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Communicating Uncertainty: Framing Effects on Responses to Vague Probabilities

Kristine M. Kuhn

University of Illinois at Urbana-Champaign

Most real-world risky decisions are based on imprecise probabilities. Although people generally demonstrate vagueness aversion, behaving as if vaguely specified probabilities are worse than comparable precisely specified probabilities, vagueness seeking also occurs. Previous explanations of vagueness preferences have been based on individual differences and regressive beliefs about extreme probabilities, and little research has examined the effect of changes in the way vagueness is communicated to the decision maker. The present study demonstrates that gain/loss framing, moderated by the operationalization of vagueness, influences how people respond to vagueness about a probability estimate. Subjects read scenarios describing consumer purchases, organizational marketing decisions, and medical treatments, and expressed preference between options having either precisely or vaguely described probabilities. Vagueness was operationalized either as a range of possible values or as verbal qualification of a single point estimate. Negative framing was associated with greater preference for vague prospects, unless vagueness was described by a numerical range with the higher value presented first, indicating a substantial primacy order effect. A second experiment demonstrates that negative framing led people to make more favorable inferences about the likelihoods of vague probabilities.

Most of the risk decisions people make are characterized by uncertain or vague knowledge about the probabilities of events. It has long been argued that

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decision making under *uncertainty,* where probability values are not known precisely, is distinct from decision making under known risk distributions, and that both a likelihood value and the confidence placed in the accuracy of that value are essential to understanding risky decision making (e.g., Keynes, 1921; Knight, 1921). But the predominant model of decision behavior under risk, subjective expected utility theory (Savage, 1954), assumes only that various outcome states each have a subjective, or personal, probability. Uncertainty about those probabilities is inherently meaningless for strict subjectivists (de Finetti, 1972), and is not allowed a role in rational decision making.

Numerous empirical studies, however, have shown that people are generally averse to taking risks with imprecisely specified—commonly referred to as *ambiguous*[1]—probabilities. Ellsberg's (1961) seminal paradox demonstrated that probability uncertainty leads to systematic violations of rational theories of choice: most people are not indifferent between a gamble with a precisely known 50% probability of winning and a gamble whose probability of winning is equally likely to lie anywhere between 0 and 100%, as they would be if they behaved in accordance with subjective expected utility theory. Several experiments using variations of Ellsberg's paradox have reported a general preference for gambles with precisely specified probabilities over vaguely specified gambles, even when indifference is allowed, and vagueness aversion has also been demonstrated in risky medical, negotiation, marketing, and insurance decisions (see Camerer & Weber, 1992, for a review). People often are willing to pay a premium in expected value to avoid vagueness (e.g., Becker & Brownson, 1964; Yates & Zukowski, 1976). Moreover, there is no correlation between the risk attitudes and vagueness attitudes of individuals (Cohen, Jaffray, & Said, 1985; Curley, Yates, & Abrams, 1986; Di Mauro & Maffioletti, 1996; Schoemaker, 1991).

The most formal psychological theory developed to explain vagueness effects is that of Einhorn and Hogarth (1985; Hogarth & Einhorn, 1990), who modeled choice under vagueness as the result of an anchoring-and-adjustment process underlying nonlinear weights on probabilities. This model is based on expected utility, but proposes that any vagueness associated with an anchor probability estimate causes it to be adjusted in such a way as to render it less extreme. Thus very small vague probabilities tend to be adjusted upward because imagined probabilities above the anchor are given more weight than imagined probabilities below the anchor, and very large vague probabilities are adjusted downward because imagined probabilities below the anchor receive greater weight. The exact location of the perceived probability curve's crossover point—where it crosses the identity line—is determined by attitude toward vagueness. Although individual differences in vagueness attitude may be considerable, in general most people are hypothesized to adopt a cautious attitude in the face

[1] Because *ambiguous* is defined as a state capable of being interpreted in multiple distinct ways, *vagueness* is a more accurate label for imprecision of probabilities (see Budescu, Weinberg, & Wallsten, 1988). In the decision making literature, however, *ambiguity* is generally understood to refer to vaguely specified probability estimates.

of vagueness. So for most of the probability continuum, vague probabilities of gains are underweighted relative to their anchors, and vague probabilities of losses are overweighted. Consequently, the model predicts that people will typically prefer precision to vagueness, with two exceptions: vagueness seeking is predicted for high probabilities of loss (vague values adjusted downward) and very small probabilities of gain (vague values adjusted upward). Empirical results from a number of studies (e.g., Casey & Scholz, 1991; Einhorn & Hogarth, 1985; Hogarth & Einhorn, 1990) have supported the model.

Other researchers have argued that vagueness effects operate through preferences rather than beliefs about probabilities. Frisch and Baron (1988) have defined vagueness as “the subjective experience of missing information relevant to a prediction.” According to this view, people naturally (and rationally) dislike making decisions when not all relevant information is available, and application of this heuristic leads to vagueness aversion. The belief that others will negatively evaluate the choice of options with missing information, leading to greater blame if the decision proves to be a poor one, may also contribute to vagueness aversion (Curley, Yates, & Abrams, 1986; Taylor, 1995). Similarly, Heath and Tversky (1991) have proposed that vagueness aversion is driven by the decision maker’s sense of competence, and Fox and Tversky’s (1995) comparative ignorance hypothesis argues that vagueness is aversive because—and only if—it leads decision makers to feel comparatively less knowledgeable or informed.

EXPLAINING VAGUENESS SEEKING

Regardless of whether vagueness affects decisions through beliefs about probabilities, preferences, or both (see Frisch & Baron, 1994), the dominant propensity for vagueness aversion is well established. But it is possible to take an “optimistic” view of vagueness, focusing on better possible values rather than worse ones, and vagueness seeking is sometimes observed. Three general types of explanations have been proposed to explain vagueness seeking. The Einhorn Hogarth model (1985) predicts that vagueness seeking will predominate for small probabilities of gain and large probabilities of loss, because of regressive weighting of extreme vague probabilities. Einhorn and Hogarth (1985) also proposed that an individual’s attitude toward vagueness may be stable across decision contexts, and other investigators (Bier & Connell, 1994; Highhouse & Hause, 1995; Sherman, 1974) have similarly discussed vagueness attitude as a trait related to generalized pessimism/optimism. Lastly, a competence-based perspective (Heath & Tversky, 1991) predicts vagueness seeking if a decision maker has high confidence in her knowledge and is evaluating her own judgment. For example, football experts who judge the probability of a team’s winning at 80% might prefer to bet on the outcome of the game rather than an experimental lottery with a precisely known 80% chance of winning, even though more vagueness is associated with the former probability; people who do not know much about football, however, will be more likely to choose the lottery (Heath & Tversky, 1991).

But little systematic research has investigated differences in expressed attitude toward vagueness as a function of the manner in which vague probability information is communicated to a decision maker. It is unknown if changes in message presentation, without any change in the underlying problem structure, influence how decision makers interpret uncertainty information and whether vagueness seeking or aversion is consequently observed. This neglect of message format is somewhat surprising given its practical importance. For many critical decisions, we depend on other people's assessments of risk; whether and how they choose to communicate uncertainty about their probability estimates may influence our decision. At the public policy level, there is increasing demand for the inclusion of uncertainty information in environmental and health risk communications (e.g., Finkel, 1990; National Research Council, 1994), but the best way to present uncertainty is a topic of debate (e.g., Commission on Risk Assessment and Risk Management, 1996; Wallsten, 1990).

Compared to precise values, vaguely specified probabilities offer the decision maker the possibility that the true value might be either better or worse. The present study argues that the framing of a message, moderated by how vagueness is operationalized, can increase a decision maker's focus on either favorable or unfavorable possible values, and differences in expressed vagueness seeking/aversion resulting from message format can therefore be predicted.

FRAMING

One of the most widely replicated and generalized findings of decision making research is the effect of framing: changes in surface representation of a problem can systematically affect judgments and decisions, even though the underlying structure remains invariant. Although the term *framing* is now used to refer to a variety of changes in problem representation, the original demonstration of the effect resulted from representing a decision either in terms of gains or of losses. Tversky and Kahneman's (1981) classic problem described two possible disease treatment programs, one certain and one risky, either in terms of lives saved or in terms of lives lost; respondents were more likely to choose the risky option when the options were framed negatively (number of deaths). This effect is explained by people's greater propensity for risk-seeking in the loss domain.

In the context of vagueness, Einhorn and Hogarth (1985; see also Fobian & Christensen-Szalanski, 1993, 1994) have shown that experimentally manipulating individual decision maker perspectives from gains to losses (e.g., playing the role of either a buyer or seller of insurance) can systematically affect vagueness preferences by altering the location of the crossover point where vagueness leads probabilities to be underweighted rather than overweighted. The Einhorn-Hogarth (1985) model posits a general aversion to vagueness over most of the probability continuum (i.e., imagined probabilities that are worse than the anchor value are overweighted), and whether unfavorable values are above or below the anchor probability depends on whether the decision maker is contemplating a gain or a loss.

But a shift in attitudes due to a switch from the loss to the gain domain (the reflection effect) is not the same thing as a framing effect, which results from altered wording rather than a change in underlying problem structure (see Fagley, 1993). In other words, a comparison between responses to an 80% chance of winning $100 and an 80% chance of losing $100 (reflection) is not the same as a comparison between an 80% chance of winning $100 and a 20% chance of **not winning** $100 (framing). Modal differences in vagueness preferences attributable to framing effects are not easily explicable by the Einhorn-Hogarth (1985) model, because the subjective probability functions for gains and losses are typically modeled as approximate reverse images of one another (i.e., vagueness should cause a 50% probability of winning a lawsuit to be underweighted to the same degree it causes a 50% probability of losing a lawsuit to be overweighted; see Fobian & Christensen-Szalanski, 1994). Thus, although the model allows for substantial individual differences, the average degree of vagueness aversion is expected to be about the same for either a gain or loss frame.

But is there reason to expect framing effects on vagueness preferences analogous to those observed for risk preferences? If people are especially averse to losses, perhaps a loss frame induces greater vagueness seeking as well as risk seeking. People may be more prepared to “gamble” on a vague probability when contemplating losses. With monetary gambles, some studies (Cohen, Jaffray, & Said, 1984; Mangelsdorff & Weber, 1994) have reported more vagueness seeking in the domain of losses than of gains. Few studies on vagueness effects, however, have specifically examined decision frame. For example, many studies on vagueness in medical treatment decisions have described options *only* in terms of the (vague or precise) probability of successful treatment (e.g., Curley, Eraker, & Yates, 1984; Highhouse, 1994). In medical practice, of course, patients are often given likelihoods for outcomes with negative valences: complications following surgery, organ rejection, etc. Two previous experiments on vagueness (Bier & Connell, 1994; Levin, Johnson, Deldin, Carstens, Cressey, & Davis, 1986) that did manipulate frame have reported contradictory results.

Bier and Connell (1994) asked subjects to choose between two hypothetical drug treatment options: for the vague prospect, two studies on the drug had found slightly different probabilities of side effects, whereas for the other drug (the precise prospect) two studies had reported the same probability of (other types of) side effects. They found significant evidence of vagueness seeking for problems presented in a **positive frame** (between *x*% and *y*% chance of no side effects) and no evidence for either vagueness seeking or aversion for the same problems framed negatively (100-*x*% to 100-*y*% chance of side effects). Noting that a number of previous studies using similar probability levels with a positive frame had found predominantly vagueness aversion, Bier and Connell (1994) suggested that the multiattribute nature of their task, in which options differed in the type of side effect experienced as well as their relative precision, diminished the salience of vagueness. Only small probabilities of side effects (large probabilities of not having side effects) were used in this study.

Levin *et al.* (1986; see also Levin, Johnson, Russo, & Deldin, 1985) compared subjects' relative preference for gambles with complete information—both probability and payoff information given—and gambles with missing information that had only one of the two attribute values specified. They manipulated positive and negative frame between-subjects by presenting either the probability of winning or of losing.[2] Although it is not clear to what extent the case of missing information is equivalent to that of vague information, it is noteworthy that Levin *et al.* (1986) found a framing effect opposite to that reported by Bier and Connell (1994): subjects were more likely to choose to play gambles with missing probability information over gambles with complete information when the gambles were framed negatively rather than positively. In other words, they seemed to demonstrate greater vagueness seeking in the **negative frame.** No difference due to frame, however, was found in choice between two-attribute and one-attribute gambles when *outcome* information was missing, and frame did not affect subjects' post-choice estimated values for the missing probability information. With completely specified (precise) gambles, subjects were more likely to take the gamble in the positive frame than in the negative frame condition, suggesting that the positive frame improved the relative scale values associated with the likelihood of winning. Levin *et al.* (1986) explained their results by positing that missing probability information had a subjective scale value of winning greater than that of a negatively framed probability but not as great as that of a positively framed probability. Accordingly, a missing probability value would be more likely to be preferred to a 100-X% probability of losing than to a X% of winning.

OPERATIONALIZATION OF VAGUENESS AS A MODERATING FACTOR IN FRAME EFFECTS

The Bier and Connell (1994) and Levin *et al.* (1986) studies differed in many ways, including decision context and probability levels. But one possible explanation for their discrepant findings on frame effects is the different ways in which the two studies operationalized vagueness: in Levin *et al.* (1986) probability information was missing, whereas Bier and Connell (1994) used a numerical range of values.

Experiments on vagueness typically contrast a precise probability X to a vaguely specified one, with the vagueness operationalized in one of two ways:

[2] In these experiments, subjects began with a small endowment which they could use to pay for the opportunity to gamble for a much larger amount; thus the probability of "losing" is the probability of not winning.

1) as a verbally qualified estimate ("around *X*," "*X*, but unsure," "an unreliable estimate of *X*," etc.) or 2) a numerical range centered on *X*. These two operationalizations are generally treated as equivalent, although they seldom have been directly compared. Two recent studies—both dealing with financial risks—that compared these two operationalizations found no resultant differences in expressed attitudes toward vagueness (Dhar, Gonzalez-Vallejo, & Doman, 1995; di Mauro & Maffioletti, 1996).

But there is some evidence that suggests decision makers may respond differently to the two methods of operationalization. Highhouse (1994) found significantly greater vagueness seeking in a medical decision scenario when vagueness was manipulated as a range (a new treatment with an estimated chance of success between 25 and 75%) rather than as a vague point estimate (new treatment which your doctor estimates to have a 50% chance of success). Subjects were much more likely to choose the new treatment over a well-established treatment having a known 50% success rate with the first, numerical range operationalization than with the second, verbally-qualified single point estimate. As noted by Highhouse (1994), providing an explicit range of values makes salient both better possible values and worse possible values, whereas a vague point estimate provides only *one* anchor value. In other words, if people have a general tendency to adopt a cautious attitude in the face of vagueness and consider possible worse values, as postulated by the Einhorn and Hogarth model (1985), presenting a range of values may make them more aware of the possible better values, whereas a vaguely described single point estimate may not. But it is also possible that people simply pay more attention to larger values, in which case the same scenario *framed negatively* might have led to the opposite result than that found by Highhouse (1994), i.e. a 25 to 75% estimated *failure* rate might be interpreted less favorably than one with an "unsure" estimate of 50% failures.

But different modes of operationalization remain a possible explanation for the discrepant findings of the Bier and Connell (1994) and Levin *et al.* (1986) studies; the former may have found greater vagueness seeking in the positive frame partly because the numerical range operationalization made salient better possible values, whereas the latter found greater preference for missing (vague) probability information in the negative frame because such anchors were lacking. The present study design crosses frame and operationalization of vagueness in order to assess whether frame effects are moderated by the salience of numerical endpoints. To that end, it also manipulates presentation order of range values; the smaller value of a range is more favorable in the negative frame, but less favorable in the positive frame. Both in real-world decisions and in laboratory experiments, numerical ranges are almost always presented with the smaller value first. But if the salience of numerical endpoints can affect preferences, then presentation order may serve as a simple way to focus attention on one or the other endpoint. Bier and Connell (1994) did manipulate presentation order and found no effect, but the probability ranges they used were small (6 and 10 points).[3] The present study uses much wider ranges, and tests whether presentation order interacts with the effect of framing; a primacy effect wherein subjects anchor on the first value presented is hypothesized, in part because presentation of the larger value first (an atypical order) may be expected to serve as a cue to place greater weight on that value.

INFERENCES ABOUT PROBABILITIES

A number of studies (see Camerer & Weber, 1992) have shown that people exhibit skewness in their perceptions of the true values of vague probabilities. If decision makers do not perceive a vaguely specified event as equivalent in mean likelihood to a precisely specified event, their preferences do not necessarily reflect attitudes toward vagueness per se. In other words, if a decision maker believes the true probability of an "around 50%" or are "unsure 50%" probability of winning to be actually *less* than 50%, she is not necessarily demonstrating vagueness aversion by preferring a known 50% chance of winning. Thus it is essential to clarify any effects of frame on vagueness preferences by also assessing whether these factors affect the inferences subjects make about probabilities.

Both verbal and numerical range operationalizations of vagueness have been found to lead to regressive perceptions about extreme vague probabilities. Heath and Tversky (1991) tested the manipulation of vagueness used by Hogarth and Einhorn (1990), wherein numerical estimates are said to be either reliable or unreliable. Told that an estimate of .01 is unreliable, most people estimated the actual probability to be somewhat greater, and, conversely, to be somewhat lower for large unreliable probabilities (Heath & Tversky, 1991). Heath and Tversky (1991) also reported data showing that when vagueness is manipulated as a range of probabilities (by numbers of winning or losing poker chips), subjects demonstrated similar regressive tendencies in their beliefs about very small and very large probabilities. But for a base probability of .50, as was used by Highhouse (1994), however, there was not a significant difference in judged probability between the vague numerical range and the precise value, although most subjects still preferred the precise .50 probability in choice (Heath & Tversky, 1991). Subjects in the range and verbal qualification conditions of the Highhouse (1994) study were not asked to give their best guess of the true probability of the vague option; judged equiprobability between the vague and precise options was not assessed. So it is unknown whether the two operationalizations differentially affect beliefs about non-extreme probabilities.

[3] Viscusi, Magat, and Huber (1991), who similarly operationalized a vague probability as different values reported by two studies, reported that subjects' judgments were more influenced by the second value presented, if the spread between the two values was relatively large, but this recency effect appeared to derive from subjects' belief that the second study was conducted more recently and was consequently superior to the first. Moreover, subjects responded with equivalency judgments rather than straightforward preferences.

Moreover, there may be differences between gambling studies, as in Heath and Tversky (1991), and hypothetical decision scenarios where hope, fear, and context-related knowledge may play a greater role in interpretations of risk information.

Does frame affect inferences about vague probabilities? Levin *et al.* (1986) found no differences between frame conditions in subjects' explicit inferences about the numerical value of missing probabilities. But several studies (e.g., Cohen & Wallsten, 1992; Mullet & Rivet, 1991; Nygren, Isen, Taylor, & Dulin, 1996), have reported an optimistic bias for inferences about vague probability phrases; judged values for phrases such as "likely" or "worse than even," are often higher when the events are associated with positive rather than negative outcomes, although this effect is typically weak and individual differences are considerable. Neither missing probability information (Levin *et al.*, 1986) nor vague verbal probability phrases, however, provide explicit numerical anchors. Furthermore, in real-world decision contexts involving non-aleatory events, frame may interact with people's prior experiences and expectations in determining beliefs about vague probabilities. Therefore it is also unknown what effect framing has on inferences about vaguely specified **numerical** probabilities, e.g., probability ranges or single probability estimates with verbal descriptions of associated uncertainty.

Because it is important to know whether any observed differences in vagueness seeking are due to changes in unqualified vagueness preferences or to differences in beliefs about probabilities, the present study includes two experiments on the effects of frame and operationalization of vagueness. The first uses expressed preferences between precisely and vaguely specified prospects as a response mode, and the second examines inferences about these prospects' probabilities.

EXPERIMENT 1

The Bier and Connell (1994) and Levin *et al.* (1986) studies on frame and probability uncertainty used very different contexts and operationalizations of uncertainty. The present study attempts to clarify their contradictory findings by systematically varying context, operationalization of vagueness, probability level, and frame in the same experiment. In general, people may be more inclined to prefer vagueness (or see it as more justifiable) with a loss frame, as with the increased risk seeking displayed for losses. Similar to Levin *et al.*'s (1986) results for missing probability information, a vaguely specified probability is hypothesized to be preferred to a precise probability more frequently when the risk problem is described in terms of undesirable rather than desirable outcomes.

H1: Expressed preference for vagueness will be greater with a negative frame than with a positive frame.

This effect of frame on vagueness preferences is hypothesized to be moderated by the manner in which vague probabilities are described; the anchors suggested by the representation of the vague prospect are expected to influence the impact of frame. H1 is expected to hold when vagueness is operationalized as a verbal qualification of a single point estimate. But when uncertainty about a probability is represented as a numerical range, as in Bier and Connell (1994), both a value more favorable and one less favorable than the anchor are made salient. With a positive frame, presentation of the higher, **more** favorable value first is expected to lead to relatively greater preference for vague options, whereas with a negative frame, presentation of the higher, **less** favorable value first will cause greater vagueness aversion, and vice versa.

> H2A: For a vague probability range framed positively, presentation of the higher value first will lead to greater vagueness seeking than will presentation of the lower value first.

> H2B: For a vague probability range framed negatively, presentation of the lower value first will lead to greater vagueness seeking than will presentation of the higher value first.

Method

Participants. Participants were 83 undergraduate students (42 men, 41 women) who took part in the study to partially fulfill a psychology course requirement.

Stimuli. Three hypothetical decision scenarios were developed. Each contrasted two risky options described as equivalent except for the precision with which their probabilities were known. Although both options reported the same expected probability, one option's probability was described as precisely or reliably known and the other was vaguely specified. Different decision contexts and causes of the uncertainty associated with the vague prospect, similar to many used singly in previous studies, were manipulated within the present study to establish generalizability of the main factors of interest. The *Medical* decision scenario described a choice between two vaccines which carried the risk of minor side effects. For the vague option, two studies were reported to have found different probabilities of side effects. The *Marketing* organizational decision scenario described a choice between developing one of two new products, given their assessed probabilities of successful market introduction. Uncertainty about the probability for the second option was said to arise from disagreement among marketing experts. The *Used Car* consumer scenario involved a choice between two used cars given a trusted mechanic's estimate of reliability; he was said to be less confident in his assessment of the "vague" car. See the Appendix for the exact wording of the scenarios.

Design and procedure. Two factors were manipulated within subjects. Three base probability levels—.20, .50, and .80—were crossed with the three decision scenarios, so each subject responded to nine decision problems. Two factors were manipulated between subjects, with a 3×2 design (Vagueness Description by Message Frame). Across the nine decision problems, the vague option was described in one of three ways:

1. as a Vague Point Estimate: a verbal qualifier of the base point estimate ("estimated to be around");

2. as a Low-High Range: a range of two probability values centered on the base probability value ("estimated to be between") with the low value presented first; or

3. as a High-Low Range: the same range of two probability values with the high value presented first.[4]

Each participant saw all scenarios either framed positively or framed negatively. For example, scenarios were presented in terms of the probability of successful market introduction, not experiencing side effects, and a car running trouble-free, or in terms of market failure, experiencing side effects, and of a car needing major repairs. The following are thumbnail sketches of the between-subject descriptions of the vague prospect for one probability level (because the specified hypotheses deal with framing effects rather than domain effects, a 20% probability in the positive frame is the same variable as the 80% probability in the negative frame, and vice versa):

1. 20% chance of good outcome, but unreliable
2. 80% chance of bad outcome, but unreliable
3. 10–30% chance of good outcome
4. 30–10% chance of good outcome
5. 70–90% chance of bad outcome
6. 90–70% chance of bad outcome

Participants were randomly assigned to conditions, and completed individual questionnaires in groups of about 20. All scenarios were presented in the same order, i.e., quasirandomized subject to the constraint that no decision scenario type or base probability level appeared twice in succession. In each problem, the vague option was presented second and participants were asked to rate on a 9-point scale their relative preference between the two options (1 = strongly prefer the first [precise] option, 9 = strongly prefer the second [vague] option). See examples in the Appendix.

Results

The mean response across all participants and conditions was 4.2 (SD = 1.36). Because the midpoint of the scale was 5, this indicates an average tendency toward vagueness aversion, as found in most previous studies. But the main experimental factors of frame and vagueness operationalization did affect expressed preferences for vagueness, and analyses of these between-subject factors, at both the group and individual level, are discussed first. More detailed results, namely the within-subject effects of scenario type and probability level, are presented later.

[4] Also manipulated between subjects in the two range conditions was the size of the probability range: ±10 probability percentage points or ±20 points. This variable was not significant in any analysis, either as a main effect or an interaction, but sample sizes were very small and power was low.

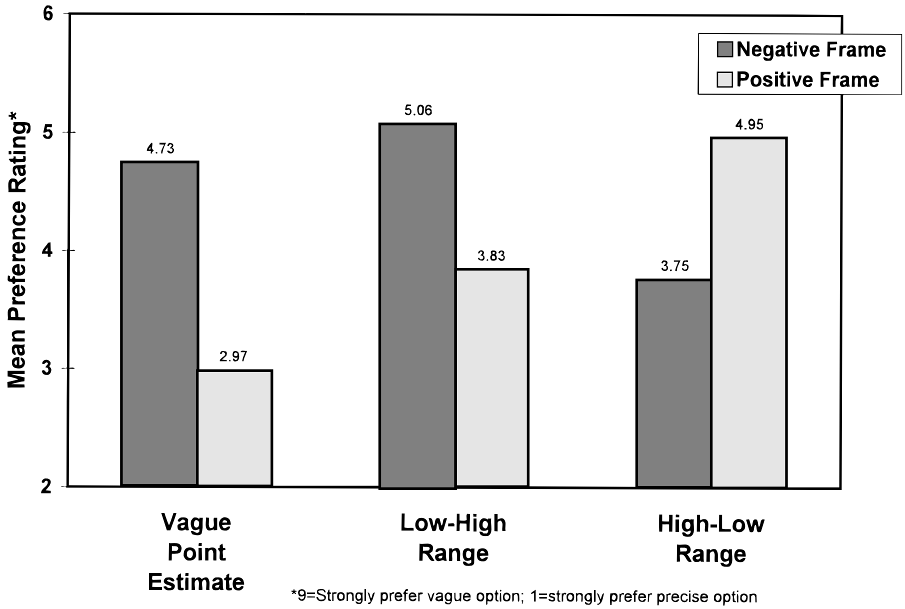

FIG. 1. Vagueness preference by frame and vagueness condition.

Between-subjects factors. Rating responses were analyzed via MANOVA, with frame and vagueness condition as between-subjects factors and probability level and scenario type as within-subjects factors. Figure 1 presents the mean responses for the between-subjects conditions, averaged across scenario type and probability level. The interaction between frame and vagueness condition is striking ($F(2,77) = 12.37$, $p < .001$, effect size = .24). For the two "standard" operationalizations of vagueness, the Vague Point Estimate and Low-High Range conditions, the effects of message frame are quite similar; as hypothesized (H1), vague options in these two conditions are more likely to be preferred when decision problems are framed negatively than when they are framed positively ($t = 4.7$, $p < .001$). But when the larger value of a vague numerical range is presented first (High-Low Range condition), observed preference for vague options is higher in the *positive* frame. Thus the primacy effect of range order posited in Hypotheses 2A and 2B was strongly supported; as shown in Fig. 1, presentation of the larger, *more favorable* value first leads to greater preference for vague options when messages are positively framed, whereas in the negative frame presentation of the larger, *less favorable* value first leads to greater vagueness aversion.[5]

Responses were also analyzed at the within-subject level by calculating for each participant the proportion of times she "chose" a vague option (made a response greater than 5 on the 9-point scale) compared to the number of times

[5] This pattern is much more marked for the larger, 40 point ranges than the 20 point ranges. The difference between the positive and negative frame means within the two probability orders is much greater with the larger range, providing limited support for the hypothesis that large ranges are necessary for primacy effects to be observed. But the interaction between range size, probability order, and frame is not significant ($F(1,46) = 1.52$, n.s.).

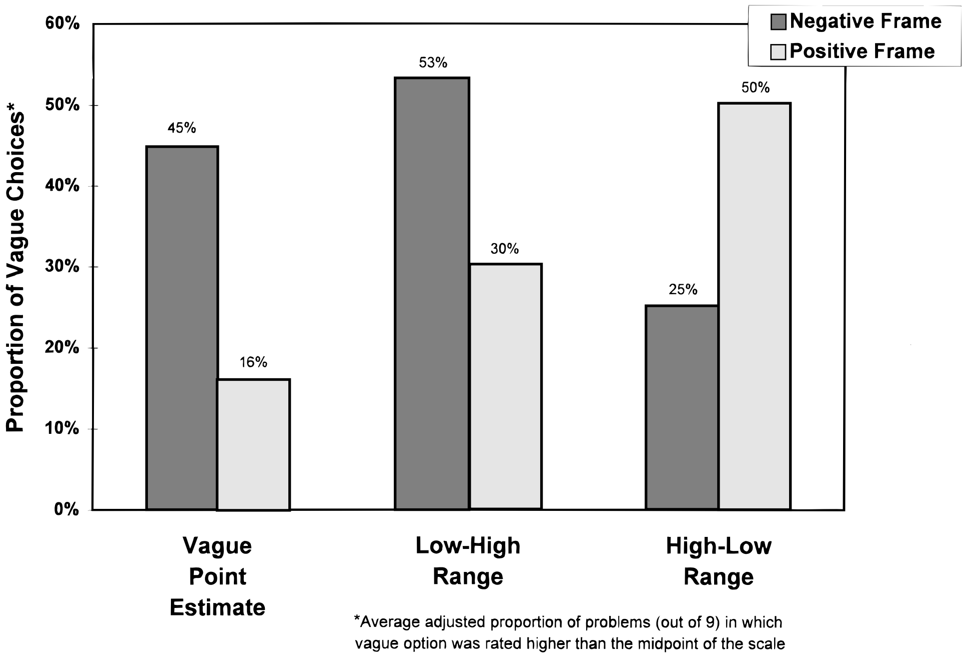

FIG. 2. Average proportion of vague choices.

she preferred the precise option (made a response of less than 5). Because each subject contributed multiple responses, the adjusted proportion (Mosteller & Tukey, 1977) of vague choices was calculated by counting the number of times a subject preferred a vague option (count V) and a precise option (count P). Both counts were initially set at $^1/_6$ to avoid extreme proportions. If a subject indicated indifference (responded with a 5 on the 9-point scale), 0.5 was added to both count V and count P. The proportion was calculated as:

$$\Pr(V) = \frac{count\ V}{count\ P + count\ V}$$

Average proportion scores by condition are displayed in Fig. 2. The pattern is very similar to that obtained with the straightforward preference ratings averaged across subjects (Fig. 1), and again the interaction between vagueness condition and frame is significant ($F(2,77) = 11.65$, $p < .001$).[6]

Within-subject factors. Table 1 presents the mean responses and standard deviations for all cells. The MANOVA of the preference ratings (as discussed above) shows that vagueness aversion was more marked in the *Used Car* scenario than in the other two. The main effect of scenario type was significant ($F(2,154) = 8.28$, $p < .001$), but this factor did not interact with either of the

[6] The actual proportions are used for presentation purposes; log-odds transformation to adjust for asymmetrical distribution does not change conclusions of the analysis.

TABLE 1

Experiment 1: Mean Vagueness Preference Rating (and Standard Deviations) by Condition and Frame

Anchor probability (positive/negative)	Used car scenario			Medical scenario			Marketing scenario		
	20/80	50/50	80/20	20/80	50/50	80/20	20/80	50/50	80/20
Condition									
Negative frame (*n* = 42)	**5.1**(2.2)	**4.3**(2.0)	**3.3**(1.5)	**5.1**(2.2)	**4.8**(2.1)	**4.1**(2.4)	**4.5**(1.8)	**4.8**(2.0)	**4.8**(2.2)
Vague point estimate (*n* = 15)	5.2(2.3)	4.4(1.9)	3.1(1.1)	5.5(1.9)	5.3(1.8)	4.1(2.2)	4.6(2.0)	5.2(2.2)	5.1(2.3)
Low-high range (*n* = 14)	6.2(1.4)	5.0(2.0)	3.9(2.0)	5.6(2.4)	4.9(2.3)	4.7(2.7)	5.4(1.5)	4.9(1.6)	4.9(2.2)
High-low range (*n* = 13)	3.8(2.2)	3.4(2.0)	2.8(1.2)	4.2(2.3)	4.0(2.2)	3.5(2.4)	3.4(1.4)	4.3(2.2)	4.4(2.4)
Positive frame (*n* = 41)	**2.8**(1.6)	**3.7**(2.3)	**3.0**(2.2)	**4.2**(2.6)	**4.7**(2.6)	**4.4**(2.7)	**4.8**(2.2)	**4.0**(2.0)	**3.6**(2.4)
Vague point estimate (*n* = 14)	2.2(1.0)	2.4(1.3)	1.9(1.0)	3.2(2.1)	3.4(2.3)	3.3(2.2)	4.5(1.8)	3.2(1.9)	2.6(1.8)
Low-high range (*n* = 14)	3.3(1.7)	4.4(2.4)	2.7(1.8)	3.9(2.8)	4.2(2.5)	4.1(2.7)	5.1(2.6)	3.4(1.7)	3.4(2.3)
High-low range (*n* = 13)	2.9(1.8)	4.4(2.5)	4.6(2.6)	5.5(2.6)	6.5(2.2)	5.8(2.7)	4.8(2.1)	5.3(1.7)	4.7(2.7)
Grand means (N = 83)	**4.0**(2.2)	**4.0**(2.2)	**3.2**(1.9)	**4.7**(2.5)	**4.7**(2.4)	**4.2**(2.5)	**4.6**(2.0)	**4.4**(2.0)	**4.2**(2.4)

Note. Nine-point scale, with 1 = strongly prefer precise option, 9 = strongly prefer vague option.

factors of interest—message frame and operationalization of vagueness—suggesting at least some degree of generalizability across different decision contexts.

There was also a main effect of probability level ($F(2,76) = 7.03$, $p < .01$). As has been found in many previous studies (e.g., Hogarth & Einhorn, 1990), preference for the vague options was least pronounced for the high probability of gain/low probability of loss (see Table 1), and most pronounced for the low probability of gain/high probability of loss. The linear trend contrast between the two probability level extremes was significant ($t = 2.13$, $p < .01$). Average vagueness preference in the High-Low Range vagueness condition did not follow the expected ordering along the probability continuum, however, and this interaction between vagueness condition and probability level was significant (Wilks' multivariate test of significance $F(4,152) = 3.97$, $p < .01$). But there was no significant interaction between scenario type and probability level, nor between frame and either of the within-subject factors. Again, this demonstrates that the framing effect is at least mildly robust across different decision contexts and probability levels.

Discussion

The results of this experiment clearly show that decision frame affects preference for vagueness, moderated by how the vagueness is operationalized. Although the overall modal preference was for precision, as found in previous studies, the level of observed preference for vagueness was manipulable simply by changing surface features of the problem representation. Moreover, these effects cannot be accounted for simply in terms of the domain differences posited by Einhorn and Hogarth (1985). Rather than demonstrating a general cautious attitude in the face of uncertainty, participants in the negative frame were more vagueness seeking than were those who read the same problems framed positively—except when the higher (unfavorable in the negative frame) probability value in a vague range was presented first. Because the majority of past experiments on vagueness have dealt with positively framed risks (chances of winning, successful medical treatment, etc.), and numerical ranges are typically presented with the lower value first, the degree of general vagueness aversion may be less marked than what has been reported in the experimental literature.

This experiment also crossed problem frame with different operationalizations of vagueness. Note that the comparison between the Low-High Range and the Vague Point Estimate conditions **in the positive frame** (Figs. 1 and 2) provides partial replication for Highhouse's (1994) finding that vagueness seeking is more common with a range rather than a vague point estimate. In the present study, vague options are also rated as more preferable in the former condition, although not to a significant degree. But the difference is negligible for the same problems framed negatively, and in the negative frame simply switching the presentation order of the range values ***reverses*** the direction of the difference between the numerical range and vague point estimate operationalizations.

These results clearly disagree with those reported by Bier and Connell (1994), in whose study—which used operationalizations of vagueness analogous to the Low-High and High-Low Range conditions in the present experiment—vagueness seeking was greater for the positive frame (although, unlike Bier and Connell's task, in the present experiment only one attribute varied between options). For the scenario most similar to those used by Bier and Connell (1994)—the low probability of side effects (high probability of none) in the *Medical* scenario—the mean preference for vagueness in the two range conditions was in fact slightly (non-significantly) higher in the positive frame ($\bar{X}_{+} = 4.7$) than in the negative frame ($\bar{X}_{-} = 4.27$). But this is not the case for the Vague Point Estimate condition, and over the other probability levels the pattern of responses to the *Medical* scenario does not differ from those of the other two scenarios. The results of the present experiment therefore demonstrate the utility of including a greater variety of probability levels, decision contexts, and operationalizations in the investigation of frame and vagueness effects.

Bier and Connell (1994) also reported no effects of probability order (i.e., no significant difference between High-Low Range and Low-High Range conditions), whereas in the present experiment an interaction of probability order and frame is clearly evident. A likely explanation for the discrepancy is the larger range sizes used in the current experiment, augmenting an order effect.

The question remains, of course, whether these observed effects of frame and vagueness operationalization on expressed preferences were due to changes in actual preference for vagueness per se, or because the manipulated factors changed people's inferences about vague probabilities. Recall that in Levin *et al.*'s (1986) study, although frame influenced preferences for vaguely specified gambles, it did not affect subjects' estimated values of the missing probability information. But unlike Levin *et al.* (1986), the stimuli in the present experiment were embedded in real-world contexts rather than aleatory gambles, and the vague prospects had numerical anchors. Accordingly, frame and operationalization are likely to have influenced how people perceived probabilities.

EXPERIMENT 2

To test whether the effects of frame and vagueness operationalization on uncertainty preferences observed in Experiment 1 could be accounted for by differences in inferences about probabilities, a second experiment was conducted. A different sample of participants from the same undergraduate population as the first experiment evaluated the same scenarios. But instead of being asked to express a preference, they simply indicated their subjective probabilities for the various options, based on the information presented. A separate sample of participants was used in order to avoid any possible demand characteristics that might arise from asking someone both to express a preference between two risky options and to give her subjective probabilities of their likelihoods.

Method

Participants. Sixty-seven volunteer subjects (22 men, 43 women; 2 did not report their gender) participated to earn extra credit in an undergraduate psychology course.

Design and procedure. The scenarios and conditions from Experiment 1 were replicated, i.e., a 3 × 3 within-subjects (Probability Level by Scenario Type) and a 2 × 3 between-subjects (Problem Frame by Vagueness Operationalization) design. A range of ±10 probability percentage points was used in the two range conditions. Instead of expressing a preference between the precise and vague options in each problem, participants in this experiment were asked only to indicate for each option what would be their "best guess of the true probability, given the information provided." For each precise probability *X*%, they were asked to check one of the following:

_____ Less than *X*%
_____ *X*%
_____ Greater than *X*%

and they also made the same judgment about the vaguely specified option, using the same three possible responses. (It may seem strange to ask for the "true" probability of the precise option, but because these responses were collected to compare to the preference data in Experiment 1, it is necessary to be able to derive a *comparative* measure of probability belief. In other words, we need to know whether a vague probability option was believed to be more or less likely than the precise probability option. To lessen demand characteristics, this method was chosen rather than a direct comparison).

Participants completed individual questionnaires in groups of about 30 and were randomly assigned to conditions. The presentation order and format of the scenarios were identical to Experiment 1. Following completion of all judgments, participants were asked to write comments explaining their responses to the first three scenarios presented (the *Used Car* 20% probability scenario, the *Marketing* 80% probability scenario, and the *Medical* 50% probability scenario).

Results

These categorical responses were analyzed with logit models, with frame and vagueness condition as independent variables. Responses were summed across the within-subject factors of scenario type and probability level, as these factors were not of interest and for presentation purposes (although, due to violations of independence assumptions, p-values may be suspect). Responses were coded in terms of favorability: a response of *less than X*% for a negatively framed problem is equivalent in terms of underlying sense to *greater than X*% for a positively framed response, i.e., it indicates a favorable or optimistic belief about the option's probability, whereas responses of *greater than X*% to negatively framed problems and *less than X*% to positively framed problem are indicative of pessimistic interpretations.

TABLE 2

Experiment 2: Distribution of Judged True Probabilities of Vague Options, Summed across Nine Probability and Scenario Combinations

	Less than	Same	Greater than
Negative frame ($n = 34 \times 9$)	**76 (25%)**	**153 (50%)**	**77 (25%)**
Vague point estimate ($n = 16 \times 9$)	41 (28%)	66 (46%)	37 (26%)
Low-high range ($n = 9 \times 9$)	19 (23%)	47 (58%)	15 (19%)
High-low range ($n = 9 \times 9$)	16 (20%)	40 (49%)	25 (30%)
Positive Frame (n = 33 × 9)	**166 (56%)**	**90 (30%)**	**41 (14%)**
Vague point estimate ($n = 14 \times 9$)	86 (68%)	26 (21%)	14 (11%)
Low-high range ($n = 10 \times 9$)	42 (47%)	42 (47%)	6 (07%)
High-low range ($n = 9 \times 9$)	38 (47%)	22 (27%)	21 (26%)
Totals ($N = 67 \times 9$)	**242 (40%)**	**243 (40%)**	**118 (20%)**

Inferred probabilities of vague options. The distribution of responses for the vague options, combined across probability levels and scenarios, is depicted in Table 2. Overall, participants took a more pessimistic view of vague options when they were framed *positively* ($\chi^2(2) = 50.5$, $p < .001$). The effect of vagueness condition was also statistically significant ($\chi^2(4) = 19.6$, $p < .001$), as was its interaction with problem frame $\chi^2(2) = 15.2$, $p < .01$). Especially remarkable is the impact of frame in the Vague Point Estimate condition; for the positive frame, 68% percent of the responses in this condition were that the true probability of the vague option was likely to be less than the anchor probability, whereas in the negative frame only 26% of the responses were unfavorable (greater than X%) interpretations. With a positive frame, participants in the High-Low Range condition were most likely to interpret the probability of the vague options auspiciously.

Inferred probabilities of precise options. The distribution of responses to the precise options, again collapsed across scenarios and probability levels, is presented in Table 3. Participants were much more likely to judge the anchor

TABLE 3

Study 1, Experiment 2: Distribution of Judged True Probabilities of Precise Options Summed across Nine Probability and Scenario Combinations

	Less than	Same	Greater than
Negative frame ($n = 34 \times 9$)	**47 (15%)**	**218 (71%)**	**41 (13%)**
Vague point estimate ($n = 16 \times 9$)	19 (13%)	113 (78%)	12 (08%)
Low-high range ($n = 9 \times 9$)	12 (15%)	57 (70%)	12 (15%)
High-low range ($n = 9 \times 9$)	16 (20%)	48 (59%)	17 (21%)
Positive frame (n = 33 × 9)	**75 (25%)**	**161 (54%)**	**61 (21%)**
Vague point estimate ($n = 14 \times 9$)	32 (25%)	78 (62%)	16 (13%)
Low-high range ($n = 10 \times 9$)	17 (19%)	55 (61%)	18 (20%)
High-low range ($n = 9 \times 9$)	26 (32%)	28 (35%)	27 (33%)
Totals ($N = 67 \times 9$)	**122 (20%)**	**389 (63%)**	**102 (17%)**

probability as the most likely true value of the precisely described option (percentage of *X*% responses = 63%) than they were for the vague options (percentage of *X*% responses = 40%). Because these options were described as precisely known or made with high confidence, it is still noteworthy that they were not always treated as such by participants. This may, however, reflect demand characteristics if simply asking people to judge the "true" value of a precisely specified prospect suggests that it should be different from what is presented.

Unlike beliefs about the vague options, there is no overall asymmetric effect of frame on beliefs about the precisely described probabilities. For the precise options, more *less than* and *greater than* responses were recorded by participants who read positively framed problems than by those in the negative frame condition, who checked X% more often ($\chi^2(2) = 18$, $p < .001$), but this effect was essentially symmetric. Participants in the High-Low condition were most likely to give *greater than* or *less than* responses to the precise options and thus the effect of vagueness condition is also significant ($\chi^2(4) = 25.2$, $p < .001$), although the interaction with frame is not ($\chi^2(4) = 5.5$, n.s.). Thus frame does not appear to bias beliefs about *precisely* specified probabilities in a particular direction.

Comparative favorability of vague and precise options. Because participants sometimes did not judge the precise option's true probability to be its stated value, the data were analyzed comparatively by determining for each decision problem whether the judged probability of the vague option was better, the same as, or worse than that of the precise option. The distribution of these responses is shown in Table 4.

This "comparative favorability of vagueness" measure was analyzed at the within-subject level by computing the adjusted proportion of times an individual judged a vague option to have a more favorable probability than the precise option (see Experiment 1). Mean scores for this adjusted proportion are presented in Fig. 3. The average proportion was .37 (*SDM* = .25), indicating that

TABLE 4

Experiment 2: Distribution of Comparative Judged True Probabilities of Precise and Vague Option Pairs, Summed across Nine Probability and Scenario Combinations

	Vague better	Same	Precise better
Negative frame (n = 34 × 9)	**68 (22%)**	**161 (53%)**	**77 (25%)**
Vague point estimate (n = 16 × 9)	32 (22%)	77 (54%)	35 (24%)
Low-high range (n = 9 × 9)	20 (25%)	43 (33%)	18 (22%)
High-low range (n = 9 × 9)	16 (20%)	41 (51%)	24 (30%)
Positive Frame (n = 33 × 9)	**30 (10%)**	**140 (47%)**	**127 (43%)**
Vague point estimate (n = 14 × 9)	10 (08%)	78 (45%)	16 (47%)
Low-high range (n = 10 × 9)	6 (07%)	44 (49%)	40 (44%)
High-low range (n = 9 × 9)	14 (17%)	39 (48%)	28 (35%)
Totals (N = 67 × 9)	**98 (16%)**	**301 (50%)**	**204 (34%)**

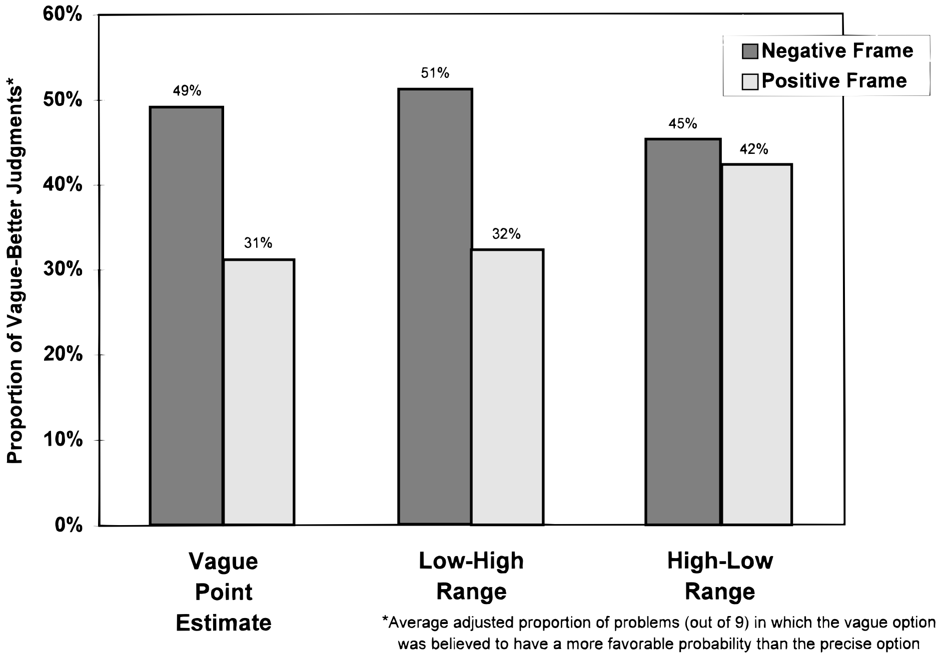

FIG. 3. Comparative inferences about probabilities.

participants usually felt the vague option to have a worse probability than the precise option. Inferences of worse probabilities for the vague option were much more common, however, in the positive frame than in the negative frame ($F(1,61) = 8.2$, $p < .01$). The effect of vagueness condition was not significant ($F(2,61) = .33$, n.s.), nor was the interaction with frame ($F(2,61) = 1.36$, n.s.), although the frame effect is minimal within the High-Low range condition.

Discussion

Comparing Fig. 3 to Figs. 1 and 2, it can be shown that the effects of frame and vagueness operationalization on vagueness preferences correspond roughly to their effects on beliefs about probabilities. Framing effects on vagueness preferences can therefore be at least partly explained as resulting from changes in beliefs about probabilities. When vagueness is operationalized as either a verbal qualification of a single point estimate, or as a low-to-high numerical range centered on the precise comparison value, a positive frame is associated with both greater vagueness aversion in preferences and less favorable beliefs about the likelihoods of vague options. Conversely, a negative frame sharply reduces observed vagueness aversion, and increases the proportion of favorable inferences about vaguely specified probabilities.

Within the High-Low Range condition, however, the implied preference for vagueness from judgments about probabilities is not greater in the positive frame than in the negative, as it was with expressed preferences in Experiment 1. Whether or not this difference between the two experiments is truly due to the different types of judgments is an interesting question for future research;

if so, it would suggest that the effects of framing and vagueness operationalization on preferences, as shown in the first experiment, cannot be solely explained through effects on beliefs about probabilities. Note, however, that within each frame condition, the relative order of the three operationalization conditions in terms of preference for vague options is the same in both Experiments 1 and 2.[7]

Because numerical ranges are commonly presented with the lower number first, one possible explanation for the somewhat anomalous results of the High–Low range condition, in both Experiments 1 and 2, is that the irregular probability order was somehow thought to be indicative of the communicators' persuasive intentions, or otherwise led participants to be suspicious. No subject in this condition in Experiment 2, however, commented on the order of the probability information.

Participant comments. Problem frame and the operationalization of uncertainty, although they did not change the deep structure of the decision problems, did systematically affect how people interpreted the probability uncertainty. The written responses of participants in Experiment 2 illustrate why they often believed the true probabilities of the vague and precise options to differ. The comments were made at the end of the experiment and participants were asked simply to explain their answer for each of the first three problems presented.

For example, one person in the Vague Point Estimate/Positive Frame condition took an unfavorable view of the uncertain probability for the first *Used Car* scenario: "Since he [the mechanic] confidently said there was a 20% chance, then I trust it is 20%. For Car #2, he isn't exactly sure so I would say it could be less than 20%." But another participant in the Vague Point Estimate condition, responding to the same problem framed negatively, judged the probability of the vague option to be more favorable than the precise option. She wrote, "Since mechanic is unsure, he's being overcautious. Figures are probably conservative."

In evaluating the decision scenarios, many participants clearly employed their own preconceptions of how people in different situations communicate probability information.[8] For example, a participant who responded to positively framed scenarios with the High-Low range operationalization checked **greater** than 80% for the **precise** *Marketing* scenario option, and =80% for the vague option:

> When people speculate on success, they tend to stay on the safe side. Even if they think it might be 90% they may say 80%. For [the vague option]—the studies might indicate the reservations of some and the hope of others, but it is still pretty likely it will be successful—80%.

[7] Note also that in Experiment 1, both 20 and 40 point ranges were used, with the interaction of probability order and frame more (non-significantly) pronounced with the larger range. In Experiment 2, only 20 point ranges were used.

[8] Participants also applied their real-world knowledge absent any consideration of uncertainty. "I always get side effects" and "I never have any side effects" were common explanations for probability judgments in the *Medical* scenario.

Consider also the comments of a participant in the Vague Point Estimate condition, negative frame, who checked the anchor probability for the precise *Medical* option and less than 50% for the vaguely stated one:

> If tests for Vaccine A are all in agreement that it will yield the same amount of people that will have side effects, I will believe them. But if the studies have conflicting data, I would guess that the doctors would try to round the number of people having these side effects to the highest number to avoid malpractice and other suits.

Some participants, however, explained their responses in a manner that subjective expected utility theorists would applaud. For example, one participant (Low-High Range condition, negative frame) picked as his best estimate the base anchor probability for both all precise and all vaguely specified options. His reasoning for the *Used Car* scenario: "The first car is given a 20% probability because I have no information the mechanic doesn't have. The second car is also 20%. Even though he has less knowledge of the car, that doesn't make it more likely to break." Similarly, he picked the midpoint of the 70 to 90% range for the *Marketing* scenario because "I have no reason to believe that one is more accurate than the other."

GENERAL DISCUSSION

Although most experimental research on vague probabilities has demonstrated significant vagueness aversion, it has long been known that responses are not uniform and vagueness seeking does occur. With the exception of vagueness seeking for large probabilities of losses and small probabilities of gains, which are attributable to bounds on probability adjustment, most previous researchers have treated this variation in vagueness preference as resulting from individual differences in general vagueness attitude (e.g., Einhorn & Hogarth, 1985). The present study demonstrates that changes in the manner in which vagueness is presented, without any underlying change in problem structure, affect observed preferences.

Framing and Vagueness Preferences

The dominant finding of this study is that negative framing leads both to more favorable beliefs about vague probabilities and to greater preference for vague probability options (with the exception of vague numerical ranges where the higher value was presented first, where anchoring on the higher, unfavorable value reverses or lessens the effect). This framing effect was obtained over a variety of decision contexts and various reported sources of vagueness. Because this study used a relatively wide range of probabilities, and the frame effect was not moderated by the level of probability, it cannot be easily explained by the Einhorn-Hogarth (1985) model. Explanations of uncertainty based on the salience of missing information (Frisch & Baron, 1988) also would not predict a frame effect, nor would a competence-based perspective (e.g., Heath & Tversky, 1991).

At first glance, a parsimonious explanation for the observed frame effects on vagueness preferences would simply be that vague numerical anchors, regardless of gain/loss frame, are generally underweighted (excepting extremely small probabilities, which were not used in this study). A positive or negative description of the outcome, however, determines whether this underweighting is more or less favorable (<50% chance of success vs <50% chance of failure) and consequently whether vagueness seeking or avoidance is observed. Note that the distributions of judged probabilities of vague options in Experiment 2, however, were *not* symmetrical between the positive and negative frames. As shown in Table 2, "underweighting" of vague probabilities was the most common response in the positive frame (56% of responses were that the true probability was less than the anchor), whereas in the negative frame the percentages of *less than* and *greater than* responses were the same (25%).

Thus a more reasonable explanation for the results is the following: people exhibit a general preference for precision that is attenuated by negative framing, which makes a favorable interpretation of vague probability information more common. This is plainly similar to the standard framing effect on risk preferences; people are also more likely to be risk seeking when a problem is framed negatively because, under prospect theory, losses loom larger than gains and a loss frame places people in the convex part of the value function. In a loosely analogous fashion, if we assume that most people typically prefer options with precise information, a greater concern for avoiding losses may provide more motivation for placing a positive spin on vague probabilities. It may seem somewhat paradoxical that a loss frame causes people to take a more optimistic interpretation of probability uncertainty. But this result fits in with a motivational approach to understanding vagueness preferences; because losses are especially aversive, people may have more reason to take a chance on a vaguely specified probability, hoping it might actually be better than the comparison precise probability. (Loss aversion leading to an optimistic bias for interpreting vagueness is perhaps more akin to a goal framing effect than to standard risky choice framing; see Schneider, Levin, and Gaeth, 1995). Whether this framing effect would be observed without a direct comparison between vagueness and precision, or with a direct comparison between precise numerical probabilities and verbal likelihood phrases without a numerical anchor (see Cohen & Wallsten, 1992), are interesting avenues for future research.

Although this study provides evidence that problem frame influences vagueness preferences, in real-world decisions frame is often not easily manipulable. Moreover, the existence of strong prior beliefs and motivations, absent any experimental manipulation, may determine how uncertainty information is interpreted; in a sense, individuals can create their own frames. Current research is addressing the impact of individual differences in context-specific priorities and values on the interpretation of vague probability information.

Operationalization of Vagueness

Unlike the vast majority of previous work, this study explicitly compared numerical range and verbal operationalizations of uncertainty within the same study. The observed differences between the operationalizations cannot be explained simply by assuming that uncertainty is unbounded in the first case and bounded in the latter, because the effects of operationalization and frame were interactive. The frame effect on preferences observed with verbal qualifications of point estimates also held if uncertainty was operationalized as a numerical range using the standard method of presenting the lower value first, but reversed when the higher value was presented first. For this presentation order, preference for vague options was greater in the positive frame (first value is more favorable) than in the negative frame (first value is less favorable). Previous studies that found no difference between numerical range and verbally qualified point estimate operationalizations of vagueness (Dhar *et al.*, 1995; di Mauro & Maffioletti, 1996) used only a low-to-high presentation order, and thus did not control for this possible confound. Although the primacy effect observed in this study was hypothesized, the change in presentation order is seemingly trivial and the strength of its impact was not expected. But it is noteworthy in that it indicates an anchoring effect, and suggests other hypotheses about order effects in more realistic presentations of uncertainty information. The switch in probability order for ranges had less of an impact on inferences about probabilities, although within the positive frame, both favorable judgments about vague probabilities (Experiment 2) and vagueness seeking expressed through preference ratings (Experiment 1) were most common in the High-Low Range. Future research is needed to further assess any response mode differences, and how people interpreted the atypical order.

Incorporating Uncertainty About Probabilities in Decision Making

Unlike laboratory gambles, few probabilities for important real-world risks can be assessed with perfect precision. Whether explicitly acknowledged or not, uncertainty is inherent in the risk information used to make many critical decisions at the individual, organizational, and public policy levels. Engineers and scientists know a great deal about how to define and calculate uncertainty in many contexts (e.g., Morgan & Henrion, 1990), yet relatively little is known about how the communication of uncertainty information influences judgments and decisions about risk. Understanding the role presentation effects play in decision making under uncertainty is especially critical because those who make decisions about risk, both individual and societal, frequently take no part in the actual risk assessment, and must rely on other people's judgments and counsel.

Whether or not it is rational for people's decisions to be affected by probability uncertainty is a separate question, and one that is a subject of controversy (see Lichtenstein, Gregory, Slovic, & Wagenaar, 1990; Lopes, 1992; Winkler, 1991). Prescriptively justified or not, probability uncertainty plays a demonstrably important role in how people think about risk. Given the potential legal, ethical, and practical reasons for communicating probability uncertainty in both formal analyses and more informal assessments of risk, the need to understand the process through which communicated vagueness affects people's perceptions and decisions can only become more pressing.

APPENDIX

The following example scenarios use the middle level base probability, negative framing, and the Vague Point Estimate operationalization. Changes for the other conditions are presented in italics.

Used Car Scenario—For the positive frame, the probability was stated in terms of a car's "running trouble-free for the next two years and not needing a major repair."

You are buying a used car. You have looked at many cars, and have narrowed your choice down to two. Both cars are available for the same price, and are equally attractive to you in terms of style, color, mileage, etc. You plan to drive the car for the next two years, and you have hired a mechanic you trust to examine both cars.

The mechanic tells you that the first car, Car #1, is in generally good shape. But he confidently tells you that it has a **50% chance of needing a major repair** within the next two years.

Car #2 is in generally good shape as well, and your mechanic estimates that [Car #2 also has **around a 50% chance of needing a major repair** within the next two years. But because he is less familiar with this make of car, he is very unsure about providing an estimate for Car #2. A 50% chance is his best estimate, however.]*

Which car would you choose to purchase? (circle the number which best reflects your preference)

1———2———3———4———5———6———7———8———9		
Strongly prefer Car #1	Not sure	Strongly prefer Car #2

Low-High Range condition [Car #2 has between a **40% and 60% chance of needing a major repair within the next two years. But because he is less familiar with this make of car, he is very unsure about providing an estimate for Car #2 and cannot be more precise.]*

High-Low Range condition [Car #2 has between a **60% and 40% chance of needing a major repair within the next two years. But because he is less familiar with this make of car, he is very unsure about providing an estimate for Car #2 and cannot be more precise.]*

Medical Scenario—For the positive frame, probabilities were given in terms of "not experiencing any side effects."

A new strain of the influenza (flu) virus has recently struck the United States. Although not usually fatal, the virus is highly contagious and very serious. Victims experience high fever, severe gastrointestinal symptoms, and are usually ill for several days to two weeks. Two vaccines have recently been developed which are both 100% effective against this strain of the flu virus. Both vaccines, however, bear a risk of minor side effects; some people who receive a vaccine experience a slight headache and muscle pain at the site of the injection, lasting a few hours. But both vaccines are equally effective and safe, and if you do not receive a vaccine it is almost certain you will contract the disease and become seriously ill.

Two studies on the effects of Vaccine A both reported that **50% of the people** who received the vaccine experienced side effects.

[For Vaccine B, two studies also reported that **around 50% of the people** who received Vaccine B experienced side effects, although the percentages reported by these two studies did not agree exactly.]*

Your doctor has strongly advised you to receive a vaccine, but has offered you the choice between the two available vaccines.

Which vaccine would you choose? (circle the number which best reflects your preference)

1———2———3———4———5———6———7———8———9

Strongly prefer Vaccine A	Not sure	Strongly prefer Vaccine B

Low-High Range condition [For Vaccine B, one study has reported that* ***40% of the people* *who received Vaccine B experienced side effects, whereas another study on Vaccine B reported that* **60% of the people** *experienced side effects.]*

High-Low Range condition [For Vaccine B, one study has reported that* ***60% of the people* *who received Vaccine B experienced side effects, whereas another study on Vaccine B reported that* ***40% of the people*** *experienced side effects.]*

Organizational Marketing Scenario—In the positive frame, "success" was used in place of "failure."

You are a manager for a large electronics manufacturing company. Your research and development personnel have developed two new television technologies: M-Resolution and ZX Enhancement. Depending on the actions of your competitors and developments in the cable television industry, both products have the potential to be extremely profitable. Your company, however, only has the resources to manufacture one product in sufficient quantities.

You must decide which of the two products to produce and market. Based on extensive research and knowledge of competing firms, your marketing experts all agree that the M-Resolution has a **50% chance of failure.**

Your marketing experts disagree somewhat about the chances of the ZX-Enhancement's success. They are less sure about whether some competing firms will produce similar products or none will, and whether it will prove compatible with new cable systems or not. [On average, though, ZX-Enhancement is also estimated to have **around a 50% chance of failure]*.**

Which product would you choose to produce? (circle the number which best reflects your preference)

1———2———3———4———5———6———7———8———9——
Strongly prefer M-Resolution | Not sure | Strongly prefer ZX-Enhancement

Low-High Range Condition [Some of your experts estimate that the ZX-Enhancement has a **40% chance of failure, whereas others estimate it has a **60% chance of failure.]***

High-Low Range Condition [Some of your experts estimate that the ZX-Enhancement has a **60% chance of failure,* whereas others estimate it has a ***40% chance of failure.]***

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