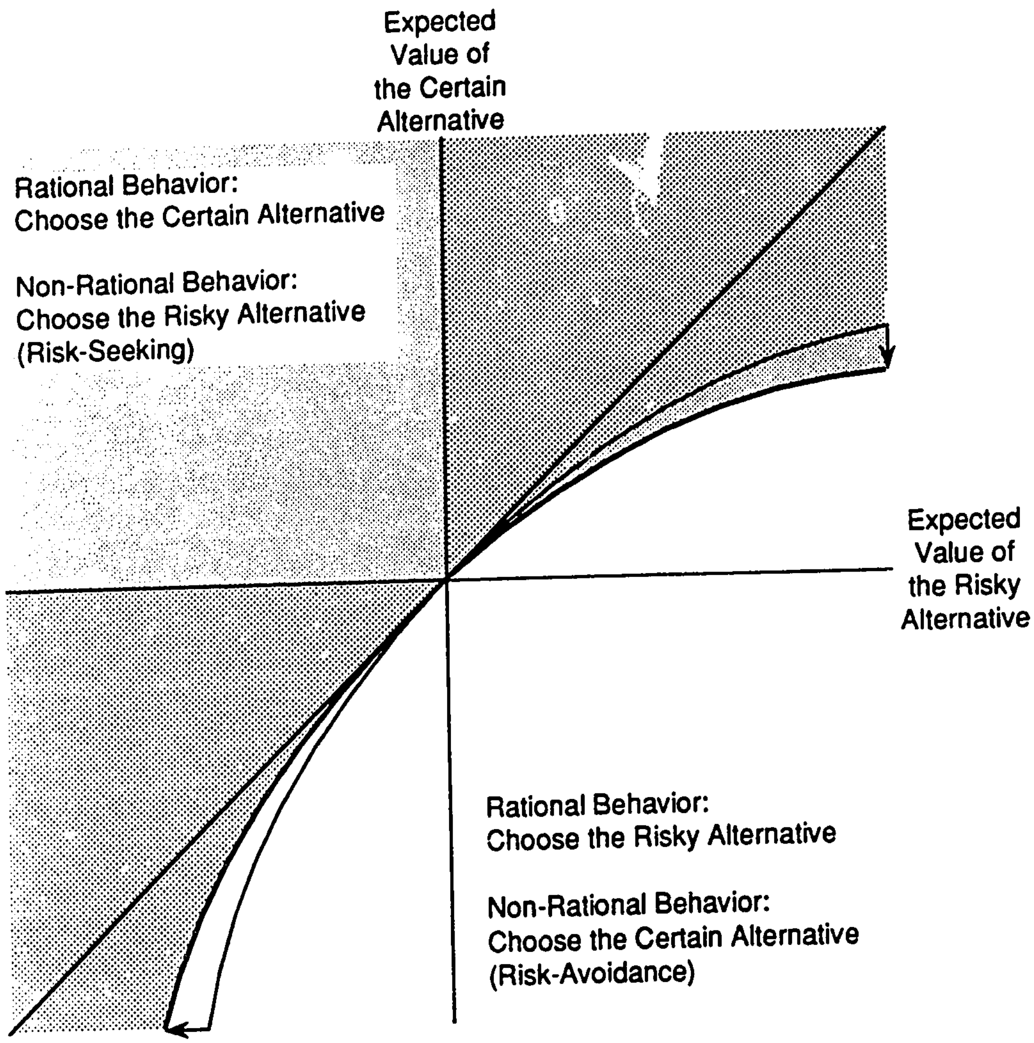


Figure A-5a. Predicted decision behavior based on subjective expected utility theory, when subjective probabilities underweight the presented objective probabilities (p > .20). Arrows (——→) indicate both the increase, and the decrease in the areas where the rational decision is to choose the certain alternative, relative to predictions based on expected utility theory.

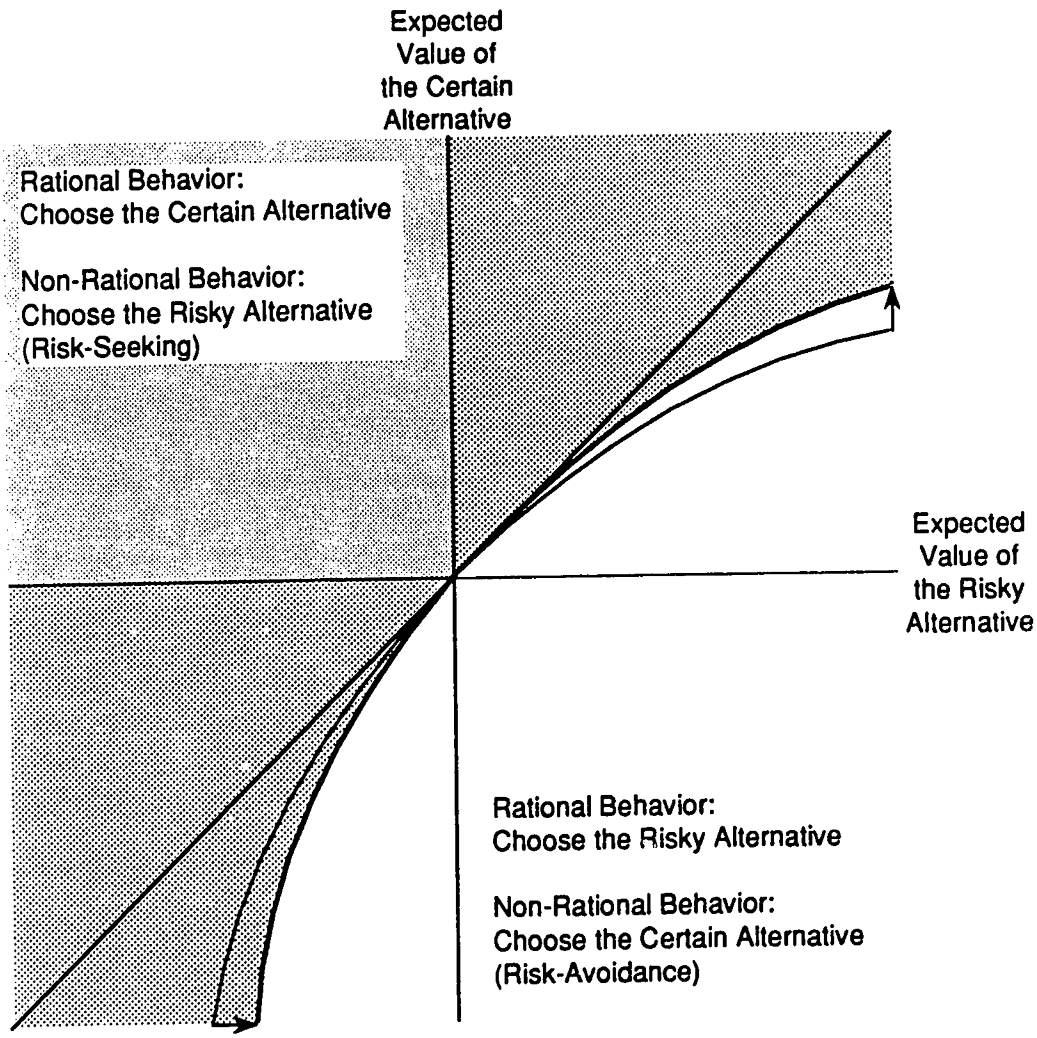


Figure A-5b. Predicted decision behavior based on subjective expected utility theory, when subjective probabilities overweight the presented objective probabilities ($p < .20$). Arrows (⟶) indicate both the increase, and the decrease in the areas where the rational decision is to choose the certain alternative, relative to predictions based on expected utility theory.

are: (a) When objective probabilities are high (approximately p > .20), and an individual must decide between two alternatives with equal expected values, one which will be received with certainty and the other which will be received with a probability less than one, he or she will make risk-averse decisions for gains, and he or she may make either risk-averse or risk-seeking decisions for losses. (b) When objective probabilities are low (approximately p < .20), and an individual must decide between two alternatives with equal expected values, one which will be received with certainty and the other which will be received with a probability less than one, he or she will make risk-averse decisions for losses, and he or she may make either risk-averse or risk-seeking decisions for gains.

In much the same way that von Neumann and Morgenstern (1947) developed axioms for rational decisions based on expected value theory, Savage (1954) developed axioms for rational decisions based on subjective expected utility theory. Savage's axioms imply that although one may not be able to predict isolated decisions on the basis of subjective expected utility theory, one can make predictions about the pattern of decisions. The overall pattern should represent a consistent ordering, even though isolated decisions may appear non-rational when evaluated according to predictions based on expected value theory.

To illustrate, suppose an individual is offered the following choice: (a) receive $10.00 for certain, or (b) accept a 60% chance of receiving $20.00 and a 40% chance of receiving nothing. If the individual refuses the risky alternative in this situation, one can predict they will also refuse the risky alternative if the probability of receiving $20.00 in this alternative is reduced to less than 60%. On the other hand, if the individual accepts the risky alternative, one can predict they will also accept the risky alternative if the probability of receiving $20.00 is increased beyond 60%.

In addition, suppose an individual is offered the following choice: (a) pay out $10.00 for certain, or (b) accept a 40% chance of paying out $20.00 and a 60% chance of paying out nothing. If the individual refuses the risky alternative in this situation, one can predict they will also refuse the risky alternative when the probability of paying out $20.00 in this alternative is increased beyond 40%. On the other hand, if the individual accepts the risky alternative, one can predict they will also accept the risky alternative if the probability of paying out $20.00 in this alternative is reduced to less than 40%. Therefore, even though isolated decisions may appear non-rational on the basis of expected value theory, the general pattern will still be a consistent one if the individual is choosing in a rational manner.

One of the underlying assumptions of subjective expected utility theory is that the subjective probability estimates associated with a particular objective probability will be constant for an individual within a given situation, and that the subjective probability estimates an individual utilizes in evaluating a risky alternative should be independent of whether the situation being evaluated involves a gain or a loss. However, subjective probability estimates may differ between individuals, and they may also change for a single individual over time.

In order to determine an individual's subjective probability function it would be necessary to present him or her with a series of decisions which would require the individual to decide between a given certain alternative and a risky alternative in which the dollar amount is held constant, and the objective probabilities are systematically varied. The definition of an individual's subjective probability function would require the isolation of at least five stable points of indifference, because subjective probabilities are assumed to follow an s-shaped function, with an inflection point at approximately 0.20. In addition, subjective values can only be calculated at points of indifference. These points of indifference would correspond to cross-over points where an individual shifted from accepting the risky alternative to refusing the risky alternative within a given series of choices containing a constant dollar value for the certain alternative, and a constant dollar value for the risky alternative.

Even though subjective expected utility theory provided for the use of subjective probabilities and subjective values (utilities) in evaluating a decision, the theory still could not account for findings such as those from a 1955 study by Ward Edwards, or those from a 1981 study by Tversky and Kahneman. Edwards (1955) presented individuals with a choice between two alternatives, one of which had a low probability of occurrence (less than 20%). He found that when a player could not lose, but could only win or "break even", that player would tend to overestimate his or her chances of winning; the subjective probability estimate exceeded the objective probability. But, when a player could only lose or "break even", and was never able to win, he or she would tend to be realistic about his or her chances; the subjective probability estimate equaled the objective probabilities. This indicates one's evaluation criteria may depend on the nature of the outcome, in other words, on whether success is at stake but not failure; or the other way round, failure is at stake but not success.

In addition, Tversky and Kahneman (1981) found that situations which offered identical outcomes based on an expected value calculations could lead to different decisions, on the basis of the "frame" in which the situation is presented. Tversky and Kahneman use the term "frame" to describe the frame of reference implied by the wording of a decision problem. For example, assume you invested $600.00 through an investment group. The investment group's financial statements from the last year are worrisome to a government auditor, and the auditor must decide whether or not to recommend the suspension of the investment group's operations. If the license is suspended $200.00 of your investment will be saved. If the license is not suspended there is a 1/3 probability that all $600.00 of your investment will be saved, and a 2/3 probability that none of your investment will be saved. What would you want the government agent to do?

Now suppose you are faced with this situation: assume you invested $600.00 through an investment group. The investment group's financial statements from the last year are worrisome to a government auditor, and the auditor must decide whether or not to recommend the suspension of the investment group's operations. If the license is suspended $400.00 of your investment will be lost. If the license is not suspended there is a 1/3 probability that none of your investment will be lost, and a 2/3 probability that all $600.00 of your investment will be lost. What would you want the government agent to do?

These two problems are exactly the same in terms of expectation theories. A total of $600.00 has been invested and the expectation is $200.00 will be saved and $400.00 will be lost. Yet, Tversky and Kahneman (1981) found in problems of this type, the majority of individuals selected the certain alternative when the problem was presented in a positive frame of reference, and the majority selected the risky alternative when the problem was presented in a negative frame of reference.

This supports Edwards' (1955) finding that individuals do not utilize the same criteria when evaluating gains as they do when evaluating losses. The use of different subjective measures for gains and losses violates both subjective expected utility theory and expected utility theory, neither of which allows for an interaction between subjective measures and domain.

Prospect Theory

Findings of this type necessitated a theory of decision making which included the interaction of the final outcome with the individual's subjective measures. Kahneman and Tversky (1979) proposed one such theory, which they termed "prospect theory." In prospect theory, probabilities are replaced by decision weights [$\pi(p)$] and utilities are replaced by a value function [$\upsilon(x)$] which is centered on the current asset position and evaluates alternatives as gains or losses from that position. Alternatives are assessed by summing across the values of all possible outcomes, each adjusted by its own decision weight:

$$\text{Valuation of Prospect} = \Sigma\pi(p_i)\upsilon(x_i)$$

In prospect theory, decision weights are described in somewhat the same terms as subjective probability estimates were in subjective expected utility theory. Decision weights are equal to the objective probabilities at the endpoints of the probability function, decision weights tend to exceed the stated probabilities when objective probabilities are low (approximately $0 < p < .12$), and decision weights tend to be lower than the stated probabilities when objective probabilities are high (approximately $.12 < p < 1.0$). However, the rules and operations governing decision weights are not the same as those governing subjective and objective probabilities. Specifically, Kahneman and Tversky (1979, p. 281) suggest the decision weights for complementary events do not sum to one: $\pi(p)+\pi(1-p) < 1$. They label this property as "subcertainty." This property means individuals who overestimate the probability of an event occurring will underestimate the probability of its non-occurrence by an even greater amount, and individuals who underestimate the probability of an event occurring will also underestimate the probability of its non-occurrence. Decision weights are not presumed to interact with the way in which a problem is framed, nor are they a function of the objective values in a problem. For a given individual, decision weights are presumed to be invariant in evaluating decisions which involve gains and those which involve losses, and invariant for decisions involving both small and large amounts.

One of the major distinguishing features of prospect theory is the value function. Kahneman and Tversky proposed that individuals do not evaluate final asset positions, but rather focus only on the amount of the gain or loss presented in a given situation. They postulate each incremental gain is worth proportionately less than the previous incremental gain: $\upsilon(2y) < 2[\upsilon(y)]$, but that each incremental loss is also viewed as being proportionately smaller than the previous incremental loss $\upsilon(-2y) > 2[\upsilon(-y)]$. This assumption leads to a value function which is concave for gains and convex for losses. This is in contrast to the utility functions which formed the basis of expected utility theory and subjective expected utility theory; these functions were presumed to be concave across their entire range.

An additional assumption Kahneman and Tversky make is that the value function is steeper for losses than for gains: $|\upsilon(y)| < |\upsilon(-y)|$. In subsequent research Kahneman and Tversky reported paradoxes in decision behavior induced by "reframing" of problems (Kahneman & Tversky, 1984; Tversky & Kahneman, 1981). These findings lend support to the idea that individuals evaluate loss situations and gain situations using different criteria. The assumption that individuals value the same objective amount differently, dependent on whether the amount represents a gain or a loss, may account for an interaction between domain and decision of the type described by Edwards (1955).

To illustrate how different value functions for gains and losses affect decision making, we will reconsider the example presented in the discussion of subjective expected utility theory. For illustrative purposes, the objective probability of .5 will first be underweighted, and then overweighted. This is not strictly in accordance with the assumptions of prospect theory, but utilizing the same objective probability provides a clearer example of how decision weights can interact with the value function to influence decision making.

Suppose an individual is faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will receive $20.00, and if the coin turns up "tails" the individual will receive nothing. However, if the individual prefers, he or she can accept a $10.00 payment and the coin toss will not take place. First, we must deflate the objective values to incorporate the continually decreasing value function. Second, we must also deflate the objective probability associated with the risky alternative, to allow for the underweighting of high probabilities postulated by Kahneman and Tversky. Finally, we must ensure that the decision weights for the complementary events sum to less than one.

A deflation of this type might result in a total valuation for the risky alternative of .4(.945)($20.00) + .4($0.00) = $7.56, and a total valuation for the certain alternative of 1.0($10.00) = $10.00. The actual value selected for the deflation isn't critical. As long as a gain of $20.00 is valued less than twice as much as a gain of $10.00, and decision weights also underweight the objective probabilities, the decision remains the same, avoid the risky alternative in this situation.

Suppose, instead of receiving money an individual is faced with the following situation: A fair coin is to be tossed, if the coin turns up "heads" the individual will pay out $20.00, and if the coin turns up "tails" the individual will pay out nothing. However, if the individual prefers, he or she can pay out $10.00 and the coin toss will not take place. First we must deflate the objective values to incorporate the value function. Second, we must ensure the deflation is less than that used in the gain situation to incorporate a value function for losses which is presumed to be steeper than the value function for gains. Finally, we must deflate the objective probabilities, just as we did for the gain situation.

A deflation of this type might result in a total valuation for the risky alternative of .4(.965)(–$20.00) + .4($0.00) = –$7.72, and a total valuation for the certain alternative of 1.0(–$10.00) = –$10.00. As was the case in the gain situation, the actual value selected for the deflation isn't critical. As long as a loss of $20.00 is viewed as less than twice the loss associated with $10.00, and decision weights also underweight the objective probabilities, the decision remains the same, select the risky alternative.

Now, suppose an individual is faced with the same two situations, but this time we will treat the objective probability associated with the risky alternative as if it were low (approximately < .12) and allow for a decision weight which exceeds the stated objective probability. How will this affect the decision outcome? When the individual is evaluating the gain situation, an overweighting of this type might result in a total valuation for the risky alternative of .6(.945)($20.00) + .3($0.00) = $11.34, and a total valuation for the certain alternative of 1.0($10.00) = $10.00. In this case, the amount of overweighting which occurs will affect the final decision. Overweighting of probabilities in a gain situation tends to negate the deflationary effect due to the value function, and may result in the acceptance of risky alternatives which would be rejected if expected value calculations formed the basis of the decision process.

When the individual is evaluating a loss situation, an overweighting of this type might result in a total valuation for the risky alternative of .6(.965)($20.00) + .3($0.00) = –$11.58, and an expected utility for the certain alternative of 1.0($10.00) = $10.00. Again, the amount of overweighting which occurs will affect the final decision. Overweighting of probabilities in a loss situation also tends to negate the deflationary effect due to the value function, and may result in the rejection of risky alternatives which would be accepted if expected value calculations formed the basis of the decision process.

The change in decision-making behavior predicted by the integration of these two theoretical assumptions into a single theory of decision making is presented graphically in Figures A-6a and A-6b. The incorporation of the decision weighting function into a rational decision theory will result in a series sion functions; there is no unique indifference line.

When the risky alternative has a high probability of occurrence (Figure A-6a), the indifference line will be pulled down above the origin, so that it lies even closer to the abscissa. Below the origin, the indifference line will be pulled up so that it also lies closer to the abscissa, but at all points it will lie farther from the abscissa than the indifference line for gains. This is because the value function for losses is steeper than the value function for gains.

When the risky alternative has a low probability of occurrence (Figure A-6b), the indifference line will be pulled upwards above the origin, so that at some points it may actually lie above the diagonal. And the indifference line will be pulled downwards below the origin, so that it lies even farther from the abscissa, and at some points may lie below the diagonal.

Therefore, two behavioral predictions for decision making which arise from using decision weights and a value function which is concave for gains, convex for losses, and steeper for losses than for gains, are: (a) When objective probabilities are high (approximately p > .12), and an individual must decide between two alternatives with equal expected values, one which will be received with certainty and the other which will be received with a probability less than one, he or she will make risk-averse decisions for gains, and he or

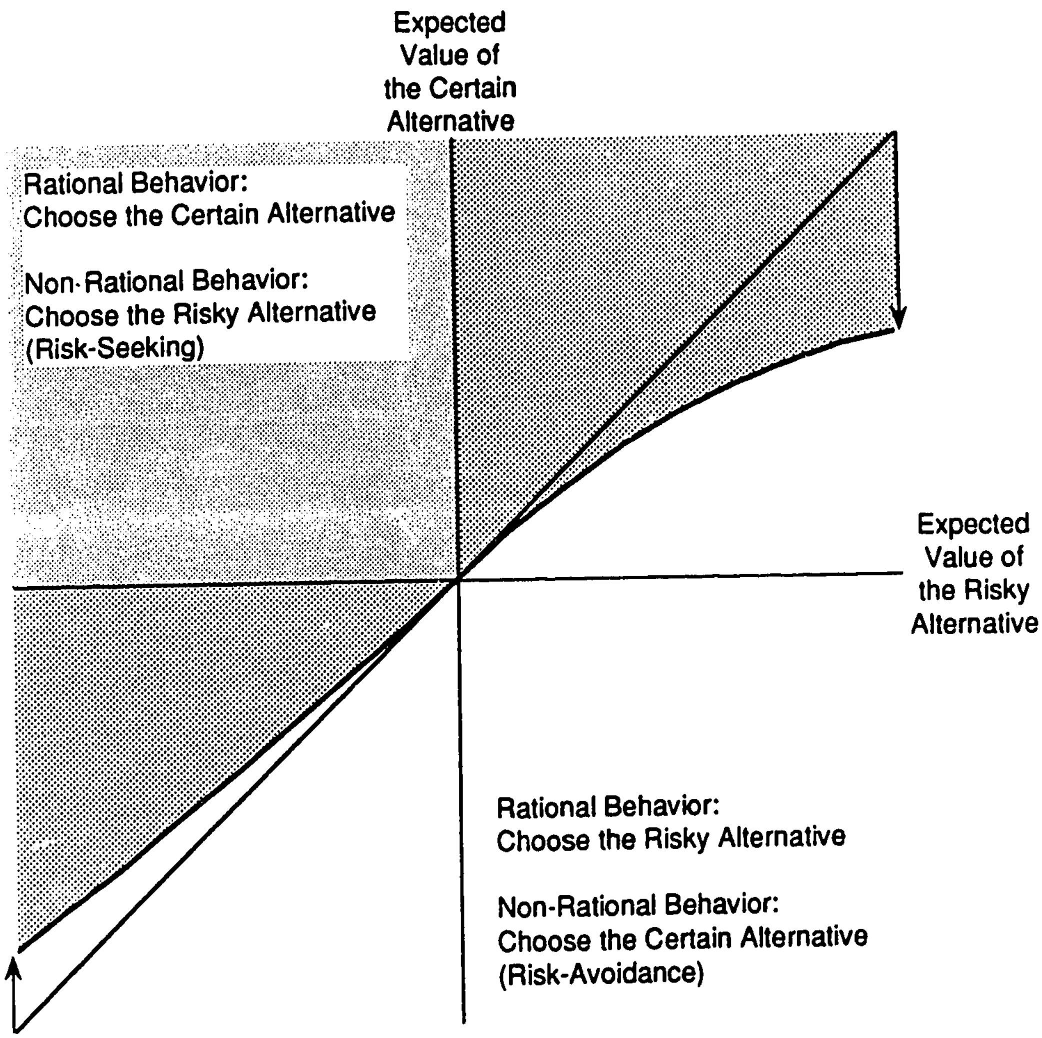


Figure A-6a. Predicted decision behavior based on prospect theory, when subjective probabilities underweight the presented objective probabilities ($p > .12$). Arrows (⟶) indicate both the increase, and the decrease in the areas where the rational decision is to choose the certain alternative, relative to predictions based on expected value theory.

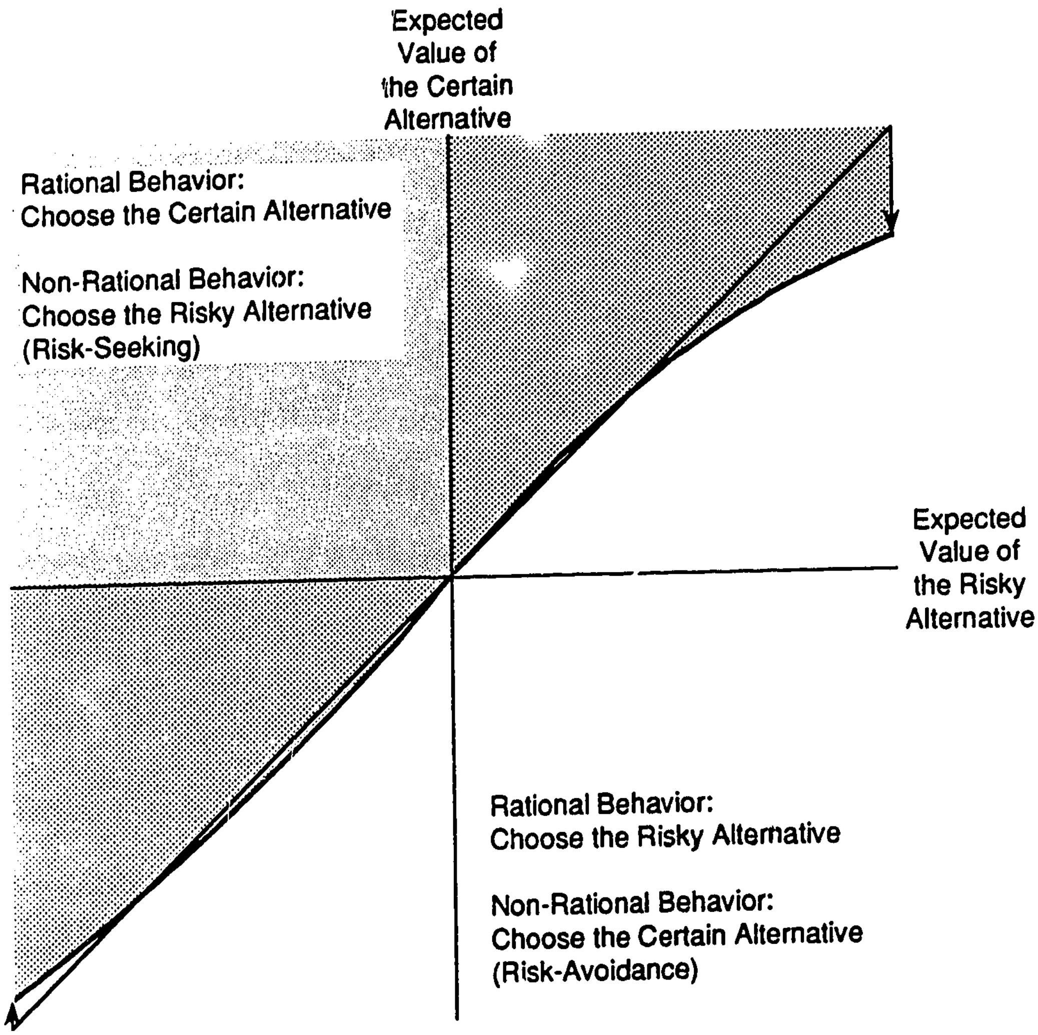


Figure A-6b. Predicted decision behavior based on prospect theory, when subjective probabilities overweight the presented objective probabilities ($p < .12$). Arrows (⟶) indicate both the increase, and the decrease in the areas where the rational decision is to choose the certain alternative, relative to predictions based on expected value theory.

she will make risk-seeking decisions for losses. (b) When objective probabilities are low (approximately $p < .12$), and an individual must decide between two alternatives with equal expected values, one which will be received with certainty and the other which will be received with a probability less than one, he or she will may exhibit one of three decision patterns, depending on the amount of overweighting which occurs: (a) risk-seeking for gains accompanied by risk-aversion for losses; (b) risk-aversion for both gains and losses; (c) risk-aversion for gains accompanied by risk-seeking for losses.

Given the number of free parameters in prospect theory, one may not be able to predict isolated decisions on the basis of the theory, but one can still make predictions about the pattern of decisions. The overall pattern should represent a consistent ordering, even though isolated decisions may appear non-rational when evaluated according to expected value predictions.

To illustrate, suppose an individual is offered the following choice: (a) receive $10.00 for certain, or (b) accept a 60% chance of receiving $20.00 and a 40% chance of receiving nothing. If the individual refuses the risky alternative in this situation, one can predict they will also refuse the risky alternative if the probability of receiving $20.00 in this alternative is reduced to less than 60%, or if the dollar value of the probabilistic gain is reduced. On the other hand, if the individual accepts the risky alternative, one can predict they will also accept the risky alternative if the probability of receiving $20.00 is increased beyond 60%, or if the dollar value is increased beyond $20.00.

In addition, suppose an individual is offered the following choice: (a) pay out $10.00 for certain, or (b) accept a 40% chance of paying out $20.00 and a 60% chance of paying out nothing. If the individual refuses the risky alternative in this situation, one can predict they will also refuse the risky alternative when the probability of paying out $20.00 in this alternative is increased beyond 40%, or if the amount of the loss is increased beyond $20.00. On the other hand, if the individual accepts the risky alternative, one can predict they will also accept the risky alternative if the probability of paying out $20.00 in this alternative is reduced to less than 40%, or if the dollar value of the probabilistic loss is reduced. Therefore, even though isolated decisions may appear non-rational on the basis of expected value theory, the general pattern will still be a consistent one if the individual is choosing in a rational manner.

Because prospect theory incorporates an interaction between the individual's value function and the domain in which a choice is presented, a full test of prospect theory would require two separate phases. First, individuals would have to be presented with a series of decisions in which the individual is required to choose between a certain alternative and a risky alternative. For each series of decisions the value of both the certain alternative and the risky alternative would be held constant, and only the objective probabilities would be systematically varied. The definition of an individual's decision weighting function would require the isolation of at least five stable points of indifference. Because prospect theory assumes a somewhat s-shaped decision weighting function, with an inflection point at approximately 0.12, a minimum of five points are required to fit the function. In addition, decision weights can only be calculated at points of indifference. These points of indifference would correspond to cross-over points where an individual shifted from accepting the risky alternative to refusing the risky alternative within a given series of decisions contain a constant dollar value for the certain alternative, and a constant dollar value for the risky alternative.

Second, in order to determine an individual's value function it would be necessary to present him or her with a series of decisions for both domains which require deciding between a certain alternative and a risky alternative.

For these decisions each series would hold the dollar value of the certain alternative and the probability associated with the risky alternative constant. The dollar value of the risky alternative would be systematically varied until at least six stable points of indifference were found, three in each domain. Because value is presumed to decrease in a non-linear manner as you move out from the origin, a minimum of three points are needed to fit a function. In addition, the value function is assumed to be steeper for losses than for gains, so a separate function must be fit for each of the domains. Values can again only be calculated at points of indifference; these points of indifference would correspond to cross-over points where an individual shifted from accepting the risky alternative to refusing the risky alternative in a series of decisions containing the same certain alternative.

Unique Predictions Generated by Each of the Theories

In order to assess the findings from recent studies designed to test the validity of the assumptions underlying prospect theory it is necessary to understand how prospect theory will lead to unique predictions which differ from those which would be generated by earlier expectation-type theories of decision making. Kahneman and Tversky (1979) describe three types of decision situations: (a) those in which all outcomes are positive, and therefore present a situation where the individual can never lose; (b) those in which all outcomes are negative, and therefore present a situation where the individual can never win; and (c) those in which there are both positive and negative outcomes, and therefore present a situation where the individual can either win or lose. They refer to these three types of situations as: (a) strictly positive, (b) strictly negative, and (c) regular.

Of particular interest to our discussion are the first two decision situations. For two-outcome decision situations which are strictly positive, and in which one outcome can be received with certainty and a second outcome, if selected, will occur with a probability less than 1.0, each of the theories would generate the following types of behavioral predictions:

1. Expected value theory would lead to predictions that an individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and will never select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. At points where the two outcomes have equal expected values, an individual will be indifferent between them, and if required to choose, he or she will select at random.

2. Expected utility theory would lead to predictions that an individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. This is described as risk-averse behavior and occurs because total expected utilities will be lower than corresponding total expected values.

3. Subjective expected utility theory would lead to two behavioral predictions which are dependent on the probability associated with the risky alternative. When the probability of occurrence for the risky alternative is low (approximately $p < .20$) an individual will usually select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome (risk-aversion). However, the individual will also occasionally fail to select the certain outcome when the

value associated with that outcome exceeds the expected value of the probabilistic outcome. This is described as risk-seeking behavior and results from the fact low probabilities tend to be overweighted. This overweighting can lead to subjective expected utilities which exceed the corresponding expected values.

When the probability of occurrence for the risky alternative is high (approximately $p > .20$), the individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. This risk-averse behavior results because high probabilities tend to be underweighted. This underweighting will lead to more instances of risk-averse decision behavior than predicted based on expected utility theory, because total subjective expected utilities will be even lower than the corresponding total expected utilities.

4. Prospect theory would also lead to two behavioral predictions (similar to those generated on the basis of subjective utility theory) which are dependent on the probability associated with the risky alternative. When the probability of occurrence for the risky alternative is low (approximately less than .12) an individual will usually select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome (risk-aversion). However, the individual will also occasionally fail to select the certain outcome when the value associated with that outcome exceeds the expected value of the probabilistic outcome.

This is described as risk-seeking behavior and results from the fact low probabilities tend to be overweighted. This overweighting can lead to valuations which exceed the corresponding expected values.

When the probability of occurrence for the risky alternative is high (approximately greater than .12), the individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. This risk-averse behavior results because high probabilities tend to be underweighted. This underweighting will result in valuations which are lower than the corresponding expected values.

For two-outcome decision situations which are strictly negative, and in which one outcome can be received with certainty and a second outcome, if selected, will occur with a probability less than 1.0, each of the theories would generate the following types of behavioral predictions:

1. Expected value theory would lead to predictions that an individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and will never select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. At points where the two outcomes have equal expected values, an individual will be indifferent between them, and if required to choose, he or she will select at random.

2. Expected utility theory would lead to predictions that an individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some

instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. This risk-averse behavior results because total expected utilities will be lower than corresponding total expected values.

3. Subjective expected utility theory would lead to two behavioral predictions which are dependent on the probability associated with the risky alternative. When the probability of occurrence for the risky alternative is low (approximately $p < .20$) an individual will always select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome. This risk-averse behavior results from the fact low probabilities tend to be overweighted. This overweighting can lead to total subjective expected utilities which are even lower than the corresponding total total expected utilities.

When the probability of occurrence for the risky alternative is high (approximately $p > .20$) an individual will usually select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome (risk-aversion). However, the individual will also occasionally fail to select the certain outcome when the value associated with that outcome exceeds the expected value of the probabilistic outcome. This risk-seeking behavior results from the fact high probabilities tend to be underweighted. This underweighting tends to negate the effect of diminishing marginal utilities, and can result in subjective expected utilities which exceed expected values.

4. Prospect theory would also lead to two behavioral predictions which are dependent on the probability associated with the risky alternative. When the probability of occurrence for the risky alternative is low (approximately less than .12) an individual will usually select the certain outcome when the expected value associated with that outcome exceeds the expected value of the probabilistic outcome, and in some instances will select the certain outcome when the expected value associated with that outcome is exceeded by the expected value of the probabilistic outcome (risk-aversion). This risk-averse behavior results from the fact low probabilities tend to be overweighted. This overweighting can lead to valuations which exceed the corresponding expected values. However, the individual will also occasionally fail to select the certain outcome when the value associated with that outcome exceeds the expected value of the probabilistic outcome (risk-seeking).

When the probability of occurrence for the risky alternative is high (approximately greater than .12), the individual will always select the risky outcome when the expected value associated with that outcome exceeds the expected value of the certain outcome, and in some instances will select the risky outcome when the expected value associated with that outcome is exceeded by the expected value of the certain outcome. This risk-seeking behavior results because high probabilities tend to be underweighted. This underweighting will always result in valuations which are less than than the corresponding expected values.

The unique predictions for each theory are summarized in Table A-1. Based on this table the following criteria can be used for empirical evaluation of each of the four theories in situations where an individual must decide between two outcomes which have equal expected values, one which will be received with certainty and the other which has a probability of occurrence less than one:

Table A-1

Decision patterns predicted by each of the economic models

Theory	Predicted Pattern of Behavior When Probability of Risky Alternative is Low	Predicted Pattern of Behavior When Probability of Risky Alternative is High
Expected Value Theory	risk-neutral/risk-neutral[a]	risk-neutral/risk-neutral
Expected Utility Theory	risk-averse/risk-averse	risk-averse/risk-averse
Subjective Expected Utility Theory	risk-averse/risk-averse, or risk-seeking/risk-averse	risk-averse/risk-averse, or risk-averse/risk-seeking
Prospect Theory	risk-averse/risk-seeking, or risk-averse/risk-averse, or risk-seeking/risk-averse	risk-averse/risk-seeking

Note. These predictions are based on a decision between a certain alternative and a risky alternative of equal expected value, and the descriptions are presented with reference to predictions based on expected value theory. The predicted behavioral tendency for strictly positive outcomes is given first in each case, followed by the predicted behavioral tendency for strictly negative outcomes.

a Risk-neutral refers to indifference between the two alternatives. An individual required to state a preference is presumed to choose randomly between the alternatives.

(a) If an individual shows evidence of risk-seeking or risk-averse behavior for either gains or losses, no matter what probabilities are associated with the risky alternative, behavior does not follow predictions based on expected value theory; (b) If an individual shows evidence of risk-seeking behavior for either gains or losses, no matter what probabilities are associated with the risky alternative, behavior does not follow predictions based on expected utility theory; (c) If an individual shows evidence of risk-seeking behavior for losses when probabilities are less than approximately 0.20, or evidence of risk-seeking for gains when probabilities are greater than approximately 0.20, behavior does not follow predictions based on subjective expected utility theory; and, (d) If an individual shows evidence of risk-seeking behavior for gains accompanied with risk-seeking behavior for losses when probabilities are less than 0.12, or evidence of risk-seeking for gains or risk-aversion for losses when probabilities are greater than 0.12 behavior does not follow predictions based on prospect theory.

Empirical Evaluations of Prospect Theory

Perhaps because of the amount of testing required to fully evaluate Prospect Theory there have been few empirical tests of the theory since it was first proposed by Kahneman and Tversky in 1979. In addition, the testing which has occurred has tended to focus on isolated aspects of the theory.

A computer search through the published literature from 1979-1989 located a total of seven studies designed to evaluate and test prospect theory; these studies are summarized below, in chronological order. Following the summary, an overall evaluation of the recent empirical evidence with respect to the fundamental assumptions of expectancy theories of decision making is presented.

<u>Hershey and Schoemaker (1980)</u>. The first published evaluation of prospect theory was undertaken by Hershey and Schoemaker (1980). They conducted three separate experiments. In each they presented subjects with several questions which required that the individual decide between a certain alternative and a risky alternative which had the same expected value.

In the first experiment there were three sets of questions. Six questions held the certain amount constant at $10.00 and varied the parameters of the risky alternative so that the objective expected value of the risky alternative was also equal to $10.00; six questions held the risky amount constant at $10,000.00 and varied the probability of the risky alternative and also the dollar value of the certain alternative in such a way the objective expected values were equal; finally, five questions held the risky probability constant at .01 and varied the dollar value of the risky alternative and also the dollar value of the certain alternative in such a way the objective expected values were equal. The entire set of 17 questions was presented to each of the subjects, in order, first in the form of a strictly negative situation, and then in the form of a strictly positive situation. In all the questions from this set the risky alternative was listed first.

The second experiment contained a different type of question. Here, in each of the strictly negative questions, a loss was unavoidable. No matter which alternative an individual selected, he or she would experience some loss. In the same way, in each of the strictly positive questions, a gain was inevitable. Three questions held the risky amounts constant at $10.00 and $20.00, while the probability of each of the risky alternatives, as well as the value of the certain alternative were varied to equate the objective expected values. For example, the individual might be asked to choose between: (a) receiving $15.00 for certain, or (b) accepting a 50% chance of receiving $10.00 and a 50% chance of receiving $20.00. There was a fourth question which adjusted the risky amounts to $12.00 and $18.00, but which maintained the probabilities for each outcome at 50%. The certain alternative was always equal to the objective expected value of the risky alternative. Three additional questions held the risky amounts constant at $500.00 and $1000.00, while the probability of each of the risky alternatives, as well as the value of the certain alternative were varied to equate the objective expected values. For example, the individual might be asked to choose between: (a) receiving $750.00 for certain, or (b) accepting a 50% chance of receiving $500.00 and a 50% chance of receiving $1000.00. There was a final question which adjusted the risky amounts to $600.00 and $900.00, but which maintained the probabilities for each outcome at 50%. Again, the certain alternative was always equal to the objective expected value of the risky alternative. This entire set of 8 questions was presented to each of the subjects, in order, first in the form of a strictly negative situation, and then in the form of a strictly positive situation. In all the questions in this set, the certain alternative was listed first.

Finally, there was a set of three questions in which two of the certain alternatives were equal to each other ($20.00), but all the other parameters between the questions were varied. These questions were presented to the subjects in pairs; the first question presented a strictly negative situation and the second question contained the same parameter values for a strictly positive situation. Subjects could refer to both questions simultaneously when making their decisions. In all the questions in this set the certain alternative was listed first.

Just over half (15) of the 28 choice combinations presented in this study involved choices where Kahneman and Tversky (1979) suggest decision weights will exceed objective probability values. Subjective expected utility theory suggests a similar effect in this probability range with subjective probability estimates exceeding objective probability estimates (Edwards, 1953; 1954a; 1954b; 1954c). Unfortunately, the way in which these decision questions are designed confounds the effects of the decision weighting function with the effects of the value function.

Because each of the questions contains alternatives which have the same expected value, and should therefore yield indifference according to expected value theory, the behavior of individuals who select the risky alternative may be described as risk-seeking, and the behavior of individuals who avoid the risky alternative may be described as risk-averse. This means that a total of four behavioral patterns are possible for each of the question pairs: (a) consistent risk-seeking, selecting the risky alternative for both the strictly positive question and the corresponding strictly negative question; (b) risk-seeking/ risk-aversion, selecting the risky alternative for the strictly positive question and switching to the certain alternative for the corresponding strictly negative question; (c) risk-aversion/ risk-seeking, selecting the certain alternative for the strictly positive question and switching to the risky alternative for the corresponding strictly negative questions; and, (d) consistent risk-aversion, selecting the certain alternative for both the strictly positive question and the corresponding strictly negative question.

The first pattern, consistent risk-seeking, would not be predicted on the basis of any of the theories of decision making discussed previously. The second pattern, risk-seeking/risk-aversion, would be predicted for some questions involving low probabilities if subjective expected utility theory or prospect theory criteria are being utilized; it would not be predicted on the basis of expected utility theory. The third pattern, risk-aversion/risk-seeking, would be predicted for all the questions where the risky alternative had a high [illegible]lity of occurrence and for some questions where the risky alternative had a low probability of occurrence on the basis of prospect theory; it would also be the predicted pattern for some questions with high probabilities on the basis of subjective expected utility theory. This pattern would not be predicted on the basis of expected utility theory. The fourth pattern, consistent risk-aversion, would be predicted for all questions on the basis of expected utility theory; for some questions with high probabilities and for some questions with low probabilities on the basis of subjective expected utility theory; and for some questions with low probabilities on the basis of prospect theory.

If individuals are choosing at random, and have no clear preferences among the offered alternatives, each of the patterns should appear equally often. However, if individuals do have preferences between the alternatives for a given question, at least one response pattern should appear at levels significantly greater than chance (i.e., for significantly more than 25% of the subjects).

In 20 of the 28 questions presented, at least one of the above patterns occurred at greater than chance levels. In 3 of the 28 questions, two different patterns each occurred at greater than chance levels. This suggests individuals are not deciding in accordance with expected value predictions, but rather are utilizing some other decision strategy, for at least some of the questions. However, Hershey and Schoemaker omitted the data from those subjects who specifically stated they were indifferent between the alternatives for any given question. The percentages of those stating they were indifferent between the alternatives varied between the questions, but in some instances up to 24% of the subjects were excluded on this basis.

In 3 of the 28 questions Pattern 1 (risk-seeking/risk-seeking) occurred at levels significantly greater than chance. This decision pattern is inconsistent with all four theoretical formulations of decision making. In 5 of the 28 questions

Pattern 2 (risk-seeking/risk-aversion) occurred at levels significantly greater than chance. Four of these questions had a relatively low probability ($p \leq .10$) associated with the risky alternative, and the other had a relatively high probability ($p > .20$) associated with the risky alternative. For the four questions involving a low probability this decision pattern is consistent with predictions generated by both subjective expected utility theory and prospect theory; for the question involving a high probability this decision pattern is inconsistent with all four theoretical formulations of decision making. In 15 of the 28 questions Pattern 3 (risk-avoidance/risk-seeking) occurred at levels significantly greater than change. Five of these questions had a relatively low probability ($p \leq .10$) associated with the risky alternative, and ten of these questions had a relatively high probability ($p > .20$) associated with the risky alternative. For the five questions involving a low probability this decision pattern is only consistent with predictions generated by prospect theory; for the ten questions involving a high probability this decision pattern is consistent with predictions generated by both subjective expected utility theory and prospect theory. Finally, in none of the 28 questions did Pattern 4 (risk-avoidance/risk-avoidance) occur at levels significantly greater than chance.

Because Pattern 4 never occurs at greater than chance levels, Hershey and Schoemaker's (1980) findings indicate decision making cannot be explained on the basis of expected utility theory. When the risky alternative has a high probability of occurrence their findings cannot differentiate between subjective expected utility theory predictions and prospect theory predictions. When the risky alternative has a low probability of occurrence predictions based on prospect theory are more consistent with their results than those based on subjective expected utility theory. However, their results provide evidence that current theories of decision making are incomplete and require further refinement in order to completely predict decision behavior; for four of the question pairs none of the expectation theories could accommodate the observed decision patterns. Hershey and Schoemaker sum up their own findings by stating "[T]he problem may well be deeper in that subjects just do not follow expectation models" (p. 417).

Fischhoff (1983). In this study a total of ten decision questions were presented to a number of groups of individuals, using slightly altered wording, in an attempt to manipulate the frame of reference which would be adopted by the decision maker. Nine of these questions required that the individuals evaluate situations involving the loss of life, and one required the evaluation of a situation involving the loss of monetary wealth. In all cases the objective values of the risky alternative and the certain alternative were equal, and expected value theory would lead to predictions of indifference between the offered alternatives. In eight of the questions the objective probabilities were greater than .2, therefore for these eight questions both subjective expected utility theory and prospect theory would lead to predictions of risk-seeking behavior. Two of the questions involved an extremely low probability of occurrence for the risky alternative (i.e., .01). For these two questions only prospect theory would lead to predictions of risk-seeking behavior.

Fischhoff found that in almost all instances, where the questions involved a loss of life, the majority of individuals exhibited risk-seeking behavior. However, for most of these question presentations the proportion of individuals selecting the risky alternative was not significantly greater than would be expected by chance. For the presentations of the problem which involved a loss of monetary wealth, in contrast to the problems involving the loss of life, in several instances the majority of individuals avoided the risky alternative, although the proportions here were also not significantly greater than chance. These results are difficult to reconcile with any of the four expectation theories of decision making.

Fischhoff (1983) found some evidence of risk-seeking behavior for both high and low probabilities. When the probability associated with the risky alternative is high, this behavior is inconsistent with expected utility theory, and when the probability associated with the risky alternative is low this behavior is inconsistent with both expected utility theory and subjective expected utility theory. However, this risk-seeking behavior was in response to questions which required the evaluation of situations involving the loss of human life. It is not clear that the utility function for human life will follow the same form as that proposed for consumer goods and monetary assets. Therefore inconsistencies in these circumstances may not provide evidence against these theories.

In addition, there is some evidence of risk-aversion for monetary losses where the probability of the risky alternative is high. These findings are inconsistent with prospect theory. Therefore, Fischhoff's (1983) findings do not show clear support for any of the four expectation theories.

Schneider and Lopes (1986). In the Schneider and Lopes study, individual subjects were initially screened for risk tendency. For this screening individuals were presented with five strictly positive two-outcome situations which contained a certain alternative and a risky alternative of approximately equal expected value. Those subjects who consistently selected the certain alternative were classified as risk-averse for gains, and those subjects who consistently selected the risky alternative were classified as risk-seeking for gains. A total of 1,382 subjects were pre-screened and of these only 1%, or 14 subjects in total, selected the risky alternative in all five of the screening problems. Therefore, to include 30 risk-seeking subjects in the main study, 16 individuals who selected the risky alternative on 4 out of 5 trials also participated.

These two groups of subjects were presented with pairs of stimuli which represented multi-outcome lotteries. There were a total of 10 lotteries, each of which had the same expected value ($100), but which differed in both variance and skew (see Schneider and Lopes, 1986, p. 539). These 10 lotteries were combined into 45 unique pairs, and each of the pairs was presented in random order, 3 times, for a total of 135 decision problems. Each of the subjects evaluated all 135 decision problems on two separate occasions. On one occasion each of the problems represented a loss situation, and on the other each of the problems represented a gain situation. Subjects were under no time constraints and could refer back and forth between each of the elements in a given problem as many times as they wished, but the two elements could not be viewed simultaneously.

The instructions given to each of the subjects explicitly stated that each of the lotteries had the same expected value, and that this expected value was +$100 for gains, and –$100 for losses. Subjects also received a brief explanation of the concept of expected value; they were told it was the average amount they would win (or lose) if they played any of the gambles for a "long, long time" (Schneider & Lopes, p. 540).

The initial analysis focused on how the two groups ordered their preferences for the individual lotteries. This was done by tabulating the number of times each lottery was selected out of the 27 times it was presented, both for gains and losses. Schneider and Lopes found that risk-averse subjects, as a group, were consistent in their preference orderings of the gain situations but inconsistent in their preference ordering of the loss situations. The reverse was true for risk-seeking subjects. As a group, these subjects were consistent in their preference orderings of the loss situations but inconsistent in their preference ordering of the gain situations.

The pattern of individual choices across the two domains were also analyzed. Schneider and Lopes found that 2 of the 30 individuals classified as risk-averse, and none of the 30 individuals classified as risk-seeking made consistently risk-averse choices in both domains. This pattern is consistent with predictions generated on the basis of both expected utility and subjective expected utility. The fit with predictions based on prospect theory cannot be assessed because it is not clear how this theory would deal with multi-outcome risky alternatives. Risk-aversion for gains coupled with risk-seeking for losses was found to be significant for 9 of the risk-averse subjects, and 6 of the risk-seeking subjects. This pattern is inconsistent with predictions based on expected utility theory, and consistent with predictions based on prospect theory. The fit with predictions based on subjective expected utility theory cannot be assessed because it is not clear how the theory would deal with multi-outcome risky alternatives. The opposite pattern, risk-seeking for gains and risk-aversion for losses was not present in the risk-averse subjects, but was evident for 2 of the risk-seeking subjects. This pattern is consistent with predictions based on both subjective expected utility theory and prospect theory, for situations where the probabilities associated with a risky alternative are low. Finally, consistent risk-seeking was found to be the pattern for 6 of the risk-seeking subjects, this pattern did not occur in risk-averse subjects. This choice pattern is not consistent with predictions based on any of the four expectation theories of decision making. The remaining 35 subjects (19 risk-averse and 16 risk-seeking) did not show evidence of a stable pattern across the two domains. For some questions they reversed their preferences between the gain and loss problems, and for others they maintained their preferences.

One other analysis Schneider and Lopes report is of interest. They assessed the degree of within-subject consistency with respect to a single pair of alternatives. Each lottery pair was presented three separate times; if subjects were selecting at random they would select the same alternative from a given pair of lotteries on all three presentations only 25% of the time. The individual consistency levels were significantly greater than this for all the pairs presented to both groups of subjects. However, risk-averse subjects show a greater degree of consistency for gains than for losses; for risk-seeking subjects the percentage of consistent choices is about the same for both gains and losses.

The major conclusion Schneider and Lopes draw is that risk tendency is an individual differences variable. They suggest the differences in risk preferences between the two groups can be partially explained if risk-aver[illegible] and risk-seeking subjects focus on different dimensio[illegible] he problem when making a decision. Schneider and Lopes conclude by stating: "[T]he evidence suggests that prospect theory will not be able to completely describe preferences under risk. This may indicate that the process leading to these preferences is different from that embodied in prospect theory" (p. 546).

Budescu and Weiss (1987). The Budescu and Weiss study evaluated decision making when individuals were required to choose between two alternatives, both of which were risky. Their main concern was the degree to which individual choices would reverse for pairs of questions which contained the same parameter values, but in which one question was strictly positive and the other question was strictly negative. However, reversal of choices above and below the abscissa is not a unique prediction of prospect theory. When both alternatives contain an element of risk, expected value theory would generate similar predictions (refer to Figure A-1). To illustrate, in one of the Budescu and Weiss decision pairs individuals were required to choose either:

(a) a 7/24 probability of receiving 200 Israeli shekels (IS), or (b) an 8/24 probability of receiving 190 IS. The expected value of these two alternatives are 58.33 IS and 63.33 IS, respectively. Therefore, an individual selecting according to expected value theory will select alternative 2. However, when the same decision problem was changed to a loss, individuals were required to choose either: (a) a 7/24 probability of paying out 200 IS, or (b) an 8/24 probability of paying out 190 IS. The expected value of these two alternatives are –58.33 IS and –63.33 IS, respectively. Therefore, an individual selecting according to expected value theory will select alternative 1. In addition, for certain parameter values both expected utility and subjective expected utility theory would allow for choice reversals between equivalent gain and loss questions when both alternatives in the decision pair contain an element of risk. Therefore, the Budescu and Weiss study cannot be used to provide unique support for prospect theory.

In addition, there is also a confound in the Budescu and Weiss (1987) study. In each pair they presented, the larger monetary amount was coupled with the smaller probability. For the specific parameter values they selected this resulted in an interactive effect such that the alternative with the larger monetary amount always had the lower expected value. Therefore, an individual who made no probability calculations and instead chose solely on the basis of monetary amount would choose in a consistent manner, and have their choices reverse from gains to losses. Specifically, an individual faced with a choice between a 7/24 probability of receiving 200 Israeli shekels (IS), and an 8/24 probability of receiving 190 IS, who selected on the basis of monetary value, will select the first alternative because it involves a greater gain. However, when the same decision problem was changed to a loss and an individual is faced with a choice between a 7/24 probability of paying out 200 Israeli shekels

(IS), and an 8/24 probability of paying out 190 IS, he or she will select the second alternative because it involves a smaller loss.

In the same way, an individual who chose solely on the basis of probability values would also choose in a consistent manner, and have their choices reverse from gains to losses. Specifically, an individual faced with a choice between a 7/24 probability of receiving 200 Israeli shekels (IS), and an 8/24 probability of receiving 190 IS, who selected on the basis of probability values will select the second alternative because it involves a greater chance of winning. However, when the same decision problem was changed to a loss and an individual is faced with a choice between a 7/24 probability of paying out 200 Israeli shekels (IS), and an 8/24 probability of paying out 190 IS, he or she will select the first alternative because it involves a smaller chance of losing. Therefore, reversal of choices for questions involving gains and losses, using the stimuli in this study, does not provide unique support for prospect theory, and it cannot even be taken as support for evidence of probabilistic reasoning in the decision-making task.

Budescu and Weiss (1987) also stress that "...transitivity is also a basic requirement of [prospect theory]. Thus, in order to identify subjects who chose as predicted by this model, we most [sic] consider those who display transitive preferences in both domains <u>and</u> also satisfy all the other tenets of [prospect theory]" (p. 196). Selecting solely on the basis of either monetary values or probabilities would also produce a consistent ordering of preferences which is a transitive ordering. The alternative which contained the largest value for one of these two parameters would be preferred to all other alternatives, and the alternative which contained the the lowest value for the same parameter would not be preferred to any other alternative. Therefore, although preference transitivity may be a necessary finding to support prospect theory, transitive preferences may also appear for individuals who do not utilize an expectation-type strategy.

Budescu and Weiss' (1987) results offer only mixed support for prospect theory. They found less than half their subjects made transitive preferences (10 out of 22). Of those who did make transitive preferences, eight ordered their preferences in a way which was consistent with decisions made on the basis of probability of occurrence, and two ordered their preferences in a way which was consistent with decisions made on the basis of monetary amount. The prevalence of an ordering consistent with the notion that individuals may select alternatives on the basis of probability of occurrence offers support for verbal reports from subjects in both Hershey and Schoemaker's (1980) study, and Schneider and Lopes' (1986) study.

Hershey and Schoemaker (1980) report: "For subjects who said they focused on one dimension only, the probability factor (p) appears most important (p. 415)." And, Schneider and Lopes (1986) found "[I]n the domain of losses, 8 of the 60 subjects suggested a strategy similar to the following: Compare the largest amounts to be lost in each lottery. If the difference is large choose the lottery with the smallest maximum loss...[i]f the difference is small or zero, choose the lottery with the best chance of losing nothing or only a small amount" (p. 546).

This last statement suggests amounts are compared first, and if the difference is negligible, the final decision is based on probability values. The risky alternatives in the Budescu and Weiss study are given in Israeli shekels. The conversion factor at the time of the study was 400 IS = $1.00; therefore, subjects were evaluating alternatives in which the objective amounts differed by as little as 10 IS or 2.5¢. It seems reasonable to suggest subjects might consider this difference to be small, or negligible and therefore select solely on the basis of probability of occurrence.

Budescu and Weiss (1987) also found that 12 of their 22 subjects did not make transitive decisions. This may be partly due to the fact the amounts involved were small, and the subjects may not have been concerned with making the "best" choice. If a subject selected the alternative with the highest expected value in each and every case, and if the ten gambles played at the end of each session were the ten best, strictly positive questions, and the individual won in all ten cases, he or she would have earned $1.34 more than if the opposite selections had been made. On the other hand, if a subject selected the alternative with the lowest expected value in each and every case, and if the ten gambles played at the end of each session were the ten worst, strictly negative questions, and if the individual lost in all ten cases, he or she would have earned $1.34 less than if the opposite selections had been made.

Because Budescu and Weiss argue that transitivity is a basic requirement of prospect theory, at best their findings provide mixed support for the theory. In addition, only six of the ten subjects who were classified as making transitive choices reversed their preference ordering between the gain and loss domains. Therefore, it appears the majority of subjects in this study are making choices in a way which is inconsistent with the prospect theory formulation of decision behavior.

Chang, Nichols and Schultz (1987). Chang et al. had 56 middle-income MBA students take part in a "tax audit lottery." They explain a tax audit lottery in the following way: "Playing a tax audit lottery entails a deliberate decision to take a questionable position on one's tax return that will reduce the immediate tax payment. The questionable position, if audited, may result in a later larger payment, including a deficiency and penalty assessment. However, a taxpayer will not necessarily be audited, and even if he is audited, the audit does not always result in a deficiency or penalty assessment. If additional later payments are not due, the taxpayer would realize a tax saving. Paying a tax audit lottery and its consequences are analogous to playing a lottery that promises a probability (p) of winning a certain sum of money (tax saving) or (1-p) probability of experiencing a loss (deficiency, penalty, etc.)" (p. 301).

Subjects received a total of six tax lottery cases in which the expected values of both options were equated. Each subject was asked to imagine he or she was faced with the choice described in each case, and to indicate the decision he or she would make. In the debriefing individuals were asked whether they perceived the tax payment as reduced gain or a sure loss, but there was no attempt to manipulate the frame of reference within the problem structure; each subject read the identical case descriptions.

The initial results, calculated for the entire group, indicate the majority of subjects were risk-averse (did not evade taxes) in five of the six cases. In the sixth case a small, but not significant, majority (55.4%) made the risk-seeking choice. On the surface, these results indicate support for expected utility theory, in that subjects made uniformly risk-averse choices. However, Chang et al. divided the responses into two groups: those from subjects who indicated they viewed the tax lotteries as strictly negative situations (i.e., a choice between a certain loss and a risky larger loss) [Group 1], and those from subjects who indicated they viewed the tax lotteries as strictly positive situations (i.e., a choice between certain amount of net income and a risky larger income) [Group 2]. When the choices were analyzed within and between groups, two separate risk-attitudes emerged.

In the first group risk-aversion for the six cases ranged from 18% to 54%, with an average of 35%. In contrast, for the second group risk-aversion for the six cases ranged from 64% to 81%, with an average of 77%. These results lend support to Kahneman and Tversky's (1979, Kahneman & Tversky, 1984) suggestion of a "framing" effect. Individuals who viewed the tax audit as a strictly negative situation responded in a different manner from those who viewed it as a strictly positive situation. However, the results obtained by Chang et al. (1987) are more consistent with a subjective expected utility description of decision-making behavior than with a prospect theory description. They report that the individuals from the first group were less inclined to make risk-seeking choices as the dollar amount was increased. The indifference curve for losses in subjective expected utility theory is concave below the origin, indicating risk-seeking behavior will decrease as one moves away from the origin along the ordinate axis. However, the indifference curve for losses in prospect theory is convex below the origin, indicating risk-seeking behavior will increase as one moves away from the origin along the ordinate axis.

One additional finding of interest in the Chang et al. (1987) study is the individual differences in personal characteristics between the two groups. In particular, they found the average age in the first group was significantly lower than in the second group. This may indicate that individual's risk perceptions, or frames of reference change as they grow older.

Therefore, Chang et al. (1987) provide evidence of a difference in decision-making behavior based on the frame of reference adopted by the decision maker, but their results are more consistent with predictions based on earlier formulations of decision making, than with prospect theory predictions.

Diamond (1988). Diamond focused on prospect theory's prediction that individuals deciding between two risky alternatives will overweight probabilities which are low, and underweight probabilities which are high. To test this prediction he had 161 undergraduate students rate the attractiveness of six target vehicles based on descriptions which contained information about the age of the vehicle (18 to 30 months), the miles per gallon (16 to 24 miles per gallon), purchase price ($2350 to $2650), along with an estimate of the probability that the car would require repairs, and the estimate of the repair bill, if the repairs were necessary. For one group of subjects the repair bills were relatively high ($375 to $1750, mean = $937.50), but the probabilities that the repair would be required were extremely low (.003 or .006). For the other group of subjects the repair bills were relatively low ($75 to $350, mean = $187.50), but the probabilities that the repair would be required were considerably higher (.3 or .6). In addition, each group also rated six other vehicles.

The six target vehicles descriptions consisted of two vehicles which had equal, relatively low expected repair bills; two vehicles with equal, medium expected repair bills; and two vehicles with equal, relatively high expected repair bills. For example, one vehicle was described as having a .3 probability of requiring a $150 repair while another vehicle was described as having a .6 probability of requiring a $75 repair. Prospect theory would lead to the prediction that the individuals who rated vehicles with a high probability of repair, would underweight probabilities, and also underweight the amount of the larger repair bill, relative to the lower repair bill. In this example, underweighting the $150 repair bill, relative to the $75 repair bill would cause the individual to rate the vehicle with the larger repair bill (and the lower probability of occurrence) as more attractive. However, if low probabilities are overweighted, as postulated by prospect theory, this overweighting may lead to the opposite decision. Therefore, when individuals rated cars which were identical in every way, but in which the probability of repair was extremely low, the vehicle with the smaller repair bill (and the higher probability of occurrence) may be rated as more attractive.

Diamond found precisely this effect. The interaction between probability and consequence was significant ($p < .001$). In the low probability condition, if two cars had the same expected repair bill, the car with the lower repair bill was rated as more desirable; in contrast, in the high probability condition, if two cars had the same expected repair bill, the car with the higher repair bill (and lower probability of repair) was rated as more attractive. However, Diamond also asked subjects to write down, in as much detail as possible, how they arrived at the rating for the last car on the form.

An analysis of these protocols indicated that individuals were not uniformly using a weighted value type of analysis to arrive at their decision. Instead, Diamond found individuals were using different strategies, depending on whether high probabilities or low probabilities were being evaluated. Of the individuals who rated vehicles where the probability of repair was high, 48% reported using a weighted value strategy to rate the vehicles; of the individuals rating vehicles where the probability of repair was low, only 19% reported using a weighted value strategy. In addition, in the low probability condition 30% of the individuals either did not mention probabilities as being a factor, or explicitly mentioned they did not use the probabilities provided; only 8% of the individuals in the high probability condition failed to utilize the probabilities provided; both these differences are significant. In contrast, the proportion of individuals who failed to make use of the information concerning the amount of the potential repair bill did not differ significantly between the conditions: 14% for the high probability condition, and 9% for the low probability condition.

Therefore, although Diamond's (1988) results are consistent with predictions based on prospect theory, the individuals in his study indicated they did not make use of a weighted value strategy when evaluating alternatives where the probability of occurrence is extremely low. Rather, when the probability of the risky alternatives is extremely low, the individuals indicated they based their decision on the objective values of the alternatives in question, ignoring the probabilities.

Duchon, Dunegan, and Barton (1989). This study was designed to replicate the framing effect described by Kahneman and Tversky (1984; Tversky & Kahneman, 1981). Duchon et al. (1989) had 110 professional employees in an engineering firm indicate whether or not they would provide additional funding to a research and development project. Subjects were randomly assigned to one of two conditions, and asked to evaluate the likelihood that they would approve a request for additional funding for a project which is already behind schedule and over budget. Both groups read the identical funding request, with one exception. For the positive frame group the final sentence of the request was: "Of the projects undertaken by the team, 30 of the last 50 have been successful." For the negative frame the final sentence of the request was changed to read: "Of the projects undertaken by the team, 20 of the last 50 have been unsuccessful" (p. 25).

Therefore, in the positive framing condition individuals are evaluating the options of: (a) saving the additional funding for certain, or (b) saving the additional investment plus entire amount invested so far with a probability of 2/5. In the negative framing condition individuals are evaluating the options of: (a) losing the entire investment so far, or (b) losing the entire investment so far plus the additional funding with a probability of 3/5. Kahneman and Tversky (1981; Tversky and Kahneman, 1984) suggest that, because the value function for losses is steeper than the value function for gains, individuals will select the risk-averse alternative for gains, and select the risk-seeking alternative for losses, if both outcomes have equal expected values.

Duchon et al. (1989) did find significant differences in the likelihood ratings between the subjects in the two conditions; however, individuals who read the funding request in the positive frame indicated they were more likely to fund the project than those who read the negative frame. This finding is the opposite to that predicted on the basis of prospect theory. Therefore, this study provides some support for the premise that individuals may focus on different aspects of a problem situation, depending on the frame of reference in which the problem is presented; however, it does not provide support of the premise that individuals will be risk-averse for gains, and risk-seeking for losses.

However, Duchon et al.'s (1989) results should be interpreted with some caution for two reasons. First, although they reported a statistically significant differences between the two groups, the interpretation of the differences they report is questionable. They had the subjects rate their responses on a five point scale: 1 = reject; 2 = lean toward rejecting; 3 = uncertain; 4 = lean toward funding; 5 = fund. The average rating for the group who read the request in the positive frame was 3.97, and the average rating for the group who read the request in the negative frame was 3.50. This means that neither group is clearly going to reject the project (i.e., average ratings for both groups are greater than 3.0), and yet neither group is clearly going to fund the project (i.e., average ratings for both groups are less than 4.0). In addition, if individuals relied on the verbal descriptions provided, it is not clear this scale provides interval-level decision alternatives. If this is the case, the use of parametric analysis is inappropriate, and non-parametric analysis may not lead to the rejection of the null hypothesis.

Second, in the problem they presented, Duchon et al. (1989) did not indicate how much money had been invested in the project so far. This changes the situation somewhat. If this information is not provided, all subjects may not be assessing the same problem; each individual may assign a different subjective amount in order to carry out a weighted value problem analysis, and the subjective amount they utilize may also be affected by the framing of the problem. This introduces a confounding factor into the study.

General Discussion of Empirical Findings

The studies which have been summarized were each designed to test some aspect of the prospect theory (Kahneman & Tversky, 1979) formulation of decision making; from these studies three general conclusions can be drawn:

1. Different attitudes toward risk exist. Schneider and Lopes (1986) specifically pre-screened subjects for risk-seeking or risk-aversion in strictly positive decision problem situations. Although risk-aversion was the prevalent risk-attitude, 1% of those screened consistently made risk-seeking decisions, and an additional 2% of those screened made risk-seeking decisions in all but one instance. Chang et al. (1987) asked subjects to state how they viewed problems which they had evaluated. Approximately half the subjects adopted a negative frame of reference, and approximately half adopted a positive frame of reference. Chang et al. found significant differences between these two groups on several demographic variables.

2. Although prospect theory has taken into account some behavioral inconsistencies which could not be explained through the use of earlier theories, decision behaviors which are inconsistent with prospect theory assumptions emerged in several of the studies. In particular, risk-seeking above and below the origin for problems which are obtained from each other by changing the sign on all outcomes, emerged in the Hershey and Schoemaker (1980) study. Decision behavior of this type is inconsistent with each of the expectation theories of decision making.

3. Prospect theory, expected value theory, expected utility theory, and subjective expected utility theory are all based on the implicit assumptions that

an individual will either assign or utilize some measure of risk and some measure of worth, and that the individual will combine these two dimensions in some logically consistent manner to arrive at an overall measure of attractiveness in decision situations. Although some mixed support for weighted value assessment of decision problems was found, this may be an artifact which is a by-product of a different type of decision-making strategy. Budescu and Weiss (1987) claim their results provide support for a weighted value assessment strategy, but for this study alternate decision strategies could be proposed which would produce identical results. Diamond (1988) also obtained results which supported a weighted value type of decision strategy. But, for low probability questions subjects reported they did not make use of probability information in arriving at their final decision. In addition, Schneider and Lopes (1986) report that some subjects reported strategies which involve an element-by-element comparison of alternatives: "Our data suggest that weighted value theories such as prospect theory are inadequate to explain the basic pattern of preferences for either risk-averse or risk-seeking subjects. We suggest that this is so because such theories pay scant attention to the goals and strategies (italics added) that people bring to risky choice" (p. 548).

This is not to suggest weighted value assessment is never used, but rather that it may not be used on all occasions. This type of decision strategy may only be used if simpler strategies are inefficient or may lead to "poorer" decisions.

In conclusion, weighted value assessment theories have tended to ignore individual differences in risk attitude, even though a number of studies have shown that individual differences in risk attitude exist; the idiographic predictions generated on the basis of weighted value assessment theories are generally derived from nomothetic data. Also, even with the most recent revisions, weighted value assessment theories still fail to describe fully observed decision-making behavior; significant numbers of individuals make decisions which are inconsistent with the basic assumptions of these theories. Finally, weighted value assessment theories fail as process models; individual subjects report the use of strategies which utilize processes that differ considerably from the subjective weighting schemes embodies in weighted value models of decision making.

Appendix B: Average Decision Times From Study 2 (in milliseconds)

Subject	Risk-gain Problems	Risk-Loss Problems	Worth-gain Problems	Worth-loss Problems	Entire Problem Set
1	4892	6202	5739	6265	5774
2	2131	2774	1873	1769	2137
3	1956	2075	1797	2428	2064
4	3237	2599	2512	2283	2658
5	2960	3772	3352	3398	3370
6	2261	2511	2087	1901	2190
7	1315	2705	2151	2041	2053
8	5928	7370	6238	6612	6537
9	2547	3481	2151	3058	2809
10	6203	5624	4129	4661	5154
11	1605	2828	1702	2151	2071
12	3409	3888	2434	3413	3286
13	1542	1520	2127	1533	1680
14	2174	2516	2181	2833	2426
15	3148	4159	2824	3410	3385
16	2640	2946	2175	4026	2947
17	3835	4317	2723	3186	3515
18	4197	3982	3001	4072	3813
19	1156	874	992	698	930
20	2669	3421	2074	2857	2755
21	3216	3794	2556	2102	2917
22	3316	3937	2287	3052	3148
23	1788	3011	2584	2259	2410
24	2192	2396	1588	2067	2061
25	2049	2342	2612	2028	2258
26	1491	2290	1379	2513	1918
27	1924	2089	1646	1852	1878
28	3265	3516	2385	2942	3027
29	2992	5370	2703	4009	3768
30	2612	2855	2282	2872	2655

Appendix C: Number of Probabilistic and Amount Statements From Study 4

8-year-old subjects:

Subject	Number of Probability Statements (Max = 60)	Number of Amount Statements (Max = 60)	Total Number of Statements (Max = 120)	Proportion of Probabilistic Statements
1	21	47	68	0.31
2	10	47	57	0.18
3	52	31	83	0.63
4	0	56	56	0.00
5	16	45	61	0.26
6	45	38	83	0.54
7	49	20	69	0.71
8	37	21	58	0.64
9	58	56	114	0.51
10	54	26	80	0.68
11	47	24	71	0.66
12	24	43	67	0.36
13	45	21	66	0.68
14	50	2	52	0.96
15	54	7	61	0.89
16	54	3	57	0.95
17	48	12	60	0.80
18	44	33	77	0.57
19	32	23	55	0.58
20	3	60	63	0.05
21	19	49	68	0.28
22	44	31	75	0.59
23	51	51	102	0.50
24	34	27	61	0.56
25	54	45	99	0.55

<u>12-year-old subjects</u>:

Subject	Number of Probability Statements (Max = 60)	Number of Amount Statements (Max = 60)	Total Number of Statements (Max = 120)	Proportion of Probabilistic Statements
1	58	13	71	0.82
2	34	39	73	0.47
3	9	44	53	0.17
4	31	29	60	0.52
5	45	24	69	0.65
6	53	16	69	0.77
7	53	35	88	0.60
8	58	50	108	0.54
9	40	38	78	0.51
10	44	28	72	0.61
11	55	4	59	0.93
12	36	27	63	0.57
13	50	6	56	0.89
14	48	9	57	0.84
15	40	20	60	0.67
16	47	24	71	0.66
17	34	12	46	0.74
18	49	37	86	0.57
19	46	28	74	0.62
20	43	28	71	0.61
21	55	13	68	0.81
22	43	19	62	0.69
23	50	33	83	0.60
24	36	23	59	0.61
25	43	32	75	0.57

<u>19-year-old subjects</u>:

Subject	Number of Probability Statements (Max = 60)	Number of Amount Statements (Max = 60)	Total Number of Statements (Max = 120)	Proportion of Probabilistic Statements
1	29	32	61	0.48
2	53	45	98	0.54
3	42	26	68	0.62
4	47	28	75	0.63
5	47	30	77	0.61
6	3	15	18	0.17
7	51	37	88	0.58
8	48	33	81	0.59
9	36	33	69	0.52
10	52	34	86	0.60
11	37	29	66	0.56
12	58	53	111	0.52
13	47	23	70	0.67
14	52	41	93	0.56
15	58	45	103	0.56
16	32	35	67	0.48
17	38	27	65	0.58
18	60	55	115	0.52
19	37	33	70	0.53
20	51	46	97	0.53
21	58	54	112	0.52
22	40	23	63	0.63
23	39	45	84	0.46
24	40	40	80	0.50
25	57	46	103	0.55