AMBIGUITY, PRECISION, AND CHOICE: A FUZZY TRACE THEORY ANALYSIS OF FRAMING EFFECTS IN DECISION MAKING UNDER UNCERTAINTY

by

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DEDICATION

What winners do not know, gamblers understand.
(with apologies to *Heart*)

This dissertation is for each of us as we make decisions.

In choice, there is freedom.
In choice, there is self.
Choose wisely.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Framing effects are inconsistencies in preference across transformations in stimulus content. In this study, I present two experiments designed to test the descriptive power of two competing theories of cognitive aspects of framing effects in choice. Traditional explanations for framing effects, such as prospect theory, suggest that choice is a function of operations on numerical elements of risky stimuli. Cognition is presumed to be quantitative in nature, including diminishing returns for the values of outcomes and discounting of probabilities. In contrast, fuzzy trace theory, a relatively new conceptualization of cognition with very different assumptions than psychophysical approaches, suggests framing effects result from qualitative processing of decision components. Participants chose between certain and risky alternatives across a variety of reflection problems. Dependent variables in these experiments include choice, confidence in choice, a sensitive weighted measure called signed confidence, and response latency. Results of both experiments suggest failures of the psychophysical approach, and highlight successful predictions based on fuzzy trace theory. These predictions are based on four principles of the fuzzy trace theory intuitive approach to cognition: gist extraction, the hierarchy of gist, the fuzzy to verbatim continuum of memorial representations, and the fuzzy processing preference. The results tend to refute explanations of framing effects as being computationally and quantitatively driven and support explanations based on qualitative processing. Intuition, rather than human information processing, is an elegant description of decision making under uncertainty.

INTRODUCTION AND BACKGROUND

In this study I present two experiments on decision making designed to test fundamental differences between two competing cognitive theoretical traditions in choice behavior, fuzzy trace theory and prospect theory. Prospect theory is currently a dominant approach, in the psychophysical tradition, to description of choice behavior. The psychophysical tradition is grounded in quantitative processing operations on precise numerical information, for choices involving uncertain, risky options. Fuzzy trace theory is a relatively new theory built on radically different assumptions of cognitive processing, and a growing body of evidence supports this perspective based on the metaphor of intuition. The intuitive approach assumes people extract multiple representations when confronted with choice stimuli, and they prefer to process fuzzy, gist-based information to make their decisions. These experiments contain critical tests embedded in the designs to provide comparisons of predictions based on the two theoretical explanations of choice. Experiment 1 contains manipulations of choice stimuli that examine which elements of risky choices people attend to and selectively process in order to reach a decision. Experiment 2 contains manipulations that examine opposing predictions for crucial relationships among elements of choices containing uncertainty. Evidence presented will enable direct comparisons of the descriptive power of these two perspectives.

Early Theories of Choice

Much of the current work in decision making has its roots in the early 18th Century. In 1713, Nicolas Bernoulli posed a question that has come to be known as the St. Petersburg Paradox. He asked people how much money they would pay to play a game with an unbiased coin flipped until it lands on tails and the following payoff scheme. If the coin comes up tails (T) on the first trial (probability = 1/2) the player wins 2 ducats. If the coin lands heads (H) on the first flip and tails on the second flip (probability

1/2*1/2=1/4) the player wins 4 ducats. If the flip sequence is HHT (probability 1/2*1/2*1/2=1/8) the amount paid is 8 ducats, and so on. This game obtains its paradoxical quality in decision making theory because the expected value of the payoff is infinite [i.e., (1/2*2) + (1/4*4) + (1/8*8) + (1/16*16) + (...) = 1 + 1 + 1 + 1 + (...) = an infinite sum of money], yet people refuse to pay large sums of money to play. Twenty-five years later Daniel Bernoulli suggested that money possesses value or utility to players that decreases with increasing winnings or wealth, in a negatively accelerated fashion. A change in wealth from 100 ducats to 200 ducats is more substantial than a change from 1100 ducats to 1200 ducats, despite the identical absolute monetary value of the change. Bernoulli (1738) wrote "a gain of one thousand ducats is more significant to a pauper than to a rich man." Bernoulli had demonstrated that the utility curve for money in the minds of players, reduced the expected value of the St. Petersburg game far below the infinite, and made the decision not to play seem more reasonable. In his findings are the beginnings of modern decision making theory and discussions of choice behavior.

An important version of modern theories of choice that incorporates the notion of decreasing utility was expected utility theory (EU) proposed by von Neumann and Morgenstern (1947). This model of choice was offered as a normative approach in that it included a set of mathematical and logical rules for how a person should act if he or she were behaving rationally. When confronted with a choice, a decision maker should calculate the expected utility of each option by multiplying the probability of outcomes within the option by the utility of the outcomes. The expected utility of an option is the sum of these computations: that is, $EU = \Sigma p(i)u(i)$. A choice between a certain outcome of \$100 and a coin flip for either \$200 or nothing would be computed as (1.0)*u(\$100) versus (0.50)*u(\$200)+(0.50)*u(\$0). People then choose by selecting the option that maximizes the utility function. Based on this model, von Neumann and Morgenstern set down axioms that ought to be followed by a rational decision maker. Many theorists regard two principles crucial to any normative theory of rational choice: dominance and invariance (e.g., Tversky and Kahneman, 1988). Dominance requires that a decision maker always choose the alternative with a higher expected utility (e.g., a 1/2 chance to win $10 should dominate a 1/3 chance to win $5). Invariance obligates a rational decision maker to make consistent choices across descriptive transformations of stimuli. For example, a rational decision maker should not change his or her preference because an option is presented as a single-stage lottery with a 25% chance to win $100 and a two-tier lottery with a 50% chance at each stage and a $100 payoff if both stages are successfully completed (from Plous, 1993). Invariance in preference dictates that because 0.50*0.50 is 0.25 the change in description from one-stage to two-stage should not influence a decision maker.

There are now many extensions and variations of expected utility theory. Among these is subjective expected utility (SEU) theory developed by Savage (1954), that allows for personal, subjective interpretation of the probabilities associated with outcomes. EU theory had dealt with probabilities as objective (i.e., verifiable by relative frequency calculations), and Savage's modification grants decision makers the ability to interpret the chance an outcome would occur. As Plous (1993, p 83) points out, "within the framework of SEU theory, it makes sense to consider the probability of an unrepeatable event such as worldwide nuclear war," whereas the likelihood of war has little meaning in EU theory. Other extensions of EU theory have been offered (e.g., Luce, 1959; Karmarkar, 1978; Fishburn, 1984).

Although EU and SEU theories maintain their status as historical normative ideals there are too many paradoxes in empirical findings to provide these theories any descriptive stature. For example, Allais (1953) and Ellsberg (1961) presented data that showed the cancellation principle of EU theory is not always followed by decision makers. Tversky (1969) showed subjects are not always transitive and Lichtenstein and Slovic (1971) found that people are not consistently invariant. Hershey and Schoemaker (1980) also presented results that ran counter to the EU model for choices in the loss domain. They found that although subjects showed significant risk seeking behavior for losses the data were inconsistent with a convex utility function across losses proposed by classic utility theories. For other discussions of the failures of EU and SEU see Tversky and Kahneman (1988) or Plous (1993). Because there are a large number of experimental results that run counter to EU theory, it has faded as a descriptive view of choice.

Current Perspectives

Some of the most devastating evidence contrary to EU and SEU predictions has been developed from preference reversals and framing effects. Explanations of these effects are essential to any normative view of decision making and current theoretical advances generally develop because empirical findings alter descriptive models of choice. Research on choice behavior has burgeoned in recent years, and a substantial amount of study has centered on descriptions of framing effects because they are fundamental to theory building. Framing effects are a class of robust inconsistencies in decision making that are a violation of the invariance principle of rational choice. The study of framing effects is highly relevant to decision making because framing effects highlight irrational aspects of cognitive processes.

In 1979, Kahneman and Tversky proposed prospect theory as a descriptive model of choice to supplant earlier EU models. In that study Kahneman and Tversky identified the certainty effect and the reflection effect. They state that the certainty effect means that "people overweight outcomes that are considered certain, relative to outcomes which are merely probable" (1979, p. 265). The reflection effect refers to a reversal of preference when outcomes are mirrored around an absolute zero point. For example, 80% of Israeli subjects preferred a certain win of 3,000 Israeli pounds to an 80% chance to win 4,000, but 92% preferred an 80% to lose 4,000 to a certain loss of 3,000. Kahneman and Tversky (1979, p. 268-269) note that "the reflection effect implies that risk aversion for gains is accompanied by risk-seeking in the negative domain," and "the certainty effect contributes to a risk averse preference for a sure gain over a larger gain that is merely probable" and "the same effect leads to a risk seeking preference for a loss that is merely probable over a smaller loss that is merely probable." They further state that their data "are incompatible with the notion that certainty is generally desirable" but that "certainty increases the aversiveness of losses as well as the desirability of gains." Thus, for reflection stimuli, subjects will tend to exhibit a strong framing effect (preference reversal).

Studies by Tversky and Kahneman (1981, 1986) demonstrate another form of a traditional framing effect. Subjects were asked to choose between treatment programs to combat a deadly disease. Two options were presented, one a certainty and the other a risk; all options--two gain frame versions and two loss frame versions--had equal expected values. The standard gain frame form of the problem was:

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

The loss frame differed only in the available options:

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

The framing effect (typically found with problems such as these examples) is a reversal from risk-aversion in gain frame version (i.e., preference for Program A) to risk-seeking in loss frame versions (i.e., preference for Program D).

In the examples just presented, Programs options A and C represent certainties while programs B and D are risky, uncertain options. Each risky option is composed of non-zero and zero outcome complements; in these examples, "600 people" is the non-zero complement and "no people" is the zero complement. Note that probabilities associated with certain outcomes are implied by "absolute" language (i.e., "will") and are equal, of course, to one. Probabilities of complements of risky options are individually less than one, but sum to unity.

In their classic paper, Kahneman and Tversky described prospect theory as an explanation for the preference reversal. Incorporating aspects of earlier theories, they suggested that subjects apply a decision weight to probabilities that involves a discount on moderate probabilities and incorporates a value function for outcomes that is a diminishing returns function for increasing amounts. According to prospect theory, subjects edit prospects by coding them as gains or losses, combine or cancel redundancies, and reduce complexity in prospect information by simplifying probabilities and detecting dominant outcomes. Then subjects evaluate each prospect by applying two mathematical functions. The decision weight, $\pi(p)$, reflects a subject's subjective belief regarding the probabilities of complements in a prospect and moderate probabilities are typically discounted such that $\pi(p) + \pi(1\text{-}p) < 1$. The value function, $v(x)$, reflects the change from the status quo and possesses the property of diminishing returns utility function of other theories. However, the certainty and reflection effects make it concave for gains and convex for loss, and Kahneman and Tversky suggested it is steeper for losses than for gains. This implies that equivalent gains and losses are subjectively interpreted such that losses loom larger than gains. A loss of "X" is more aversive than a gain of "X" is desirable.

So, according to prospect theory, after subjects codify and simplify information in prospects they evaluate each prospect by applying a mental computation represented by the following formula:

$$V(x,p;y,q) = \pi(p)v(x) + \pi(q)v(y)$$

where, x and y are outcomes within a prospect, and p and q are the probabilities associated with those outcomes, respectively. This formula means that to determine the value of a prospect, a subject multiplies a subjective interpretation of the chance of outcome x by the subjective value of outcome x and adds to that the product of a subjective interpretation of the chance of outcome y and the subjective value of outcome y. The disease problem examples provided above allow illustration of this process. For the gain frame version, subjects would calculate the value of Program B as

$$V(600,1/3;0,2/3) = \pi(1/3)v(600) + \pi(2/3)v(0)$$

Note that computations based on prospect theory preclude any relevance of zero complements in risky options, because zero multiplied by any value is null. Prospect theory explicitly requires that subjects ignore zero complements as they add no useful information to the mental computations of the value of a prospect.

Thus, the prospect theory account for the framing effect is that subjects overweight certain options and discount risky options (and outcomes) in both frames. In the gain frame, this yields risk-aversion because the overall utility of the sure option is higher than the risky option (i.e., a larger number of people are saved), and, in the loss frame, the overall utility of the gamble is higher (i.e., a smaller number of people die) eliciting risk-seeking behavior for losses. As Rachlin (1989, p. 100) notes, "prospect theory explains the reversals of preference due to the problem's language (its frame)." Prospect theory predicts framing effects because of changes (gains or losses) from a reference point (the status quo).

Reyna and Brainerd (see Brainerd and Reyna, 1990; Reyna and Brainerd, 1990, 1991, in press; Reyna, Brainerd, and Connolly, 1990; for complete discussions) suggested a fuzzy-trace theory account for framing effects radically different than the quantitative processing approach of such psychophysical theories as prospect theory. The fuzzy-trace theory account involves four primary principles: gist extraction, fuzzy-to-verbatim continua of memory traces, the fuzzy-processing preference, and the hierarchy of gist. When they encounter stimuli, people extract multiple forms of memorial traces, from fuzzy, gist patterns to rich, detailed, verbatim traces of the precise stimuli. All of the traces are encoded in parallel and provide a decision maker with varying mental representations of the task at hand, along a fuzzy-to-verbatim continua of memorial specificity. People make their choices by examining the most fuzzy level of gist trace available and ascending the hierarchy of gist only as task demands require. That is, people show a preference for processing imprecise, fuzzy representations and access more highly detailed mental representations only if the task absolutely requires them to do so.

Considering the examples of decisions just presented, fuzzy trace theory principles suggest that when approaching the gain frame problems people extract something like the following nominal gist representations.

> If Program A is adopted, some will be saved.
> If Program B is adopted, there is a chance that some will be saved,
> and a chance that none will be saved.

Similarly for the loss frame options people would also extract nominal gist patterns.

> If Program C is adopted, some will die.
> If Program D is adopted, there is a chance that none will die,
> and a chance that some will die.

The fuzzy-trace theory explanation for framing is that decision makers examine the gist of the options for differences allowing a discrimination to be made. Since "some" is present in both options it does not differentiate the options, and the distinction is between "some" in the sure option and "none" in the risky option. Since some is better than none, they choose "some saved" in the gain frame. However, for losses none is better than some and subjects choose "none die" in the loss frame and exhibit the standard framing effect.

As can be readily seen from the preceding examples, hypotheses about processing are markedly different. Psychophysical theorists would argue that the non-zero complements of the risky option in these stimuli are the only relevant portion of the task, because the mental multiplication of the outcome zero by any probabilistic value would yield zero for that complement and decision makers would remove that complement from further consideration in their choice. Fuzzy trace theorists hold that the zero complement is the more relevant complement because of the contrasting gist value of the zero complement ("none") from the gist value of the non-zero complement ("some") in their representation of the entire choice.

The fundamentally different aspect of this approach is that people begin choice processing by making qualitative comparisons and process numerical quantities only if cruder more qualitative distinctions do not allow a choice to be made. Dawes (1988, p. 174) mentions this theoretical view for human cognition (perhaps unwittingly) when he asks:

> Don't we suffer enough from the "tyranny of numbers" when our opportunities in life are controlled by scores of aptitude tests and numbers entered on rating forms by interviewers and supervisors? In short, isn't the human spirit better expressed by intuitive choices than by "crunched" numbers?

Dawes' answer is a resounding "no." He says

> It is only rational to conclude that if one method (a linear model) does not predict well, something else may do better. What is not rational...is to conclude that the "something else" is intuitive global judgment.

However, there is a growing body of evidence to support fuzzy trace theory principles. Results from several research studies have demonstrated the efficacy of the fuzzy-trace theory position. Strong evidence for qualitative processing stems from critical theoretical tests regarding framing effects in the absence of numerical information or under ambiguous conditions. For example, two experiments provided direct tests of processing propositions by presenting problems with varying levels of numerical specificity.

If numerical quantities are necessary to produce framing effects, as is posited by quantitatively driven theoretical approaches, then removing the numbers should eliminate framing (Reyna and Brainerd, 1991). Subjects were presented with problems containing only qualitative descriptions of outcomes and probabilities (e.g., "200 people will be saved" was presented as "*some* people will be saved" and "a 1/3 chance" was presented as "*some* chance") [emphasis added]. When only the outcomes were presented as qualitative pronouncements, a standard framing effect was obtained (i.e., 64% chose the certain option in gain frame versions and only 27% chose certain option for losses). A framing effect of nearly identical proportions (60% chose the certain option for gains and 25% for losses) was obtained when only numerical probability information was exchanged. And notably, the strongest framing effect emerged when subjects handled completely qualitative problems (90% chose the certain option for gains, and 14% for losses). This was a rather profound demonstration that non-zero quantities are not necessary to elicit framing effects; subjects can and do make crude distinctions that result in a framing bias without any numerical processing. This result was replicated in another experiment in which Reyna and Fulginiti (1992) found that presenting the nominal gist directly in word problems yields a strong framing result.

A second critical test of numerical processing assumptions was provided by Reyna and Brainerd (1991) and Fulginiti and Reyna (1993). In these studies, subjects were given problems with truncated risky options. Recall that prospect theory assumes the zero complement of the risky option recedes from a decision makers' attention because computation provides a null value. Presenting problems containing only non-zero complements or only zero complements provides an immediate test of the disparity between the prospect theory and fuzzy trace theory views. As Reyna and Brainerd (in press) point out, providing subjects with only the relevant non-zero complements of risky options is a test of "whether processing this information is sufficient to produce framing effects." Presenting problems with only the zero complements of risky options examines the fuzzy trace theory position that framing results because of the distinction between the zero complement in the risky option and the certain outcome. Both Reyna and Brainerd (1991) and Fulginiti and Reyna (1993) found that framing effects effectively disappeared when only non-zero information was presented, but that subjects viewing only zero complements showed strong framing effects.

In a study of how individual decision makers manage probabilities, Cohen, Jaffray, and Said (1987, p. 20) reported that subjects "who take precise probabilities into account on the gain side, seem to distinguish only coarser categories of belief on the loss side in comparable situations." Wallsten (1990, p. 34) said that, with regard to probabilistic forecasts, "numerical expressions are preferred only when the data base warrants them....Otherwise, verbal expressions are preferred because they seem more natural, easy to use, and consistent with the underlying uncertainty." Wallsten argued that "people can handle verbal information more optimally than numerical information because they are more skilled at the rules of language than at the rules of arithmetic or probability." According to Wedell and Böckenholt (1994, p. 513), subjects approaching a single play gamble (i.e., a risky option played only once as opposed to repeatedly) will "tend to use low-level coarse categorization strategies for considering single plays and more integrative and quantitative strategies for considering multiple plays of a gamble." Legrenzi, Girotto, and Johnson-Laird (1993, p. 38) examined how people reason and reach framed decisions and suggested that "when individuals construct (mental) models, they make explicit as little information as possible... and they inevitably focus on that information which is explicit in their models and concomitantly fail to consider other alternatives."

Reyna and Brainerd (in press) point out that fuzzy trace theory does not suggest that subjects are incapable of rendering mathematical solutions to choice problems involving numerical quantities. The fuzzy to verbatim continua principle of fuzzy trace theory implies that multiple representations are extracted from stimuli from very qualitative, gist memorial traces to rich, detailed verbatim traces and traces are all available for processing. Subjects prefer to operate more qualitatively at first (the fuzzy processing preference) and ascend to more quantitative processing only as the task requires. Fulginiti and Reyna (1993) tested this effect explicitly by presenting subjects with numerically converging or diverging problems (i.e., expected values of the options were unequal) in addition to standard formulations (in which the expected values are equal). Converging problems altered the expected values such that options not generally preferred when people frame had slightly higher expected values than preferred options. Diverging problems altered expected values such that the opposite was true; options preferred when framing is present had slightly higher expected values. For example, one version of the diverging problem consisted of presenting "Option A: 204 people will be saved" (Option A) versus "a 1/3 chance that 599 people will be saved and a 2/3 chance that no one will be saved" (Option

B) giving the risky option a slight quantitative superiority while preserving identical nominal gist comparisons to standard versions (i.e., "some saved" versus "none saved") Sensitivity to numerical quantities was demonstrated by subjects handling those stimuli. Framing diminished somewhat for converging problems and increased for diverging problems. As Reyna and Brainerd (in press) note, "subjects show framing effects in spite of their ability to process expected values."

Other researchers have discovered effects that suggest people process qualitatively as a matter of first priority. Beach (1993, p. 215) suggested that subjects perform a screening operation on options prior to making a choice. He notes that "while screening may indeed reduce the effort required for choice, equally or more important is the fact that it reduces opportunities for bad choices...by limiting choice to only those options that at least meet the decision maker's minimal standards." Payne (1982; see also Payne, Bettman, and Johnson, 1988) report that decision makers alter their choice behavior (i.e., select a choice strategy appropriate for the task at hand) due to a wide array of influences including: context effects such as similarity of options or global attractiveness of an option, task complexity effects such as the number of alternatives or number of dimensions, response mode effects such as judgment versus choice, and stimulus presentation effects such as sequential versus simultaneous display of alternatives in a choice and partially described options. Kleinmuntz and Schkade (1993, p. 223) argue that decision makers prepare for a choice by engaging in an initial planning stage during which they account for variations in the problem features; for example they argue that "decision makers respond to increases in the number of alternatives by switching to simpler, less accurate strategies."

Lippman-Hand and Frazier (1979) found that parents facing a reproductive decision, with the possibility of genetic abnormality in the child, tended to reduce genetic risk to a dichotomy, either their baby would or would not be abnormal, and they gave these complements equal weight in their deliberations.

Returning to truncated stimuli, note that the missing complements introduce an element of ambiguity to choice options. Ellsberg (1961) identified the influence of ambiguity on choice in a classic demonstration of ambiguity avoidance behavior, the "Ellsberg paradox." His results show that subjects prefer to bet on an outcome when they know its associated probability than when the outcome is ambiguous. For example, he demonstrated that subjects would rather bet that they will draw a red ball from an urn containing a known proportion of red and black balls than they would bet that they would draw a red ball from another urn containing an unknown proportion of red and black balls. Loke (1989) also found subjects' inclination to accept or reject gambles was affected by missing information; subjects were more likely to refuse gambles when only probability information was given. Referring to ambiguous choice situations, Einhorn and Hogarth (1985, p. 459) stated that "there are costs of investing in imagination, increased mental effort and the discomfort that results from greater uncertainty." But Einhorn and Hogarth also point out that "the benefits of considering the world that isn't protects one from over-confidence" and finding a compromise between what is known and what isn't known "is central to inferences under ambiguity and uncertainty."

Frisch and Baron (1988) defined ambiguity as a subjective experience of missing information and suggested that ambiguous situations can often be changed into unambiguous situations, or unambiguous situations into ambiguous ones by directing decision makers' attention toward or away from missing information. Again, note that truncating complements from choice stimuli has the effect of producing ambiguity. However, these manipulations yield an effective test of competing theoretical views. Reyna and Brainerd (in press) report an experiment designed to test selective processing effects. Two groups of subjects were presented with problems consisting of a certain option and truncated risky options (one group received problems with only zero complements and another group saw problems with only non-zero complements--identical to problems described above from Fulginiti and Reyna, 1993), but the problems were disambiguated by printing the missing information above the options on the page and instructing subjects to read the entire problem carefully. In this way, ambiguity is removed by explicit presentation of missing information but subjects are coaxed toward selectively processing information in the options. In other words, subjects will focus on the immediate task at hand of selecting between two options and ignore disambiguating material. Reyna and Brainerd report the same findings as Fulginiti and Reyna (1993) found with truncated (ambiguous) problems; that is, there is no relationship between processing relevant numbers and framing, but large framing effects when subjects focused on zero complements. These findings coincide with the suggestion by Legrenzi, Girotto, and Johnson-Laird (1993) that focusing "may well account for a number of so called 'framing' effects in decision making" (p. 61).

Other research on truncated information was done by Levin, Johnson, Deldin, Carstens, Cressey & Davis (1986; see also Levin, Johnson, Russo & Deldin, 1985). Levin, et al. (1986) found that subjects framed consistently across problems with missing probability information and missing numerical information. People were almost indifferent about selecting gambles with missing probability information over complete gambles in pairwise choices for losses and much more likely to reject gambles with missing probability information in gains. However, when relevant outcome values were deleted, subjects did not frame; they rejected gambles with missing outcomes equally for both gains and losses. (Note that, from a fuzzy trace theory position, removal of probability information does not interfere with extraction of nominal gist and qualitative processing of the numerical amounts, but that removal of the outcomes decidedly alters gist representations of the outcomes and qualitative processing is no longer possible.)

Some inconsistent findings have been reported in this research. For example, Fagley and Miller (1987) found no framing effect for a sample of MBA students, primarily due to indifference for loss frame problems. They suggest that these results may be due to homogeneity of their sample and a risk-averse tendency among MBA students, or an alteration of the probabilities in their stimuli (i.e., they used 2/5 and 3/5 for risky complements instead of the traditional 1/3 and 2/3 from Tversky and Kahneman (1981, 1986). Fagley and Miller (1990) performed separate framing analyses for samples of women and men and found that framing was not a significant pattern for men but women framed significantly. Miller and Fagley (1992) replicated this effect due to sex finding a significant correlation between framing and choice for women and no such relationship for men. And finally, Miller and Fagley (1991) demonstrated that framing effects disappeared when probabilities associated with the numerical complement in risky options was set at 2/3, indicating a potential failure of the decision weight function proposed by Kahneman and Tversky, 1979). They suggest that their data indicate that above a 50/50 gamble, subjects do not underweight probabilities and therefore framing diminishes.

Finally, it should be noted that direct tests of predictions based on the prospect theory and fuzzy trace theory approaches are possible through manipulations of the risk level and magnitude of outcomes. Predictions based on the value function and decision weight function of prospect theory are direct. Due to decreasing marginal differences as magnitude of outcomes increases, the value function suggests that framing should diminish as non-zero outcomes in the risky prospect rise. The fuzzy trace theory gist extraction principle suggests that since difference between the certain option and the zero complement of the risky option does not change as risk and the value of non-zero complement value increases.

Purpose of the Current Study

The purpose of the current study is to examine the effects of ambiguity, precision of information, truncation, probability level, changes in outcome values, and sex of participants on choice patterns for gain and loss frames, from a fuzzy trace theory perspective. The fuzzy-trace theory approach is relevant to these effects because gist and qualitative processing lend themselves to examining non-quantitative descriptions of rational thought.

In addition, response latency for framing problems has not been thoroughly investigated. Current technology (e.g., computers) allows presentation of information at various levels of ambiguity and precision and the collection of accurate response latency data. This study employs this methodology. Patterns of subjects' response latencies would potentially reinforce the fuzzy trace theory view that qualitative processing is performed first and allows for faster choice, if response latencies for problems containing zero complements are faster than those containing non-zero complements. This study provides insights into the real-time processing of information (including probabilities) involved in decision-making and choice, as well as the effects of ambiguity and precision on certain forms of framing effects. I conducted two separate experiments with different samples of participants and unique designs and purposes. I will first discuss these experiments separately and then discuss connections between them in the Discussion section.

METHOD

Experiment 1

According to the psychophysical approaches, choices are made by processing relevant numerical quantities of available options; complements of risky alternatives containing zeros are removed from consideration by these computations. The fuzzy trace theory position is that people choose by qualitatively processing relationships among vague, gist representations of options; especially pivotal in these comparisons is that between "some" and "none" and, therefore, complements of alternatives containing zeros are selectively processed as a matter of first priority. Providing stimuli with complements of risky options deleted allows an immediate test of this selective processing. This experiment contains a between-subjects factor (Truncation) that I used to place participants in one of two groups--one group saw choices with the zero complement of the risky alternative deleted and the other group saw problems with the numerical complement deleted. If the fuzzy trace theory supposition that subjects selectively process the zero complement first is correct, then framing effects should be observed for subjects seeing only zeros and framing should be decreased or eliminated for subjects seeing numerical quantities. Also, presenting choices with missing information creates ambiguity. I crossed a second between-subjects factor (Ambiguity) with Truncation in this experiment. Some participants saw disambiguated problems (i.e., the information missing from the risky alternative was presented above the truncated options and it remained in view during the choice), some saw disambiguated problems (i.e., the information missing from the risky alternative was presented above the options but it was removed from view when they made their selection), and other participants saw no potentially useful disambiguating information. This factor allows further examination of what information people process, by manipulating what information is available to decision makers. Fuzzy trace theory predictions for disambiguated stimuli include stronger framing for those problems which contain zeros even if numerical information is available. However, predictions based on prospect theory are that framing will be stronger in groups provided with relevant numerical quantities. Increases in risk and magnitude of outcomes also produce different predictions from these two theories; as risk and outcome values increase, prospect theory implies weaker framing, while the fuzzy trace theory prediction is increased framing or no decrease. The Probability and Magnitude factors in this experiment provide critical tests for these manipulations.

Participants. Participants were recruited from the general public in Tucson and Phoenix Arizona. Specific criteria for selection were that one be an adult (i.e., at least 18 years of age), be able to read English, and be capable of performing simple keyboard functions on a computer. Ninety-nine people volunteered for the study. One subject stopped after fifteen minutes claiming he had forgotten an appointment and he did not return to complete the experience. Data from one subject were damaged during computer file manipulation. Responses from these two participants were not included in analyses due to incomplete data. The final sample for this experiment consisted of 97 people, 42 men and 55 women.

Some participants were students of the University of Arizona and Pima Community College, including undergraduates in Psychology, Physics, and Speech and Hearing Sciences courses, and graduate students in Psychology, Educational Psychology, and Medicine. Other participants were staff and faculty of the University of Arizona Colleges of Medicine and Education, and members of the general public. Participants were personally invited to participate by this researcher or they responded to bulletin board signs placed at various locations around the University of Arizona campus. Several responded to an electronic mail announcement on a local computer system at the University of Arizona College of Medicine.

The mean age of these participants was 35.6 years (range = 19 to 73 years , standard deviation = 14.4 years, median = 31.0 years). A positive skew in the age distribution resulted because I did not accept minors as participants and ten high-functioning older adults volunteered to participate.

The education and life experience of these participants was diverse. Participants reported educational attainment on a 7-point scale: 1) did not complete high school, 2) completed high school, 3) completed some college--no degree, 4) Associate's degree, 5) Bachelor's degree, 6) Master's degree, and 7) completed doctoral or professional degree. One reported not completing high school; six completed high school but had never attended college; 33 had attended or were attending college but had not obtained a degree; seven had earned Associate's degrees; 27 reported earning Bachelor's degrees; six had earned Master's degrees; sixteen were in training for or had earned a professional or doctoral degree; and, one did not provide an educational attainment response.

Participants reported their employment status at the time they participated as follows: four in administration, three in business, one in civil service, twelve educators, two professional fine artists, one attorney, eleven physicians including ten medical students who view medical school as their employment, five nurses, one in public service, four in research science, one in retail sales, eleven secretarial/clerical employees, three in skilled trades, 28 students, one unskilled laborer, two unemployed, one omitted response, and five "other" including one hairstylist, a homemaker, a computer programmer, a designer, and a physician's assistant. I also asked these participants to report what their major area of study was in school. These responses spanned a broad spectrum of over 30 different disciplines, with four clusters: ten participants in biology, nine in education, nine in nursing, and, seven in speech and hearing sciences.

On a seven-point scale (1=Not at all, 2=Probably Not, 3=Possibly Not, 4=As likely as Not, 5= Possible Could, 6=Probably Could, and 7=Easily Could) the mean self-rating for these participants on their ability to calculate probability outcomes in word problems was 4.90 (SD = 1.82).

Apparatus. I used a DOS-based computer and a program I developed to present stimuli and collect data on several dependent variables. The program recorded: (a) the time each subject required to read problem components, (b) the decision time (based on keystroke latencies--accurate to milliseconds), (c) the preference for the certain or risky option, and (d) a confidence rating in the choice on a scale from 1 (No confidence) to 20 (Complete Confidence).

In addition to the data collected automatically, I computed a weighted measure called signed confidence. If a subject chose the sure option, I weighted the associated confidence rating for that problem by +1, and if they chose the risky option, their confidence was weighted by -1; this yielded a score for problems on a scale from -20 to +20. The signed confidence captured the degree to which participants preferred either the sure or risky option. This sensitive measure preserved information contained in the choice data, and incorporated fine-tuning from confidence ratings. The typical framing result is characterized by positive scores in the gain frame and negative scores in the loss frame.

I developed reflection stimuli to present hypothetical situations involving a choice between a certain option and a risky option. These problems are mirror images across frame. For example, a gain frame certain option "You will win $200" is reflected around zero by reversing its sign and becomes "You will lose $200." Both gain and loss versions of these stimuli have a reference point of zero and explicitly present gains and losses from that common reference. Some problems involved decisions about treatment programs for fatal diseases in which the decision related to human lives saved or lost depending on the outcome of the selected programs.

For example, a gain frame Disease problem was:

> Imagine that two programs have been proposed to combat the outbreak of a fatal disease. Assume the exact scientific estimates of the consequences of the programs are as follows:
>
>> If Program A is adopted, there is a 1/4 probability that 800 people will be saved, and a 3/4 probability that no people will be saved.
>> If Program B is adopted, 200 people will be saved.

The loss frame version has the same preamble but different alternatives.

>> If Program A is adopted, there is a 1/4 probability that 800 people will die, and a 3/4 probability that no people will die.
>> If Program B is adopted, 200 people will die.

The other problems were a Regular Monetary problem and a Casino Monetary version of the choice problem that involved winning or losing monetary amounts. The Regular Monetary problem contained straightforward presentations of probability estimates and outcomes. The gain frame version of this problems is as follows.

> Imagine that you face the following decision between two options.
>
>> Option A: There is a 25% chance that you will win $800, and a 75% chance you will win nothing.
>> Option B: You will win $200.

The loss frame options are different.

>> Option A: There is a 25% chance that you will lose $800, and a 75% chance you will lose nothing.
>> Option B: You will lose $200.

The third class of problems was a variant of the money problem, a Casino problem in which probability information was provided through a spinner with appropriate sections of various colors.

An example of the gain frame version is:

> Imagine that you must choose between the following two options.
>
> Option A: You spin a spinner that is 1/2 red and 1/2 blue. If the spinner lands on red, you will win $400, and if the spinner lands on blue you will win nothing.
>
> Option B: You will win $200.

The loss frame has different options.

> Option A: You spin a spinner that is 1/3 orange and 2/3 green. If the spinner lands on orange, you will lose $600, and if the spinner lands on green, you will lose nothing.
>
> Option B: You will lose $200.

In addition to these variations, participants responded to the original versions of the Disease problem used by Tversky and Kahneman (1981), and several special pilot problems. As can be seen from these examples, valence of the problems is balanced across gain frame (positively worded) and loss frame (negatively worded).

One obvious manipulation of problem presentation reflected in these examples requires mention here. Until a few recent studies, these stimuli were presented with paper and pencil protocols (i.e., a packet of stapled pages and responses circled or checked by participants). In these experiments the problems offered the certain option first and the risky option second. I decided to offer these options in the opposite order to facilitate interpretation of the response latency data. Risky options in these problems vary in length and have two complements that were often manipulated; certain options were uniformly short and the same length (e.g., four words such as "200 people will live" or "You will lose $2,000"). In unpublished data collected during the Reyna and Fulginiti (1992) and Fulginiti and Reyna (1993) experiments, we found that order of alternatives plays little role in choice. So, reversing the order of the alternatives has no effect on choice patterns while allowing accurate estimation of response latency across various manipulations of the risky component of these problems.

Procedure. I told participants they would be Involved in a study on thinking and decision-making, and I informed them that they could stop at any time, according to policies regarding human subjects in research. Participants first read and signed a Human Subjects Consent Form. I then responded to any questions they may have had, and signed the Consent form to indicate we both were satisfied they were aware of the nature of the study. I provided a brief introduction to the study and to the computer they would be using. Appendix A contains a full account of the instructions to participants.

After being informed that I wanted them to respond as quickly as possible, some of the participants asked if they could fully think about the problems or if they had to respond as quickly as possible without thinking. I reinforced that they were to take as much time as they needed to fully understand the choice, but they were not to waste their own time by agonizing over every problem. I also told them that a response by single person to a single problem was not relevant to my results, as I needed numerous responses by a large number of participants to reach my conclusions. A few of the participants with more sophisticated scientific experience asked if they were to respond quickly because their responses were being timed. In order not to allow these participants to contaminate response latency data, I asked them to proceed at a steady pace and not waste time on any one problem.

When a participant was satisfied they knew what to expect, he or she sat at a desk facing a computer monitor and I demonstrated hand positioning for use of the computer keyboard. I started a practice program that displayed simple sentences instead of actual problem components (e.g., the practice routine displayed "This is where you will see

Option A" instead of an actual option). I then instructed participants on the use of specially designated keys, that made the problems appear and allowed them to make their choice. They pressed the space bar to make each successive component of a problem appear (i.e., "Press the space bar once, the preamble appears; press it again, Option A appears" etc.). Once they had all parts of a problem displayed, they used two specially marked keys to indicate whether they preferred Option A or Option B. I had placed two large stickers prominently marked with "A" and "B" over two keys just above the space bar to facilitate immediate response uncontaminated by searching for the actual "a" or "b" keys on the keyboard. In order to effectively interact with the program, participants only had to place one hand with a finger extended over the space bar and the two "option" keys to proceed through a problem, although many opted to use one hand for the space bar and one for the selection keys.

Participants used the numeral keys 0 through 9 and the "Enter" key to indicate a confidence in their choice for each problem. I designed the program so that, after a subject made a choice, a message on the screen reminded the subject what their choice had been for the current problem and prompted them for a confidence rating ranging from 1 (No confidence) to 20 (Complete Confidence). When this message appeared during practice, I told participants some of the decisions they would be making would be difficult and that they might not necessarily like the options presented. In order to provide me with a measure of how strongly they preferred the option they selected from the two presented I had given them an opportunity to rate how much confidence they had that they preferred one option over the over. I suggested that this confidence rating was their opportunity to tell me how strongly they felt about the option they had selected.

I allowed participants to repeat the practice problem until they said they felt comfortable with the necessary keystrokes. I terminated the practice program, indicated that they were about to begin the actual experiment, and told them it would take about 20 to 40 minutes to complete the experience. I started the experimental program and watched participants respond to several problems to be certain there were no difficulties, and then allowed participants to proceed at their own pace. I provided a full debriefing presentation when they had finished, answering any questions they raised.

Design. Participants in this experiment received three blocks of problems. Blocks I and II were related by two between-subjects factors Truncation and Ambiguity. The between-subjects factor Truncation factor separated the participants into one of two groups seeing different problems: Non-Zero (Only non-zero portions of the risky options were presented, during Block I.), or, Zero (Only zero portions of the risky options are presented, during Block I). Because information is missing from truncated options, it is possible to manipulate what information participants bring to bear on the choice, by differentially presenting information that removes (or does not remove) ambiguity. Missing information can be incorporated into the stimulus presentation by printing it above the options (see examples below). I incorporated such a disambiguation scheme into another factor, Ambiguity. The Ambiguity factor separated participants into three conditions: Ambiguous (No disambiguating information.), Simultaneous (Disambiguating information was displayed and remained available.), or, Sequential (Disambiguating information was displayed but erased.). Thus, six conditions resulted from crossing these factors: Ambiguous Non-Zero (AmbNZ), Ambiguous Zero (AmbZ), Simultaneous Disambiguation Non-Zero (SimNZ), Simultaneous Disambiguation Zero (SimZ), Sequential Disambiguation Non-Zero (SeqNZ), Sequential Disambiguation Zero (SeqZ). Approximately equal numbers of men and women were randomly assigned to one of the six conditions. Table 1 contains details of cell sizes.

Table 1

Number of Participants in Each Experimental Condition for Experiment 1

Ambiguity Group	Truncation Group	Number of Men	Number of Women
Ambiguous	Non-Zero	7	9
	Zero	7	9
Sequential	Non-Zero	7	10
	Zero	7	10
Simultaneous	Non-Zero	7	9
	Zero	7	8

Block I contained ambiguous problems with some information missing from the risky option and disambiguated (or not) according to the Ambiguity grouping. Block II consisted of regular, reflection problems with risky options containing complete information. Following exposure to Block I and Block II all participants received all Block III problems, including traditional, standard framing problems identical to those used by Tversky and Kahneman (1981) and several pilot problems. I randomized presentation of problems to each subject within Blocks. Counter-balancing these blocks was inappropriate because manipulations in Blocks II and III could countermand those in Block I.

During Block I, participants in the AmbNZ condition saw problems of the following form.

> Imagine that you face the following decision between two options.
> Option A: There is a 25% chance that you will win $800.
> Option B: You will win $200.

Participants in the AmbZ condition saw problems of this form.

> Imagine that you face the following decision between two options.
> Option A: There is a 75% chance that you will win nothing.
> Option B: You will win $200.

During Block I, participants in the Simultaneous conditions saw problems containing a phrase that disambiguated the truncated risky option and remained in view while they made their choice. Participants in the SimNZ condition saw problems of the following form. (Italics added below for emphasis only; participants saw normal text.)

> Imagine that you face the following decision between two options.
> *Assume for Option A, if the stated outcome does NOT occur, then you will win nothing.*
> Option A: There is a 25% chance that you will win $800.
> Option B: You will win $200.

Participants in the SimZ condition saw problems of this form.

> Imagine that you face the following decision between two options.
> *Assume for Option A, if the stated outcome does NOT occur, then you will win $800.*
> Option A: There is a 75% chance that you will win nothing.
> Option B: You will win $200.

A few participants indicated minor confusion when they first viewed the disambiguating statements but adapted readily to further exposure with a simple explanation that "the stated outcome" referred to specific portions of the risky option (e.g., "win $800" or "win nothing" for these SimNZ and SimZ examples, respectively). In other words, participants in these two conditions saw problems with complete information for the risky option, *disambiguated problems* containing both relevant portions of risky options, that were simply displayed differently than regular versions. The disambiguating information remained available to them on the screen as they indicated their preference for Option A or Option B.

During Block I, participants in the SeqNZ and SeqZ conditions saw versions identical to those presented to the SimNZ and SimZ conditions respectively, except that the disambiguating information was erased when they proceeded to the Options. Participants in these conditions had to maintain in memory any of the disambiguating information they felt they would need to make their selection.

All participants in all six conditions saw regular reflection versions of all problems during Block II (i.e., risky options contained both non-zero and zero complements). For each truncated problem they had seen in Block I they saw a fully identified reflection problem in Block II.

Blocks I and II each consisted of 54 problems developed from a combination of four within-subjects factors: *Problem Content*--three levels (Disease, Regular Monetary, Casino Monetary), *Probability* of the occurrence of the numerical outcome in the risky option--three levels (1/4, 1/3, 1/2), *Magnitude* of the expected value of the options--three levels (Hundreds, Thousands, Millions), and, *Valence*--two levels (Gain, Loss). Problems were presented in a random order to each subject, within each block.

Block III consisted of sixteen problems; participants responded to gain and loss versions of: (a) two replications of the traditional framing Disease problems, and (b) six other pilot problems, presented in a random order to each subject.

Thus, for Experiment 1, each subject saw 124 replications of a problem containing a choice between a certainty and a risky option: 54 truncated problems, followed by 54 regular, fully identified problems, and finally sixteen special problems.

Statistical Analyses. I performed repeated measures analysis of variance (ANOVA) to test effects and interactions of Ambiguity, Truncation, Sex, Block, Probability, Magnitude, Problem Content, and Valence. I conducted four separate analyses for: choice, confidence, signed confidence, and response latency. Because there are several corresponding analyses and a relatively large number of effects in this design, I interpreted only those effects obtaining significance at $p < .01$. I performed 2 by 2 crosstabulation analyses, collapsing across relevant combinations of factors to obtain Frame (Gain/Loss) by Choice (Certainty/Risk), for specific framing effects in choice data accepting $\chi^2(1) > 3.84$ (i.e., $p < .05$) as significant . I conducted separate analyses for Block III related to the traditional framing problems.

Experiment 2

Traditionally for problems of the type employed in this paradigm in which both options have equal expected value, some of the dimensions of options are confounded. If the difference between the sure outcome and the numerical complement of the risky option (termed Delta for this experiment) is held constant, the probability level in the risky option must vary. For example, if the certain option is a \$200 win, and the numerical complement of the risky option is \$600 (Delta = 400) then the probability of winning the \$600 must be 0.33 if the expected value of the options is to remain constant. Another problem with the same Delta value (e.g., a \$400 certain option and an \$800 risky option) requires a probability level of 0.50 to maintain equivalent expected values. Similarly, if the probability level in the risky option is held constant, then the delta value varies.

Fuzzy trace theory and prospect theory made very different predictions for problems containing options that are dissimilar with regard to the distance between values of the certain outcome and the non-zero complement of the risky option, and also the distance between the value of the certain option and a zero reference point . If the expected values of the certain option and the risky option remain the same distance from each other but both move away from the zero reference point (as they do when Delta or risk levels increase), the prediction from the prospect theory position is diminished framing. Due to the increasing difference between the certain option and the zero reference point, a prediction based on fuzzy trace theory calls for increased framing. Experiment 2 was designed to address fuzzy-trace theory assumptions about reference points and the distance from reference points.

Participants. Participants were recruited from the general public in Tucson and Phoenix Arizona. Criteria for selection were identical to those for Experiment 1. Twenty-nine participants volunteered for the study. Data from one participant were damaged during computer file manipulation, and I did not include responses from this subject in analyses due to incomplete data. The final sample for this experiment consisted of twenty-eight adults, 13 men and 15 women.

Participants volunteered for this experiment from the same sources as Experiment 1. The mean age of these participants is 29.0 years (range = 18 to 63 years , standard deviation = 10.9 years, median = 26.0 years). As with Experiment 1, a positive skew to the age distribution resulted because several high-functioning older adults volunteered and I did not permit minors to participate.

The education and life experience of these participants was diverse. Participants in Experiment 2 responded to the same scale for educational attainment as was used in Experiment 1. Two completed high school but had never attended college; twelve had attended or were attending college but had not obtained a degree; two had earned Associate's degrees; five reported earning Bachelor's degrees; five had earned Master's degrees; three were in training for or had earned a professional or doctoral degree; and one subject did not provide an educational attainment response.

Participants reported their employment status at the time they participated as follows: one educator, one journalist, three physicians-in-training, one in the military, one nurse, one in retail sales, three secretarial/clerical employees, one skilled trade person, seventeen students, and one omitted response. These participants' responses to a question on their major area of study in school spanned almost twenty different disciplines, with a cluster of five participants in biology.

On the same 7-point scale used for Experiment 1, the mean self-rating for these participants on their ability to calculate probability outcomes in word problems was 5.14 (SD = 1.71).

Except for being (on average) approximately 6 years younger, possessing a slightly lesser educational attainment, and rating themselves slightly better able to calculate probabilities, this group of people is similar to participants in Experiment 1.

Apparatus. Physical apparati used for Experiment 2 were similar to those described for Experiment 1. A computer program presented stimuli and recorded choice, confidence, and response latency data; I also computed signed confidence scores.

Hypothetical situations were presented involving a choice between a certain option and a risky option. Some problems involved decisions about treatment programs for fatal diseases in which the decision concerned human lives. Other problems involved winning or losing monetary amounts in one of two forms, a Regular problem with presentations of probability estimates and outcomes, and, a variant of the money problem, a Casino problem in which probability information was provided through a spinner with appropriate sections of various colors. Except for variations in expected values of outcomes, these problems are the same as those seen by participants in Experiment 1.

Procedure. After preliminary instructions similar to those described for Experiment 1, the participant sat at a desk facing a computer monitor, and I showed them how to position their hands over the computer keyboard. I used the same practice program as used in Experiment 1 to demonstrate keyboard manipulations and allowed them to familiarize themselves with the procedure. Just as in Experiment 1, I terminated the practice program, indicated that they were about to begin the actual experiment, and told them it would take about 20 to 40 minutes to complete the experience. I started the experimental program and watched participants respond to several problems to be certain there were no difficulties, and then allowed participants to proceed at their own pace. I provided a full debriefing presentation when they had finished, and answered any questions they posed.

Design. Participants in this experiment saw two blocks of problems. This experiment was a completely within-subjects design; every subject in this experiment saw all problems. Block I contained problems that addressed the confounded relationship between probability level and outcome magnitude in standard problems with options of equal expected value. Block II contained traditional, standard Disease problems (Tversky and Kahneman, 1981) and special pilot problems. Counter-balancing these blocks was inappropriate because manipulations in Block II could interfere with those in Block I.

Participants saw problems during Block I with six values of Delta and three levels of probability in the moderate range. I selected six *Delta* values (400, 800, 4,000, 8,000, 40,000, 80,000) to produce expected values for problem magnitudes ranging from hundreds to hundreds of thousands, and combined them with three moderate *Probability* values (1/3, 1/2, 2/3). This resulted in eighteen stimulus categories, each containing Disease, Regular Monetary, and Casino Monetary problems of both gain and loss valences. I randomized presentation of problems to each subject within Blocks.

For Experiment 2, each subject saw 124 problems containing a choice between a certainty and a risk: 108 problems with varying *Delta* and *Probability* values, followed by sixteen special problems.

Statistical Analyses. I performed repeated measures analysis of variance (ANOVA) to test effects and interactions of Sex, Delta, Probability, Problem Content, and Valence. I conducted four separate analyses for: choice, confidence, signed confidence, and response latency. Because there are several corresponding analyses and a relatively large number of effects in this design, I interpreted only those effects obtaining significance at $p < .01$. I performed 2 by 2 crosstabulation analyses, collapsing across relevant combinations of factors to obtain Frame (Gain/Loss) by Choice (Certainty/Risk), for specific framing effects in choice data accepting $\chi^2(1) > 3.84$ (i.e., $p < .05$) as significant . I conducted separate analyses for Block II related to the traditional framing problems.

RESULTS

Experiment 1

Choice. In order to facilitate interpretation of framing effects, I chose to present preference patterns as a percentage of participants' choices of the certain option. The typical framing choice pattern is therefore characterized by a significantly larger percentage of participants choosing the certain option in the gain frame (generally more than 50%) than in the loss frame (generally less than 50%).

To address questions regarding task demand and response differences between framing problems and reflection problems, I included a sample of traditional, standard framing problems from the work by Tversky and Kahneman (1981). Participants chose the certain option in 70% of the gain frame versions of these traditional problems, and in 39% of the loss versions [$\chi^2(1)$, $N = 388) = 36.16$, $p < .001$]. This finding demonstrated that the participants in this study were subject to the classic framing effect; it parallels the 72% for gains and 22% for losses that Tversky and Kahneman reported for the disease problem. Since these stimuli were presented in Block III, this response pattern occurred despite prior exposure to at least 108 other stimuli. Framing was a significant and notable response pattern among participants.

For the reflection stimuli in this study, collapsed across Blocks I and II and all other factors, I elicited a strong framing pattern. Seventy-four percent of participants were risk-averse in the gain frame and 22% were risk-averse the loss frame [$F(1, 85) = 301.29$, $MSE = 2.280$, $p < .001$].

Participants' preferences were significantly different for the Truncation by Frame by Block interaction. Preferences of participants in the Non-Zero and Zero groups significantly shifted in opposite directions from Block I to Block II [$F(1, 85) = 22.58$, $MSE = 0.493$, $p < .001$]. As Table 2 shows, participants viewing only zero complements of risky options in Block I framed much more strongly than those viewing non-zero, numerical information. Participants in the Non-Zero group framed more during Block II than they had during Block I, and participants in the Zero group framed less in Block II than they had in Block I. The framing effect for both groups is virtually identical in Block II, during which all participants were responding to regular, fully identified reflection problems.

Table 2

Percentage of Participants Choosing the Certain Option for Truncation by Block by Frame in Experiment 1

Truncation Group	Frame	Block I	Block II
Non-Zero	Gain	69.4	73.8
	Loss	32.9	20.5
Zero	Gain	77.7	74.4
	Loss	14.4	20.8

Framing did not differ significantly among levels of the Ambiguity groups, and framing was not significantly different across Blocks when these factors were considered as main effects. There was a five-way interaction among the Ambiguity, Truncation, Block, Frame, and Sex factors [$F(2, 85) = 5.14$, $MSE = 0.493$, $p = .0078$]. Table 3 contains the percentage of participants choosing the certain option for this effect.

Table 3

Percentage of Participants Choosing the Certain Option for Ambiguity by Truncation by Sex by Block by Frame for Experiment 1

			Male		Female	
Ambiguity	Truncation	Frame	Block I	Block II	Block I	Block II
Ambiguity	Non-Zero	Gain	71.4	74.1	65.8	71.6
		Loss	30.2	25.9	36.2	14.0
	Zero	Gain	65.6	78.3	88.9	65.0
		Loss	7.4	15.3	6.6	21.8
Sequential	Non-Zero	Gain	81.5	82.5	66.3	73.0
		Loss	22.2	16.4	33.3	10.7
	Zero	Gain	90.5	82.0	72.6	77.8
		Loss	16.4	19.6	20.0	23.3
Simultaneous	Non-Zero	Gain	74.1	79.4	57.2	62.1
		Loss	33.9	24.9	40.3	30.9
	Zero	Gain	70.4	59.8	78.2	83.3
		Loss	19.0	26.5	16.7	18.1

This effect seems primarily due to variations from Block I to Block II between the sexes, but no clear pattern emerges. Since none of the lower-order interactions with Sex is significant, this effect is probably a sampling error due to the small cell sizes.

Seen collapsed across all grouping factors, Problem Content interacted with frame [$F(2, 170) = 6.08$, MSE = 0.325, $p = .0028$]. Participants framed slightly less with the Disease problem (71% for gains, 24% losses) than with either the Regular Monetary problem (77% for gains, 20% for losses) or the Casino Monetary problem (74% for gains, 23% for losses). Magnitude of the expected value of outcomes influenced framing monotonically. Participants framed more as Magnitude increased [$F(2, 170) = 26.18$, MSE = 0.196, $p < .001$]. With hundreds of dollars or lives, 68% of participants chose the certain option for gain frame problems and 24% for losses. When the magnitude increased to thousands of dollars or lives, 74% chose the certain option for gains, and 22% for losses. At the Millions level, 79% chose certain outcomes for gains and 20% for losses. Table 4 displays this effect.

Table 4

Percentage of Participants Choosing the Certain Option for Magnitude by Frame in Experiment 1

	Magnitude of Outcome		
Frame	Hundreds	Thousands	Millions
Gain	68	74	74
Loss	24	22	20

The probability level in the risky option also influenced framing significantly. Participants framed less as the probability that the numerical complement of the risky option would occur increased (i.e., framing decreased with increasing risk) [$F(2, 170) = 16.74$, MSE = 0.164, $p < .001$]. At the 50/50 level, 77% of the participants chose the certain option for gain frame problems, and 19% for losses. When the chance was 1 in 3, 74% chose the certain option for gains, and 23% for losses, and when the chance was 1 in 4, 70% chose certain outcomes for gains and 24% for losses. Table 5 displays these results.

Table 5

Percentage of Participants Choosing the Certain Option for Probability by Frame in Experiment 1

	Probability Level for Non-Zero Complement of Risky Option		
Frame	1/2	1/3	1/4
Gain	77	74	70
Loss	19	23	24

Confidence. Confidence ratings provided another indicator of participants' greater conflict with human life problems versus monetary problems. Collapsed across all other factors, participants were approximately 1.5 points less confident about decisions related to life than they were with either version of the money decisions [$F(2, 100) = 31.86$, $MSE = 50.1854$ $p < .001$]; on a scale from 1 to 20, their average confidence was 14.1 for disease problems while it was 15.7 and 15.6 for the versions of the monetary choices. Participants' slight conservative tone with decisions on human life is reflected in the Problem Content by Probability effect [$F(4, 200) = 3.65$, $MSE = 7.556$, $p = .0068$]. Mean confidence rose from 13.8 to 14.5 as probability moved from 0.50 to 0.25 for disease problems while remaining between 15.8 and 15.6 for all probability levels of both monetary problems. Although these effects were statistically significant, these findings do not suggest any lack of confidence by participants on any specific problem as these ratings are at the 70%-of-maximum point, well above the central point of the scale. The differences between confidence ratings on problems, or among probability levels, is small compared to the difference from a complete lack of confidence.

Similar patterns of mean confidence differences appeared for Frame [$F(1, 50) = 24.23$, $MSE = 187.924$, $p < .001$], and Problem Content by Frame [$F(2, 100) = 30.51$, $MSE = 29.705$, $p < .001$]. Participants indicated less than 2 points difference in confidence for problems of differing valences (16.0 for gains, 14.3 for losses). Interestingly, the difference across frames for disease problems was insubstantial (14.2 for gains, 14.0 for losses), but participants expressed a confidence of 17.0 for gains and 14.4 for losses for the Regular Monetary problem, and 16.8 for gains and 14.4 for losses for the Casino Monetary problem. While they were almost uniformly confident about their choice regarding human life (in both frames) and the loss of money, they were slightly more confident about their choices when they were winning money.

Both Magnitude of the expected value of the problem [$F(2, 100) = 16.23$, $MSE = 13.09$, $p < .001$] and Probability level in the risky option [$F(2, 100) = 7.74$, $MSE = 9.964$, $p < .001$] interacted with Frame. Participants' mean confidence increased from 15.7 to 16.4 for gain frame problems as the magnitude moved from hundreds to thousands to millions. Mean confidence diminished from 14.4 to 14.0 across the same range for loss frame problems (see Table 6). Participants' mean confidence was nearly unchanged (16.0, 16.0, 15.9) for gain problems as the chance moved from 1/2 to 1/4 for gain frame problems, while increasing from 13.9 to 14.6 across the same probability changes for loss frame problems (see Table 7).

Table 6

Mean Confidence Ratings for Magnitude by Frame in Experiment 1

	Magnitude of Outcome		
Frame	Hundreds	Thousands	Millions
Gain	15.7	15.9	16.4
Loss	14.4	14.4	14.0

Table 7

Mean Confidence Ratings for Probability by Frame in Experiment 1

	Probability Level for Non-Zero Complement of Risky Option		
Frame	1/2	1/3	1/4
Gain	16.0	16.0	15.9
Loss	13.9	14.3	14.6

Signed Confidence. As noted previously, signed confidence enhances information contained in choices, fine-tuning it with confidence data. Framing is characterized by positive scores for gains and negative scores for losses, with a total range of +20 to -20.

Table 8 displays significant changes in participants' signed confidence from Block I to Block II in the two Truncation conditions for each frame [$F(1, 50) = 19.82$, $MSE = 474.613$, $p < .001$]. Participants' who saw numerical complements in Block I (Non-Zero group) were more confident in their selection of the certain option in the gain frame than they were in their selection of the risky option in the loss frame. But when they reached Block II problems, their confidence in those same selections was more balanced. This is in contrast to participants who saw zero complements of risky options during Block I (Zero group) who were more confident in their selection of the risky option in the loss frame than they were in their selection of the certain option in the gain frame. These data coincide with results from the choice analyses; the pattern is opposite for the Non-Zero and Zero groups.

Table 8

Signed Confidence for Truncation by Block by Frame in Experiment 1

Truncation Group	Frame	Block I	Block II
Non-Zero	Gain	8.20	9.17
	Loss	- 5.54	- 9.42
Zero	Gain	8.37	6.14
	Loss	-12.79	- 9.97

Both Magnitude [$F(2, 100) = 14.23$, $MSE = 226.991$, $p < .001$] and Probability [$F(2, 100) = 21.64$, $MSE = 111.010$, $p < .001$] effects interacted with Frame in the signed confidence data. While participants showed relatively stable signed confidence in the risky option for losses across magnitude changes (-8.91 for hundreds, -9.73 for thousands, -9.65 for millions), their signed confidence in the certain option rose sharply in the gain frame problems (5.79 for hundreds, 8.10 for thousands, 10.02 for millions). And as the chance associated with the numerical complement of the risky option decreased from 1/2 to 1/3 to 1/4, participants' confidence in the certain option increased (6.80, 7.82, 9.28 respectively) for gain frame versions. Through the same probability space confidence in the risky option for loss versions increased in a roughly equivalent fashion (-8.62 for 1/2, -9.25 for 1/3, -10.43 for 1/4) albeit with somewhat stronger feelings of confidence at each level than in the gain frame.

Response Latency. Response latency for this study was the time a subject required to read the second option and press a key to indicate a preference between the options. As I noted previously, certain options throughout the stimuli had a length of 4 to 5 words (e.g., "200 people will be saved," "you will lose $4,000"). In unpublished data collected during the Reyna and Fulginiti (1992) and Fulginiti and Reyna (1993) experiments, we found that these options require, on average, just under 2 seconds to read. Therefore, the remaining time can be attributed to decision making processes.

Repeated exposure to similar stimuli created a mild practice effect in reaction time [$F(1, 85) = 21.79$, $MSE = 192.156$, $p < .001$]. Participants' mean response latency during Block I was 7.306 seconds while it took 6.029 seconds on average for a response in Block II despite the more complicated, fully identified stimuli. Participants' conflict is apparent in these data, as participants took 8.424 seconds to respond to disease problems, but only 5.384 seconds for the regular monetary scenario and 6.195 seconds for casino versions

[$F(2, 85) = 4.47$, MSE = 192.156, $p < .001$]. Note that it took participants less than 1 second longer to respond to Casino spinner presentations of probability.

Probability level also influenced participants reaction time [$F(2, 170) = 7.82$, MSE = 26.646, $p < .001$]. Responses to chance levels of 1/4 and 1/2 were approximately equivalent, 6.495 seconds and 6.557 seconds respectively, while responses to problems at the 1/3 level required 6.950 seconds.

Different response latencies for the Frame main effect [$F(1, 85) = 21.08$, MSE = 91.765, $p < .001$] and the Problem Content by Frame interaction [$F(2, 170) = 25.35$, MSE = 33.999, $p < .001$] also suggested that participants were more concerned about human life and losses of both life and money. On average the gain frame problems required 6.233 seconds and loss frame problems 7.102 seconds. Reaction time to Disease problems was similar across frames (8.548 for gains, 8.299 for losses). However, for Regular Monetary problems participants took 4.803 seconds for gain frame versions and 5.965 seconds for losses, while for Casino Monetary problems they needed 5.349 seconds for gains and 7.041 seconds for losses.

Table 9 contains average response time for the significant Truncation by Block by Frame interaction [$F(1, 85) = 11.27$, MSE = 32.111, $p = .0012$]. Participants who saw only quantitative complements of the risky option in Block I required about 1 second less to respond to gain frame problems in Block II that included the zero complement. However, they took 1.7 seconds less to respond to loss frame problems of the same variety in Block II than they did in Block I. Participants who saw only zero complements of risky options during Block I needed 1.5 seconds less during Block II for gain frame problems, but needed less than 3/4 of a second less during Block II for loss problems when the quantitative numerical information was introduced.

Table 9

Mean Response Latencies for Truncation by Block by Frame in Experiment 1

Truncation Group	Frame	Block I	Block II
Non-Zero	Gain	6.448	5.316
	Loss	7.923	6.141
Zero	Gain	7.347	5.823
	Loss	7.507	6.835

The interaction of Magnitude of the expected value by Probability of occurrence of the numerical complement of the risky option by Frame produced a significant effect [$\underline{F}(4, 340) = 4.03$, $\underline{MSE} = 25.821$, $\underline{p} = .0033$] (see Table 10). Loss frame problems generally resulted in longer response times across all levels of Magnitude, and probability levels of 1/4 and 1/2 generally took longer than problems containing a chance at the 1/3 level. This interaction resulted primarily from larger differences in response time between frames at the 1/3 level for hundreds of lives or dollars and the 1/2 level for millions.

Table 10

Mean Response Latencies for Magnitude by Probability by Frame in Experiment 1

		Probability Level for Non-Zero Complement of Risky Option		
Magnitude	Frame	1/4	1/3	1/2
Hundreds	Gain	6.453	6.525	6.237
	Loss	7.012	8.059	6.682
Thousands	Gain	5.876	6.475	6.416
	Loss	6.767	7.271	6.974
Millions	Gain	6.020	6.427	5.671
	Loss	6.844	6.944	7.363

A significant, 7-way interaction among the Ambiguity group, Truncation group, Block, Problem Content, Magnitude, Probability, and Frame factors resulted from subtle and inconsequential differences to various factor combinations [$F(16, 680) = 2.11$, $MSE = 24.471$, $p = .0066$]. This effect possesses no patterns that lend themselves to interpretation..

Experiment 2

Choice. As with Experiment 1, I included a sample of traditional, standard framing problems from the work by Tversky and Kahneman (1981) to disallow any suggestion that these effects are due solely to task demand and response differences between framing problems and reflection problems. Participants opted for the certain option in 77% of the gain frame versions of these traditional problems, and 44% of the loss versions [χ^2 (1, N = 112) = 12.13, p < .001]. This finding demonstrated that the participants in this experiment were subject to the classic framing effect.

For the reflection stimuli, Frame produced a significant preference reversal [F(1, 26) = 39.53, MSE = 1.820, p < .001]. Participants chose the certain option for 66% of the gain frame stimuli and for 35% of the losses.

The combination of Delta values (the differential between the expected value of the certain option and the numerical complement of the risky option) and Frame produced a significant interaction with respect to choice [F(5, 130) = 6.44, MSE = 0.135, p < .001] (see Table 11 for mean percentages choosing the certain option between frames as Delta values increased.). Because the Probability factor did not interact with Frame or Delta, participants treated all three moderate values of probability similarly. There is an almost unvarying increase in the choice of the certain option for gain frame problems as Delta increased. Participants were much less likely to choose the certain option when it differed from the risky option's numerical complement by only hundreds of dollars or lives than they were if it differed by tens-of-thousands. However, there is little fluctuation in the pattern for choices in the loss frame. Participants were similarly drawn to the certain option across all levels of Delta; they chose the certain option at a minimum level of 31% for Delta = 4000, and at a maximum level of 39% in Delta = 800 versions. The general pattern as Delta increases is a steady increase in framing.

Table 11

Mean Percentage Choosing the Certain Option for Delta by Frame in Experiment 2

	Delta					
Frame	400	800	4000	8000	40000	80000
Gain	56.0	58.0	69.8	65.2	72.9	72.8
Loss	33.6	39.1	30.7	32.7	37.4	35.6

Confidence. Participants indicated their consternation with losses through a more than 4- point difference in their rating of their confidence in gain frame decisions over loss frame decisions (14.86 for gains, 12.44 for losses--on a 20-point scale) [$F(1, 23) = 32.56$, $MSE = 121.130$, $p < .001$]. However, they showed little effect when it came to choices related to human life. Delta, Problem Content, and Frame factors interacted significantly [$F(10, 230) = 4.82$, $MSE = 10.508$, $p < .001$]. Confidence ratings for gain frame disease problems were higher than monetary problems except for Delta values of 4,000 for Regular money problems and 8,000, 40,000, and 80,000 for Casino problems. Ratings of confidence for loss frame disease problems were higher than monetary problems except for Delta values of 400, 8,000, and 80,000, all for Casino versions. No clear pattern is evident in these data (see Table 12).

Table 12

Mean Confidence Ratings for Delta by Problem Content by Frame in Experiment 2

Problem Content / Frame	Delta					
	400	800	4000	8000	40000	80000
Disease						
Gain	15.7	16.3	16.2	15.0	15.6	15.7
Loss	12.3	12.4	11.9	13.4	12.6	12.4
Regular Monetary						
Gain	15.3	15.5	16.1	12.9	13.3	13.0
Loss	11.6	12.4	12.0	12.2	12.5	12.1
Casino Monetary						
Gain	13.6	13.3	13.1	15.3	15.6	15.7
Loss	12.4	12.3	11.8	14.0	12.5	13.0

Confidence ratings for the Probability effect showed a reversal [$F(2, 46) = 21.91$, $MSE = 17.192$, $p < .001$]. Participants' confidence in the gain frame was lowest for Probability = 1/3 problems (14.3) and rose to 15.0 at 1/2 and to 15.3 at 2/3, steadily climbing as risk decreased. The opposite pattern was evident in the loss frame: 13.2 at 1/3, 12.3 at 1/2, 11.7 at 2/3. While not influencing choices, the altered chance of the numerical complement in the risky option reversed confidence patterns. The global pattern of confidences with increasing risk is similar to the Experiment 1; confidences converge.

Signed Confidence. Signed confidence data detected patterns not illuminated by either choice or confidence ratings viewed independently. As I noted previously, participants did frame, and on average showed lower confidence in choices they made in the loss frame than in the gain frame. However, the signed confidence data show that participants were more confident about their choice of the risky option in the loss frame (-5.4) than they were about choosing the certain option in the gain frame (4.9) [$F(1, 23) = 47.13$, $MSE = 1520.574$, $p < .001$]. Frame also interacted with Delta [$F(5, 115) = 7.35$, $MSE = 111.029$, $p < .001$] (see Table 13). Participants were much less confident in their selection of the certain option in gain frame problems at Delta values 8,000 and 40,000, and more confident in the certain option at Delta values 800 and 4,000. For loss frame versions, they were more confident in the risky option at Delta values 8,000 and 80,000, and least confident in the risky option at the Delta level 4,000.

Table 13

Signed Confidence for Delta by Frame in Experiment 2

	Delta					
Frame	400	800	4000	8000	40000	80000
Gain	4.5	7.2	8.1	1.0	2.6	6.0
Loss	-5.9	-5.0	-4.9	-6.2	-4.2	-6.0

Probability level did not significantly affect choice although it did reverse confidence rating patterns as I stated previously. Combining choice and confidence (as signed confidence is designed to do), allowed detection of a subtle pattern in participants responses for the Probability by Frame interaction [$F(2, 46) = 5.37$, $MSE = 490.281$, $p = .008$]. Signed confidence for gain frame problems was nearly identical when the chance of the numerical complement of the risky option was 1/3 or 1/2 (5.9 and 5.7 respectively) but dropped strongly at 2/3 to 3.1. Similarly in the loss frame problems, signed confidence of problems at Probability levels 1/3 and 1/2 was nearly identical (-6.5 and -6.4 respectively) and moved to -3.2 at 2/3 (see Table 14). These data reflect a framing choice pattern (i.e., positive scores for gains and negative scores for losses) but show that when Probability climbs above an even chance in the risky option, subject tend to frame much less and lose confidence in those decisions.

Table 14

Signed Confidence for Probability by Frame in Experiment 2

	Probability Level for Non-Zero Complement of Risky Option		
Frame	1/3	1/2	2/3
Gain	5.9	5.7	3.1
Loss	-6.5	-6.4	-3.2

Response Latency. Response time for the Frame effect showed a significant tendency for longer contemplation of losses than gains [$F(1, 26) = 13.67$, $MSE = 86.032$, $p = .0010$]. Participants took 6.903 seconds to choose in loss versions and 5.653 seconds for gains.

Frame also interacted with Delta and Problem Content [$F(10, 260) = 3.02$, $MSE = 35.185$, $p = .0012$] (see Table 15). Participants took longer to respond to Casino Monetary problems in both frames for Delta values of 400 and 800. Longer reaction times were recorded for the Regular Monetary problem for Delta values of 8,000, 40,000, and 80,000. The Casino problem accounted for the longest response time in the gain frame and the Regular money problem for the loss frame for Delta 4,000.

Table 15

Mean Response Latencies for Delta by Problem Content by Frame in Experiment 2

	Delta					
Problem Content Frame	400	800	4000	8000	40000	80000
Disease						
Gain	4.684	4.466	4.491	4.828	5.251	4.748
Loss	5.372	6.377	5.657	6.340	6.338	6.349
Regular Monetary						
Gain	5.632	4.228	3.805	8.259	7.595	7.961
Loss	5.380	5.266	7.380	9.113	9.233	8.652
Casino Monetary						
Gain	6.935	6.388	9.090	4.616	4.060	4.710
Loss	9.884	8.830	6.684	5.525	5.939	5.938

The Problem Content main effect indicated that participants took the least time to respond to Disease problems (5.408 seconds), the most time for Regular monetary problems (6.875 seconds), and in between those two for the Casino problems (6.550 seconds) [$F(2, 52) = 15.74$, $MSE = 37.810$, $p < .001$].

DISCUSSION

As the patterns in the results of this study show, fuzzy trace theory provides an accurate description of behavior and cognitive processing for a variety of decision making and choice phenomena. Explanations and predictions of choice based on psychophysical theories, such as prospect theory, do not withstand scrutiny, either generally or for specifically defined criteria. Choice is not about humans computing precise, detailed, quantitative solutions to formulaic questions; cognition is fluid pattern recognition--seeing global relationships and responding to approximations.

In their 1992 paper expanding prospect theory, Tversky and Kahneman present a quantitative perspective on cognitive issues involved in choice and an experiment to demonstrate the efficacy of such a view. Prospect theory in its original and recently updated form are noted by the authors as equivalent for two option gambles. The theory is a computationally oriented, psychophysical view of mental events driving a person's selection of one option over another. In the final discussion they say:

> Theories of choice are at best approximate and incomplete. One reason for this pessimistic assessment is that choice is a constructive and contingent process. When faced with a complex problem, people employ a variety of heuristic procedures in order to simplify the representation and the evaluation of prospects. These procedures include computational shortcuts and editing operations, such as eliminating common components and discarding nonessential differences (p. 317).

Fuzzy trace theorists do not suffer from this pessimism. Those simplified representations, computational shortcuts, and editing procedures employed by decision makers are the fundamental components of choice. Because cognition is fluid and ranging and primarily driven by fuzzy, gist representations and a preference for operation on imprecise information, and despite the capability of people to process computationally when some tasks require it, a computational view is, generally speaking, an overly complicated representation of human cognition.

Fuzzy trace theory is a relatively new conceptualization of human cognition (see Brainerd and Reyna, 1990, 1993; Reyna and Brainerd, 1990, 1991, in press). The theory contains substantially different assumptions from psychophysical approaches about cognitive processes related to behavioral phenomena. Four of the principles of fuzzy trace theory are critical to discussion of choice behavior, including gist extraction, the fuzzy-to-verbatim continua of memorial representations, the fuzzy processing preference, and the hierarchy of gist.

Gist extraction refers to automatic pattern recognition in complex stimuli. people encountering complex environmental events cull incoming stimuli for global patterns and encode these patterns as gist. They do this simultaneously as they form other more detailed representations including verbatim memorial traces. Then, when a task requires use of these encoded traces of the stimuli, people show a marked preference for decision making processes utilizing the most imprecise representation that allows completion of the task. They ascend the hierarchy of representations only so far as the task requires.

In the following discussion I will approach the findings from this study from a fuzzy trace perspective, with relevant comparisons to psychophysical theory as they become necessary. I have separated this discussion into three major sections. I will discuss the results of Experiments 1 and 2 in turn followed by a general discussion of the findings and theoretical relevance.

Experiment 1

The ambiguity manipulation in this experiment is a direct test of a potential criticism of truncated stimuli. When information is missing from a risky option, there is an opportunity for participants to bring to bear unknown information. The ambiguity factor is a manipulation of attention to and awareness of disambiguating information. The computer program requires participants to tap a specified key to see each component of a problem, including the disambiguating component. Participants in the Sequential ambiguity group spent about four seconds looking at the disambiguation (a little more than one second longer than participants in the Simultaneous group). They know they must maintain any of the information they want to use in memory as they make their choice. Participants in the Zero Truncation group spent a little over one second longer reading their disambiguating information than do participants in the Non-Zero Truncation group. This finding is expected because the information the Zero group sees is novel for each problem while the Non-Zero groups always see a null disambiguating complement. Neither of these groups has a different choice pattern from the group seeing totally Ambiguous stimuli. Disambiguating information did not alter their selections, suggesting that while participants are aware of the information and spend a short time reading it they do not use the information when making their choices. All participants in this experiment see truncated problems followed by standard problems, and the various disambiguation schemes do not influence the degree of framing. Some participants in the completely Ambiguous conditions commented during debriefing that they had imagined various scenarios for outcomes related to missing information rather than ignoring the unknowns. Participants do spend time reading the disambiguating information but they apparently do not base their decisions on it. These participants approach their choice between Option A and Option B by paying attention only to Option A and Option B. Fundamentally, participants in all three groups choose based on truncated problems. That is, they all extract similar gist patterns for Block I problems equivalently.

Furthermore, there are no significant interactions of this grouping factor with other factors except with respect to an interaction with Sex. Men in the groups seeing ambiguous stimuli actually frame less than groups that had disambiguating information available while women across all three Ambiguity groups frame approximately the same amount. This interaction is primarily due to small differences between the gender groups across Block but there is no discernible pattern. The Ambiguity factor played no other role in preferences, confidence, or reaction times for these participants and I consider this five-way interaction to be an unreliable anomaly, potentially due to sampling frequencies.

Truncating complements in the risky option allows a direct, critical test of accounts for framing implied by fuzzy-trace theory and prospect theory. The fuzzy-trace theory account suggests that participants in the Zero condition will show stronger framing bias than those in the Non-Zero condition, because these stimuli produce selective processing of the different complements. The findings related to the Truncation by Block by Frame interaction supported the fuzzy trace hypothesis. Block I problems contain only one or the other of the risky option complements. Participants who see Non-Zero complements initially frame less than participants viewing Zero complements first. Within Block II, these two groups show framing tendencies of nearly identical proportions. The appearance of the zero complement during Block II moves participants in the Non-Zero group to a stronger framing tendency, while participants who see Zero complements initially show diminished framing tendencies during Block II. Thus, these groups' framing patterns move in opposite directions when the missing complement of their problems appears.

More telling about the null complements' effect than opposite shifts in framing patterns is the magnitude of those shifts. When problems become fully identified, participants in the Non-Zero group shift almost twice as much as those in the Zero group. This suggests that when information at the "none" level of gist appeared to participants seeing numerical information they are more strongly influenced by its appearance than participants in the Zero group are by the appearance of quantities. This is in direct conflict with the prospect theory assumptions about the determination of uselessness and subsequent editing of zero complements due to the mental computation of the value and utility of these options. According to the prospect theory view, the Zero complement of the risky option is meaningless to choices because it is computationally removed during the evaluation stage of the decision. However, these results indicate that participants were more strongly influenced by Zero complements than by Non-Zero complements, as fuzzy trace theory predicts.

Members of the Zero group are not insensitive to numerical information and scale back their framing somewhat when numerical information becomes available. According to expectations based on the fuzzy trace theory principle of a hierarchy of gist, participants calibrate their responses according to the level of processing required to perform the task at hand. When the non-zero complements appeared in Block II, these participants recalibrated to account for the novel information, although framing did not diminish substantially indicating that the zero complement is still pivotal to their choices. Participants' adjustments in the loss frame are responsible for the differences in the magnitude of this shift. Losses do appear to loom larger than gains, as Kahneman and Tversky (1979) noted with regard to reflection effects. For loss frame problems, participants in the Non-Zero group became more sure of their increasing choice of the risky option (that now contains a zero complement) nearly twofold over truncated versions containing only non-zero information. Participants encountering non-zero complements after seeing only Zero complements, on the other hand, lower their confidence in their choice of the risky option in loss problems only slightly.

The reaction time data further bolsters the argument for the powerful effect of the null complement. All participants take less time to respond during Block II despite having more information to process, due most probably to practice. However, the Non-Zero group diminished their response time from Block I for losses by 1.7 seconds suggesting the appearance of the zero complement made their selection much simpler; participants in the Zero group took only about three-quarters of second less during Block II for losses suggesting the addition of numerical quantities provided relatively less useful information requiring their attention.

The levels of probability I used here are all in the moderate range. However, the outcome value increases directly with the increased risk, and the prediction based on prospect theory is that framing should diminish outcomes increase due to the discounting of outcomes suggested by the negatively accelerated value function. The fuzzy trace theory position holds that the degree of framing should be similar across probability levels when the difference between the certain option and the zero complement is held constant (as it is in this experiment), although there may be slightly increased framing as some participants react to the qualitative change in the level of risk. Choice and signed confidence data support conclusions based on fuzzy trace theory. Participants not only frame more as risk increases from 50/50 to 1-in-3 to 1-in-4, they become more confident in that pattern. Signed confidence patterns also reflect this pattern.

Response latencies suggest that probability values 1/2 and 1/4 are simpler to process than 1/3. Participants take the least time to make a selection when the chances of the numeric complement and the zero complement of the risky option are equal. They almost as quickly process the high risk scenario, in which the probability of the null complement is very large compared to the numerical complement's probability value. They need more time to represent and process the middle range probability of 1-in-3.

The critical theoretical test embedded in the Magnitude effect provides another strong clue to the inadequacy of the psychophysical tradition. Prospect theory makes an unequivocal prediction regarding this issue. As the magnitude of the numerical outcome value rises, the certain option and risky option become less and less distinct and prospect theory contains the explicit computational requirement that framing diminish. In direct conflict is the fuzzy trace theory position that framing will increase as magnitude rises because framing is due to qualitative disparities between the certain option and the zero complement of the risky option. My results support the fuzzy trace theory perspective. Viewed as the difference between gain frame and loss frame versions, framing increases a dramatic 15 points as the magnitude of these outcomes increases from hundreds of lives or dollars to millions. Signed confidence data shows that participants strongly increase their desire to select the certain option for gains as magnitude rises, while maintaining a similar level of confidence across the loss frame. As magnitude increases, the gist of the certain option in gain frame problems can be interpreted as moving from "some" to "a lot;" people gravitate toward that option and grow more secure. For the loss frame, they tend to select the risky option more (i.e., "none die" or "lose nothing") and their confidence in that selection does not waver. Reaction time data for the Magnitude by Probability by Frame interaction show that participants require more time for loss problems in general. This reflects more thorough processing of loss options and possibly explains the stability of confidences in the loss realm. Response times for combined conditions of probability and magnitude show no clear pattern as participants require the most time to decide for loss problems in the 1/3-Hundreds, 1/2-Millions, and 1/3-Thousands conditions and the least time for gain problems in the 1/2-Millions, 1/4-Thousands, and 1/4-Millions conditions. A complex interplay between risk level and outcome value exists in these responses.

Throughout Experiment 1, predictions based on fuzzy trace theory hold up for choice, confidence, and response latencies. While some findings do not necessarily deny psychophysical explanations others do run counter to predictions of this theoretical tradition and cannot be ignored. Based on Experiment 1 results, prospect theory is at best an inadequate and at worst a faulty description of adult decision making in risky situations.

Experiment 2

This experiment addresses the confounded relationship between increasing risk and outcome and contains a critical test of the fuzzy-trace theory and prospect theory accounts for the framing bias. All problems in this experiment consist of fully identified problems. As previously noted, if the level of risk is held constant and the options are of equal expected value, the magnitude of the outcome increases, and, if the Delta value between the sure option and the value of the numerical risky option is held constant, the probability must vary. Fuzzy-trace theory and prospect theory yield opposite predictions. When the delta value is held constant, prospect theory suggests a diminished framing bias with increasing risk because as the magnitudes of the outcome values increase the marginal utilities associated with the options become less disparate; framing decreases because the options are more numerically alike. The principles of fuzzy-trace theory suggest increased framing, because as the risk increases, the disparity between the value of the certain option and the zero complement are growing more disparate; framing increases because the options are becoming qualitatively more different. Varying levels of Delta allows further analysis of the effect of magnitude. I chose values of Delta to maintain the level of probability within the moderate range for all versions. This precludes a prospect theory explanation, based on the decision-weight function that people simply over- or under-estimate extreme values of risk.

Strong framing is present in responses for this experiment indicating the presence of the expected bias. However, some manipulations of the stimuli created anomalous patterns. Although framing generally increases as Delta increases for choice data (except for one point), the signed confidence data show that degree of preference fluctuates for the Delta by Frame interaction. Combining choice and confidence shows very little stability exists in their approach to these stimuli.

Another result highlighted by signed confidence may indicate that participants show a tendency to be influenced by probability values above the 50/50 level, similar to that found by Miller and Fagley (1991). The signed confidence data for the Probability by Frame interaction reflect a substantial drop in the framing tendency coupled with diminished confidence in the altered choice at the probability level 2/3. The 1/3 and 1/2 levels of probability elicit nearly identical patterns of moderate confidence in certain options for gains and moderate confidence in risks for losses. (Although it did not obtain statistical significance, the choice data reflect this diminished framing at the 2/3 probability level.) One possible explanation based on fuzzy trace theory the gist extraction principle is that people extract a gist representation of the risk above 50/50 as "in my favor;" risk recedes as a concern and people back away from their tendency to frame somewhat with these stimuli because the qualitative comparison of "some" (for the certain option) to "more" (for the non-zero complement) is highlighted. Winning "more" is better than winning "some" and losing "some" is better than losing "more" so framing is reduced.

This sample show some random variations for different Problem Contents. Participants in Experiment 1 showed some differences for the Disease problem but those in Experiment 2 showed differences for the Casino Monetary problem. These are not reliable patterns that can be generalized to choice behavior. These effects are due to unpredictable interactions between different samples of individuals and various choice stimuli. These data show no clear pattern, except that these participants do not show the same effects with human life and money as other factors vary. Response latency data for this effect indicates that some participants generally take more time to handle Disease problems than they do for monetary problems, but others show a tendency for the reverse. Some of these data may be compromised as there are only 3 replications of similar stimuli for each condition (Experiment 2).

General Discussion

The findings in this study consistently deny the descriptive power of psychophysical theory while highlighting strengths of fuzzy trace theory. As noted previously, numerical processing is neither sufficient nor necessary to produce framing effects (Reyna and Brainerd, in press). This study also replicates the finding that gist comparisons of "none" to "some" produce strong framing effects, whereas numerical processing does not. This finding is particularly damaging to prospect theory as it fundamentally rejects that cognition is based on processing quantitative, numerical details as prospect theory predicts.

Manipulations of ambiguity level produced no changes in framing patterns (similar to findings presented in Reyna and Brainerd, in press). Participants under all conditions of ambiguity framed similarly when confronted with truncated stimuli, and paid little heed to explicitly stated disambiguation. The precise information provided with Non-Zero stimuli produced less framing than did the imprecise, qualitative information provided in Zero stimuli. This pattern of processing imprecise information is seen in choice, signed confidence and response latency data. Again, these data support fuzzy trace theory predictions and run counter to numerical processing models.

Increases in the magnitude of outcome values produced increased framing (replicated in both experiments). The prospect theory formulation of choice predicts that framing should diminish under these conditions; fuzzy trace theory predicts the opposite and was supported by choice, and signed confidence results.

These findings support fuzzy trace theory, and a qualitative model of cognitive processing. Essentially, the quantitatively driven view of prospect theory is an overly complex model of decision making processes. Cognition clearly does not operate in a computational manner; it is generally far less precise. Fuzzy trace theory contains several tenets that allow accurate depiction of choice behavior parsimoniously. The fuzzy processing preference seems at first glance to suggest that humans are irrational and exhibit framing tendencies because cognitive processes are imprecise and careless. However, as results of this and other studies show, explanations based on gist representations and fuzzy processing are inherently superior to explanations requiring that cognition operate on precise details.

People do not frame because they compute utilities of options based on mental computation involving discounted probabilities and reductions in values of outcomes. Framing results because the gist of problems contains obvious patterns that allow fast (and accurate) comparisons. When people encounter stimuli such as are presented in this study, data indicate that they intuitively choose options that appear better in a global sense. Qualitative processing is faster (without loss of accuracy) and allows people to process highly detailed, precise information efficiently.

Problems in this experiment are reflections around a true zero point so people extract gist representations that highlight changes from a null status quo and they react to gains and losses differently. They are more often attracted to winning "some" money or saving "some" lives than "none." And they are reciprocally repelled by losing "some" money or accepting the deaths of "some" people or the loss of "some" money.

Responses in the first experiment of this study show that participants are aware of all the information provided, but if it does not lend itself to incorporation into the pattern of the options they ignore it as irrelevant. Relational comparisons of "some" to "a chance of more" gist in truncated numerical problems elicit framing at a lower rate than do more nominal comparisons of "some" to "none" in zero problems because the distinction is more glaring in the latter. As the disparity between "some" and "none" grows with increased magnitude of the outcome the choice becomes more and more obvious and elicits stronger framing. Further, people become more confident in their selections as gist highlights the disparity.

Risk levels in choices are assumed in psychophysical approaches to diminish a tendency to frame because with increased risk comes increased outcome. Data reflect exactly the opposite pattern; people frame more as risk rises. Nominal gist in problems with increasing risk remains the same (i.e., "some" for the certainty and "none" for the risk) but the hierarchy of gist allows for fluctuations as people utilize a slightly more detailed representation of the problem and attenuate their bias somewhat. Response latencies show that participants do take longer to handle subtle variations in risk levels, and notably take the least time when the gist of the risk is "half and half" or "in my favor."

Predictions based on prospect theory are directly challenged by data on the disparity between values of certain options and numerical complements of risks. If cognitive processing were performed, and decisions made, based on computational details of these problems, framing would diminish dramatically, because these values are becoming more similar. Instead, framing generally increased, except for one anomalous condition in which it increased substantially. This effect is explained by gist representations of the relevant values. As the disparity between the certain option and the risky options grows, so does the disparity between the "some" gist of the certainty and the "none" gist of the zero complement of the risk. People detect this disparity in the nominal gist and choose based on the larger difference between gist representations.

All in all, the findings of the two experiments in this study continue to develop the data base in support of fuzzy trace theory. Several findings, such as the response patterns to truncated stimuli revealing that zero complements and gist representations rather than precise calculations produce framing effects, replicated results of earlier work and demonstrate a consistency to predictions based on fuzzy trace theory. Other results, such as the finding that response latencies are strongly influenced by zero complements, open new avenues of inquiry for fuzzy trace theorists.

The purpose of this study was to evaluate the descriptive power of fuzzy trace theory for choice phenomena. Data from choice, confidence and response latency all show patterns that reflect the efficacy of the fuzzy trace theory view. Fuzzy trace theory is a relative newcomer to the field of decision making. Research covering a full range of cognitive effects and covariates in decision making is progressing well. Research investigating potentially relevant affective or personality correlates of choice behavior is also forthcoming. Based on results of this study (and the growing body of evidence in other research areas), it seems apparent that an intuitive approach to cognition provides the soundest explanation of decision making.

APPENDIX A

INSTRUCTIONS TO PARTICIPANTS

There will be series of hypothetical problems in which you will make a choice between two options. Each choice involves you deciding which of two alternatives you like better. I am interested in what you, as an individual, prefer. I want your "gut" response; which do you like best? Different people have different preferences. There are no correct or incorrect answers, only preferences.

Each problem has an opening statement or "preamble", followed by two choices "A" and "B", and then you will indicate which choice you prefer. Although aspects of problems may seem familiar to you, you feelings may differ for any one problem. Respond according to how you feel at that moment. Treat each problem separately. Go with your gut feeling when you read THAT problem.

Read through each problem, as there may be crucial differences. I want you to think about the problem but please respond as quickly as you can to each problem.

Don't feel compelled to change your answers, but if you see a problem presented in a different way, feel free to change your answers.

Numbers may be presented in several forms. Use the information as you would in everyday life.

In some problems involving diseases and human life, you may see the phrase "no one survives" or "everyone dies." These descriptions only apply within the context of the problem you are currently reading and do not apply to "no one in the world" or "everyone in the world." Please keep in mind that diseases do not affect everyone; they are not that absolute. Do not read anything into the problem, simply react to it in its own context.

And finally, some things may be repeated for statistical reasons. Please continue to approach each problem in a natural way.

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