AMBIGUITY AVERSION AND COMPARATIVE IGNORANCE*

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Decisions under uncertainty depend not only on the degree of uncertainty but also on its source, as illustrated by Ellsberg's observation of ambiguity aversion. In this article we propose the comparative ignorance hypothesis, according to which ambiguity aversion is produced by a comparison with less ambiguous events or with more knowledgeable individuals. This hypothesis is supported in a series of studies showing that ambiguity aversion, present in a comparative context in which a person evaluates both clear and vague prospects, seems to disappear in a noncomparative context in which a person evaluates only one of these prospects in isolation.

I. INTRODUCTION

One of the fundamental problems of modern decision theory is the analysis of decisions under ignorance or ambiguity, where the probabilities of potential outcomes are neither specified in advance nor readily assessed on the basis of the available evidence. This issue was addressed by Knight [1921], who distinguished between *measurable uncertainty* or *risk,* which can be represented by precise probabilities, and *unmeasurable uncertainty,* which cannot. Furthermore, he suggested that entrepreneurs are compensated for bearing unmeasurable uncertainty as opposed to risk. Contemporaneously, Keynes [1921] distinguished between *probability,* representing the balance of evidence in favor of a particular proposition and the *weight of evidence,* representing the quantity of evidence supporting that balance. He then asked, "If two probabilities are equal in degree, ought we, in choosing our course of action, to prefer that one which is based on a greater body of knowledge?" [p. 313]. The distinction between clear and vague probabilities has been rejected by proponents of the subjectivist school. Although Savage [1954] acknowledged that subjective probabilities are commonly vague, he argued that vagueness has no role in a rational theory of choice.

Interest in the problem of decision under ignorance was revived by a series of papers and commentaries published in the early sixties in this *Journal.* The most influential of these papers, written by Ellsberg [1961], presented compelling examples in which people prefer to bet on known rather than on unknown

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probabilities (see also Fellner [1961]). Ellsberg's simplest example, known as the "two-color" problem, involves two urns each containing red and black balls. Urn 1 contains 50 red and 50 black balls, whereas urn 2 contains 100 red and black balls in an unknown proportion. Suppose that a ball is drawn at random from an urn and one receives $100 or nothing depending on the outcome. Most people seem indifferent between betting on red or on black for either urn, yet they prefer to bet on the 50-50 urn rather than on the urn with the unknown composition. This pattern of preferences is inconsistent with expected utility theory because it implies that the subjective probabilities of black and of red are greater in the 50-50 urn than in the unknown urn, and therefore cannot sum to one for both urns.

Essentially the same problem was discussed by Keynes some 40 years earlier: "In the first case we know that the urn contains black and white balls in equal proportions; in the second case the proportion of each color is unknown, and each ball is as likely to be black as white. It is evident that in either case the probability of drawing a white ball is ½, but that the weight of the argument in favor of this conclusion is greater in the first case" [1921, p. 75]. In the spirit of Knight and Keynes, Ellsberg [1961] argued that people's willingness to act in the presence of uncertainty depends not only on the perceived probability of the event in question, but also on its vagueness or ambiguity. Ellsberg characterized ambiguity as "a quality depending on the amount, type, and 'unanimity' of information, and giving rise to one's degree of 'confidence' in an estimate of relative likelihoods" [p. 657].

The preference for the clear over the vague bet has been demonstrated in many experiments using several variations of Ellsberg's original problems (for a comprehensive review of the literature, see Camerer and Weber [1992]). As noted above, these observations provide evidence against the descriptive validity of expected utility theory. Furthermore, many authors have attempted to justify the preference for risk over ambiguity on normative grounds, although Raiffa [1961] has argued that ambiguity can be reduced to risk by tossing a coin to decide whether to guess red or black.

Ambiguity aversion has attracted much attention because, with the notable exception of games of chance, decision makers usually do not know the precise probabilities of potential outcomes. The decisions to undertake a business venture, to go to court, or to undergo medical treatment are commonly made in the absence of a clear idea of the chances that these actions will be successful. The question arises, then, whether the ambiguity aversion demonstrated using the Ellsberg urn applies to such decisions. In other words, is the preference for clear over vague probabilities confined to the domain of chance, or does it extend to uncertain beliefs based on world knowledge?

To answer this question, Heath and Tversky [1991] conducted a series of experiments comparing people's willingness to bet on their uncertain beliefs with their willingness to bet on clear chance events. Contrary to ambiguity aversion, they found that people prefer to bet on their vague beliefs in situations where they feel especially competent or knowledgeable, although they prefer to bet on chance when they do not. In one study, subjects were asked to choose among bets based on three sources of uncertainty: the results in various states of the 1988 presidential election, the results of various professional football games, and the results of random draws from an urn with a known composition. Subjects who were preselected for their knowledge of politics and lack of knowledge of football preferred betting on political events rather than on chance events that they considered equally probable. However, these subjects preferred betting on chance events rather than on sports events that they considered equally probable. Analogously, subjects who were preselected for their knowledge of football and lack of knowledge of politics exhibited the opposite pattern, preferring football to chance and chance to politics. Another finding that is consistent with Heath and Tversky's competence hypothesis but not with ambiguity aversion is people's preference to bet on their physical skills (e.g., throwing darts) rather than on matched chance events despite the fact that the perceived probability of success is vague for skill and clear for chance [Cohen and Hansel 1959; Howell 1971].

If ambiguity aversion is driven by the feeling of incompetence, as suggested by the preceding discussion, the question arises as to what conditions produce this state of mind. We propose that people's confidence is undermined when they contrast their limited knowledge about an event with their superior knowledge about another event, or when they compare themselves with more knowledgeable individuals. Moreover, we argue that this contrast between states of knowledge is the predominant source of ambiguity aversion. When evaluating an uncertain event in isolation, people attempt to assess its likelihood—as a good Bayesian would—paying relatively little attention to second-order characteristics such as vagueness or weight of evidence. However, when people compare two events about which they have different levels of knowledge, the contrast makes the less familiar bet less attractive or the more familiar bet more attractive. The main implication of this account, called the *comparative ignorance hypothesis,* is that ambiguity aversion will be present when subjects evaluate clear and vague prospects jointly, but it will greatly diminish or disappear when they evaluate each prospect in isolation.

A review of the experimental literature reveals a remarkable fact: virtually every test of ambiguity aversion to date has employed a within-subjects design in which respondents compared clear and vague bets, rather than a between-subjects design in which different respondents evaluated each bet. This literature, therefore, does not answer the question of whether ambiguity aversion exists in the absence of a contrast between clear and vague bets. In the following series of studies we test the hypothesis that ambiguity aversion holds in a comparative context (or a within-subjects design) but that it is reduced or eliminated in a noncomparative context (or a between-subjects design).

II. Experiments

Study 1

The following hypothetical problem was presented to 141 undergraduates at Stanford University. It was included in a questionnaire consisting of several unrelated items that subjects completed for class credit.

> Imagine that there is a bag on the table (*Bag A*) filled with exactly 50 red poker chips and 50 black poker chips, and a second bag (*Bag B*) filled with 100 poker chips that are red and black, but you do not know their relative proportion. Suppose that you are offered a ticket to a game that is to be played as follows: First, you are to guess a color (red or black). Next, without looking, you are to draw a poker chip out of one of the bags. If the color that you draw is the same as the one you predicted, then you will win $100; otherwise you win nothing. What is the most that you would pay for a ticket to play such a game for each of the bags? ($0–$100)

Bag A	*Bag B*
50 red chips	? red chips
50 black chips	? black chips
100 total chips	100 total chips

The most that I would be willing to pay for a ticket to *Bag A* (50 red; 50 black) is: ____
The most that I would be willing to pay for a ticket to *Bag B* (? red; ? black) is: ____

Approximately half the subjects performed the comparative task described above; the order in which the two bets were presented was counterbalanced. The remaining subjects performed a noncomparative task: approximately half evaluated the clear bet alone, and the remaining subjects evaluated the vague bet alone.

TABLE I
RESULTS OF STUDY 1

	Clear bet	Vague bet
Comparative	\$24.34 (2.21) $N = 67$	\$14.85 (1.80) $N = 67$
Noncomparative	\$17.94 (2.50) $N = 35$	\$18.42 (2.87) $N = 39$

Mean willingness to pay for each bet is presented in Table I. As in all subsequent tables, standard errors (in parentheses) and sample sizes (N) are listed below the means. The data support our hypothesis. In the comparative condition, there is strong evidence of ambiguity aversion: subjects were willing to pay on average \$9.51 more for the clear bet than for the vague bet, $t(66) = 6.00$, $p < 0.001$. However, in the noncomparative condition, there is no trace of ambiguity aversion as subjects paid slightly less for the clear bet than for the vague bet, $t(72) = -.12$, n.s. This interaction is significant ($z = 2.42, p < 0.01$).

Study 2

Our next study tested the comparative ignorance hypothesis with real money at stake. Subjects were recruited via signs posted in the psychology building at Stanford University, promising a chance to win up to \$20 for participation in a brief study. We recruited 110 students, faculty, and staff; six subjects were excluded because of inconsistent responses.

Subjects were run individually. Participants in the comparative condition priced both the clear bet and the vague bet. Half the subjects in the noncomparative condition priced the clear bet alone; the other half priced the vague bet alone. The clear bet involved a draw from a bag containing one red Ping-Pong ball and one green Ping-Pong ball. The vague bet involved a draw from a bag containing two Ping-Pong balls, each of which could be either red or green. Subjects were first asked to guess the color of the ball to be drawn. Next, they were asked to make a series of choices between receiving \$20 if their guess is correct (and nothing otherwise) or receiving \$X for sure. Subjects marked their choices on a response sheet that listed the various sure amounts (\$X) in descending order from \$19.50 to \$0.50 in steps of 50 cents. They were informed that some participants would be selected at random to play for real money. For these subjects, one choice would be selected at random, and the subjects would either receive \$X or play the bet, depending on the preference they had indicated. This procedure is incentive-compatible because subjects can only make themselves worse off by misrepresenting their preferences.

Cash equivalents were estimated by the midpoint between the lowest amount of money that was preferred to the uncertain bet, and the highest amount of money for which the bet was preferred. Mean cash equivalents are listed in Table II. The procedural variations introduced in this study (real bets, monetary incentive, individual administration) did not affect the pattern of results. In the comparative condition, subjects priced the clear bet \$1.21 higher on average than the vague bet, $t(51) = 2.70$, $p < 0.01$. However, in the noncomparative condition, subjects priced the vague bet slightly above the clear bet, $t(50) = -.61$, n.s. Again, the interaction is significant ($z = 1.90, p < 0.05$).

TABLE II
RESULTS OF STUDY 2

	Clear bet	Vague bet
Comparative	\$9.74 (0.49) $N = 52$	\$8.53 (0.58) $N = 52$
Noncomparative	\$7.58 (0.62) $N = 26$	\$8.04 (0.43) $N = 26$

Two comments regarding the interpretation of studies 1 and 2 are in order. First, subjects in both the comparative and noncomparative conditions were clearly aware of the fact that they did not know the composition of the vague urn. Only in the comparative task, however, did this fact influence their prices. Hence, ambiguity aversion seems to require a direct comparison between the clear and the vague bet; an awareness of missing information is not sufficient (cf. Frisch and Baron [1988]). Second, it is noteworthy that in both Studies 1 and 2, the comparative context enhanced the attractiveness of the clear bet somewhat more than it diminished the attractiveness of the vague bet. The comparative ignorance hypothesis, however, makes no prediction about the relative magnitude of these effects.

Study 3

In addition to the two-color problem described above, Ellsberg [1961] introduced a three-color problem, depicted in Table III. Consider an urn that contains ten white balls, and twenty balls that are red and blue in unknown proportion. In decision 1 subjects are asked to choose between f_1, winning on white ($p = 1/3$); or g_1, winning on red ($0 \leq p \leq 2/3$). In decision 2 subjects are asked to choose between f_2, winning on either white or blue ($1/3 \leq p \leq 1$), or g_2, winning on either red or blue ($p = 2/3$). As suggested by Ellsberg, people typically favor f_1 over g_1 in decision 1, and g_2 over f_2 in decision 2, contrary to the independence axiom of expected utility theory.

From the standpoint of the comparative ignorance hypothesis, this problem differs from the two-color problem because here the description of the bets (especially f_2) involves both clear and vague probabilities. Consequently, we expect some ambiguity aversion even in a noncomparative context in which each subject evaluates only one bet. However, we expect a stronger effect in a comparative context in which each subject evaluates both the clear and vague bets. The present study tests these predictions.

Subjects were 162 first-year law students at Willamette University who completed a short questionnaire in a classroom setting. Three subjects who violated dominance were excluded from the analysis. Subjects were informed that some people would be selected at random to be paid on the basis of their choices. The instructions included a brief description of an incentive-compatible payoff scheme (based on Becker, DeGroot, and Marschak [1964]).

TABLE III
ELLSBERG'S THREE-COLOR PROBLEM

		10 balls	20 balls	
	Bet	white	red	blue
Decision 1	f_1	\$50	0	0
	g_1	0	\$50	0
Decision 2	f_2	\$50	0	\$50
	g_2	0	\$50	\$50

Subjects were asked to state their minimum selling price for the bets displayed in Table III. In the comparative condition, subjects priced all four bets. In the noncomparative condition, approximately half the subjects priced the two complementary clear bets (f_1 and g_2), and the remaining subjects priced the two complementary vague bets (f_2 and g_1). The order of the bets was counterbalanced.

Let $c(f)$ be the stated price of bet f. As expected, most subjects in the comparative condition priced the clear bets above the vague bets. In particular, we observed $c(f_1) > c(g_1)$ for 28 subjects, $c(f_1) = c(g_1)$ for 17 subjects, and $c(f_1) < c(g_1)$ for 8 subjects, $p < 0.01$. Similarly, we observed $c(g_2) > c(f_2)$ for 36 subjects, $c(g_2) = c(f_2)$ for 12 subjects, and $c(g_2) < c(f_2)$ for 5 subjects, $p < 0.001$. Moreover, the pattern implied by ambiguity aversion (i.e., $c(f_1) \geq c(g_1)$ and $c(f_2) \leq c(g_2)$, where at least one inequality is strict) was exhibited by 62 percent of the subjects.

In order to contrast the comparative and the noncomparative conditions, we have added for each subject the selling prices of the two complementary clear bets (i.e., $c(f_1) + c(g_2)$) and the selling prices of the two complementary vague bets (i.e., $c(g_1) + c(f_2)$). Obviously, for subjects in the noncomparative condition, we can compute only one such sum. These sums measure the attractiveness of betting on either side of the clear and of the vague bets. The means of these sums are presented in Table IV. The results conform to expectation. In the comparative condition, subjects priced clear bets \$10.68 higher on average than vague bets, $t(52) = 6.23$, $p < 0.001$. However, in the noncomparative condition, the difference was only \$3.85, $t(104) = 0.82$, n.s. This interaction is marginally significant ($z = 1.37, p < 0.10$).

Inspection of the individual bets reveals that for the more probable bets, f_2 and g_2, there was a strong preference for the clear over the vague in the comparative condition ($c(g_2) = \$33.75$,

TABLE IV
RESULTS OF STUDY 3

	Clear bet	Vague bet
Comparative	\$55.60 (2.66) $N = 53$	\$44.92 (3.27) $N = 53$
Noncomparative	\$51.69 (2.94) $N = 54$	\$47.85 (3.65) $N = 52$

$c(f_2) = \$24.66, t(52) = 5.85, p < 0.001$) and a moderate preference for the clear over the vague in the noncomparative condition ($c(g_2) = \$31.67, c(f_2) = \$26.71, t(104) = 2.05, p < 0.05$). However, for the less probable bets, f_1 and g_1, we found no significant differences between selling prices for clear and vague bets in either the comparative condition ($c(g_1) = \$20.26, c(f_1) = \$21.85, t(52) = 1.05$, n.s.) or the noncomparative condition ($c(g_1) = \$21.13$, $c(f_1) = \$20.02, t(104) = 0.43$, n.s.). The aggregate pattern displayed in Table IV, therefore, is driven primarily by the more probable bets.

Study 4

In the preceding three studies, uncertainty was generated using a chance device (i.e., drawing a ball from an urn with a known or an unknown composition). Our next study tests the comparative ignorance hypothesis using natural events. Specifically, we asked subjects to price hypothetical bets contingent on future temperature in a familiar city (San Francisco) and an unfamiliar city with a similar climate (Istanbul). Ambiguity aversion suggests that our subjects (who were living near San Francisco) should prefer betting on San Francisco temperature, with which they were highly familiar, to betting on Istanbul temperature, with which they were not.

Subjects were asked how much they would be willing to pay to bet on each side of a proposition that offered a fixed prize if the temperature in a given city is above or below a specified value. The exact wording was as follows.

> Imagine that you have been offered a ticket that will pay you $100 if the afternoon high temperature in [San Francisco/Istanbul] is *at least* 60 degrees Fahrenheit one week from today. What is the most you would be willing to pay for such a ticket?
>
> The most I would be willing to pay is $____
>
> Imagine that you have been offered a ticket that will pay you $100 if the afternoon high temperature in [San Francisco/Istanbul] is *less than* 60 degrees Fahrenheit one week from today. What is the most you would be willing to pay for such a ticket?
>
> The most I would be willing to pay is $____

In the noncomparative condition one group of subjects priced the above two bets for San Francisco, and a second group of subjects priced the same two bets for Istanbul. In the comparative condition, subjects performed both tasks, pricing all four bets. The order of the events (less than 60 degrees/at least 60 degrees) and of the cities was counterbalanced. To minimize order effects, all subjects were asked before answering the questions to consider their best guess of the afternoon high temperature in the city or cities on which they were asked to bet.

Subjects were 189 pedestrians on the University of California at Berkeley campus who completed a five-minute survey (that included a few unrelated items) in exchange for a California lottery ticket. Ten subjects who violated dominance were excluded from the analysis. There were no significant order effects. Let $c(SF \geq 60)$ denote willingness to pay for the prospect "Win \$100 if the high temperature in San Francisco one week from today is at least 60 degrees," etc. As in Study 3 we added for each subject his or her willingness to pay for both sides of complementary bets. In particular, we computed $c(SF \geq 60) + c(SF < 60)$ for the San Francisco bets and $c(Ist \geq 60) + c(Ist < 60)$ for the Istanbul bets. Table V presents the means of these sums. The results again support our hypothesis. In the comparative condition subjects were willing to pay on average \$15.84 more to bet on familiar San Francisco temperature than on unfamiliar Istanbul temperature, $t(89) = 5.05, p < 0.001$. However, in the noncomparative condition subjects were willing to pay on average a scant \$1.52 more to bet on San Francisco than on Istanbul, $t(87) = 0.19$, n.s. This interaction is significant ($z = 1.68, p < 0.05$).

TABLE V
RESULTS OF STUDY 4

	San Francisco bets	Istanbul bets
Comparative	\$40.53 (4.27) $N = 90$	\$24.69 (3.09) $N = 90$
Noncomparative	\$39.89 (5.06) $N = 44$	\$38.37 (6.10) $N = 45$

The same pattern holds for the individual bets. In the comparative condition, $c(SF \geq 60) =$ \$22.74, and $c(Ist \geq 60) =$ \$15.21, $t(89) = 3.13$, $p < 0.01$. Similarly, $c(SF < 60) =$ \$17.79 and $c(Ist < 60) =$ \$9.49, $t(89) = 4.25, p < 0.001$. In the noncomparative condition, however, $c(SF \geq 60) =$ \$21.95, and $c(Ist \geq 60) =$ \$21.07, $t(87) = 0.17$, n.s. Similarly, $c(SF < 60) =$ \$17.94, and $c(Ist < 60) =$ \$17.29, $t(87) = 0.13$, n.s. Thus, subjects in the comparative condition were willing to pay significantly more for either side of the San Francisco proposition than they were willing to pay for the corresponding sides of the Istanbul proposition. However, no such pattern is evident in the noncomparative condition. Note that unlike the effect observed in Studies 1 and 2, the present effect is produced by the reduction in the attractiveness of the less familiar bet.

Study 5

We have interpreted the results of the preceding studies in terms of comparative ignorance. Alternatively, it might be argued that these results can be explained at least in part by the more general hypothesis that the difference between cash equivalents of prospects evaluated in isolation will be enhanced by a direct comparison between them. Such enhancement would apply whether or not the prospects in question involve different sources of uncertainty that vary with respect to familiarity or ambiguity.

To test this hypothesis, we recruited 129 Stanford undergraduates to answer a one-page questionnaire. Subjects were asked to state their maximum willingness to pay for hypothetical bets that offered $100 if the daytime high temperature in Palo Alto (where Stanford is located) on a particular day falls in a specified range. The two bets were described as follows:

> [A] Imagine that you have been offered a ticket that will pay you $100 if the afternoon high temperature *two weeks* from today in Palo Alto is *more than* 70 degrees Fahrenheit. What is the most you would be willing to pay for such a ticket?
> The most I would be willing to pay is $____
>
> [B] Imagine that you have been offered a ticket that will pay you $100 if the afternoon high temperature *three weeks* from today in Palo Alto is *less than* 65 degrees Fahrenheit. What is the most you would be willing to pay for such a ticket?
> The most I would be willing to pay is $____

Subjects in the comparative condition evaluated both [A] and [B] (the order was counterbalanced). Approximately half the subjects in the noncomparative condition evaluated [A] alone, and the remaining subjects evaluated [B] alone.

Because Palo Alto temperature in the springtime (when the study was conducted) is more likely to be above 70 degrees than below 65 degrees, we expected bet [A] to be generally more attractive than bet [B]. The enhancement hypothesis, therefore, implies that the difference between $c(A)$ and $c(B)$ will be greater in the comparative than in the noncomparative condition. The mean values of $c(A)$ and $c(B)$ are presented in Table VI. The results do not support the enhancement hypothesis. In this study, $c(A)$ was greater than $c(B)$. However, the difference $c(A) - c(B)$ was roughly the same in the two conditions (interaction $z = 0.32$, n.s.). In fact, there were no significant differences between the comparative and noncomparative conditions in the cash equivalents of either prospect ($t(87) = 0.53$ for A; n.s.; $t(85) = 0.48$ for B, n.s.). This pattern contrasts sharply with the results of the preceding studies (see especially Table V), that reveal substantially larger differences between stated prices in the comparative than in the noncomparative conditions. We conclude that the comparative ignorance effect observed in Studies 1–4 cannot be explained by the more general enhancement hypothesis.

TABLE VI
RESULTS OF STUDY 5

	Bet A	Bet B
Comparative	\$25.77 (3.68) $N = 47$	\$6.42 (1.84) $N = 47$
Noncomparative	\$23.07 (3.42) $N = 42$	\$5.32 (1.27) $N = 40$

Study 6

The comparative ignorance hypothesis attributes ambiguity aversion to the contrast between states of knowledge. In the first four studies we provided subjects with a comparison between more and less familiar events. In our final study we provided subjects with a comparison between themselves and more knowledgeable individuals.

Subjects were undergraduates at San Jose State University. The following hypothetical problem was included in a questionnaire containing several unrelated items that subjects completed for class credit.

> Kaufman Broad Homes (KBH) is one of the largest home sellers in America. Their stock is traded on the New York Stock Exchange.
>
> [1] Do you think that KBH stock will close higher or lower Monday that it did yesterday? (Circle one)
> - KBH will close higher.
> - KBH will close the same or lower.
>
> [2] Which would you prefer? (Circle one)
> - receive \$50 for sure
> - receive \$150 if my prediction about KBH is correct.

Subjects in the noncomparative condition ($N = 31$) answered the above questions. Subjects in the comparative condition ($N = 32$) answered the same questions with the following additional item inserted between questions 1 and 2.

> We are presenting this survey to undergraduates at San Jose State University, graduate students in economics at Stanford University, and to professional stock analysts.

Subjects were then asked to rate their knowledge of the item on a scale from 0 to 10.

The present account implies that the suggested comparison to more knowledgeable individuals (i.e., graduate students in economics and professional stock analysts) will undermine the subjects' sense of competence and consequently decrease their willingness to bet on their own judgment. The results support this prediction. The uncertain prospect of winning $150 was preferred to the sure payment of $50 by 68 percent of subjects in the noncomparative condition and by only 41 percent of subjects in the comparative condition, $\chi^2(1) = 4.66, p < 0.05$.

We replicated this effect using a different subject population (undergraduates at Stanford University enrolled in an introductory psychology course) and a different uncertain event. The following hypothetical problem was included in a questionnaire that contained several unrelated items that was completed for class credit.

> [1] Do you think that the inflation rate in Holland over the past 12 months is greater than or less than 3.0 percent? (Circle one)
> - *less than* 3.0 percent
> - *at least* 3.0 percent
>
> [2] Which of the following do you prefer? (Circle one)
> - receive $50 for sure
> - receive $150 if I am right about the inflation rate.

As before, subjects in the noncomparative condition ($N = 39$) evaluated the items above, and subjects in the comparative condition ($N = 37$) answered the same questions with the following additional item inserted between questions [1] and [2].

> We are presenting this survey to undergraduates in Psych 1, graduate students in economics, and to professional business forecasters.

Subjects were then asked to rate their knowledge of the item on a scale from 0 to 10.

The uncertain prospect was preferred to the sure payment by 38 percent of subjects in the noncomparative condition and by only 11 percent of subjects in the comparative condition, $\chi^2(1) = 7.74$,

$p < 0.01$. Thus, the tendency to bet on a vague event is reduced by a suggested comparison to more knowledgeable individuals. Note that the results of this study, obtained by the mere mention of a more expert population, should be distinguished from the finding of Curley, Yates, and Abrams [1986] that ambiguity aversion is enhanced when people anticipate that their decision will be evaluated by their peers.

Market Experiments

Before we turn to the implications of the present findings, the question arises whether the effects of ambiguity and comparative ignorance persist when decision-makers are given an opportunity to make multiple decisions in a market setting that provides incentives and immediate feedback. A positive answer to this question has been provided by Sarin and Weber [1993], who compared subjects' bids for clear and for vague bets in several experimental markets using sealed bid and double oral auctions. In one series of studies involving graduate students of business administration from Cologne University, the clear bet paid 100 Deutsche Marks (DM) if a yellow ball was drawn from an opaque urn containing ten yellow and ten white tennis balls, and nothing otherwise. The vague bet was defined similarly except that the subject did not know the proportion of yellow and white balls, which was sampled from a uniform distribution. In some studies, subjects traded both clear and vague bets in each market. In other studies, subjects traded clear bets in some markets and vague bets in other markets. Thus, all subjects evaluated both clear and vague bets. The comparative ignorance hypothesis predicts that (1) the clear bet will be generally priced above the vague bet, and (2) the discrepancy between the prices will be more pronounced when clear and vague bets are traded jointly than when they are traded separately. The data support both predictions. The difference between the average market price of the clear and the vague bets across both auction types (for the last trading period in experiments 11 through 14) was more than DM 20 in the joint markets and less than DM 5 in the separate markets. This effect was especially pronounced in the double oral auctions where there was no difference between the market price of the clear and the vague bets in the separate markets, and a substantial difference (DM 18.5) in the joint markets. Evidently, market setting is not sufficient to eliminate the effects of ambiguity and comparative ignorance.

III. Discussion

The preceding studies provide support for the comparative ignorance hypothesis, according to which ambiguity aversion is driven primarily by a comparison between events or between individuals, and it is greatly reduced or eliminated in the absence of such a comparison. We hasten to add that the distinction between comparative and noncomparative assessment refers to the state of mind of the decision-maker, which we have attempted to control through the experimental context. Of course, there is no guarantee that subjects in the comparative conditions actually performed the suggested comparison, or that subjects in the noncomparative conditions did not independently generate a comparison. In Ellsberg's two-color problem, for example, people who are presented with the vague urn alone may spontaneously invoke a comparison to a 50–50 urn, especially if they have previously encountered such a problem. However, the consistent results observed in the preceding studies suggest that the experimental manipulation was successful in inducing subjects to make a comparison in one condition but not in the other.

The comparative ignorance hypothesis suggests that when people price an uncertain prospect in isolation (e.g., receive $100 if Istanbul temperature one week from today exceeds 60 degrees), they pay little or no attention to the quality or precision of their assessment of the likelihood of the event in question. However, when people are asked to price this prospect in the context of another prospect (e.g., receive $100 if San Francisco temperature one week from today exceeds 60 degrees), they become sensitive to the contrast in their knowledge regarding the two events, and as a result price the less familiar or vaguer prospect lower than the more familiar or clearer prospect (see, e.g., Heath and Tversky [1991] and Keppe and Weber [forthcoming]). Similarly, an uncertain prospect becomes less attractive when people are made aware that the same prospect will also be evaluated by more knowledgeable individuals. Thus, ambiguity aversion represents a reluctance to act on inferior knowledge, and this inferiority is brought to mind only through a comparison with superior knowledge about other domains or of other people.

Theoretical Implications

The comparative ignorance effect violates the principle of procedure invariance, according to which strategically equivalent elicitation procedures should produce the same preference order (cf. Tversky, Sattath, and Slovic [1988]). In the preceding studies, the vague and clear bets were equally valued when priced in isolation, yet the latter was strictly preferred to the former when the two bets were priced jointly. Like other instances of preference reversal (see, e.g., Tversky and Thaler [1990]), a particular attribute (in this case knowledge of probabilities) looms larger in comparative than in noncomparative evaluation. However, the most noteworthy finding is not the illustration of a new variety of preference reversal, but rather the conclusion that the Ellsberg phenomenon is an inherently comparative effect.

This discrepancy between comparative and noncomparative evaluation raises the question of which preference should be considered more rational. On the one hand, it could be argued that the comparative judgment reflects people's "true" preferences and in the absence of comparison, people fail to properly discount for their ignorance. On the other hand, it might be argued that the noncomparative judgments are more rational, and that subjects are merely intimidated by a comparison with superior knowledge. As we see it, there is no compelling argument to favor one interpretation over the other. The rational theory of choice (or more specifically, the principle of procedure invariance) requires that the comparative and noncomparative evaluations will coincide, but the theory does not provide a method for reconciling inconsistent preferences.

What are the implications of the present findings for the analysis of individual decision-making? To answer this question, it is important to distinguish two phenomena that have emerged from the descriptive study of decision under uncertainty: source preference and source sensitivity [Tversky and Fox 1995; Tversky and Wakker forthcoming]. Source preference refers to the observation that choices between prospects depend not only on the degree of uncertainty but also on the source of uncertainty (e.g., San Francisco temperature versus Istanbul temperature). Source preference is demonstrated by showing that a person prefers to bet on a proposition drawn from one source than on a proposition drawn from another source, and also prefers to bet against the first proposition than against the second (e.g., $c(SF \geq 60) > c(Ist \geq 60)$, and $c(SF < 60) > c(Ist < 60)$; see Study 4 above). We have interpreted ambiguity aversion as a special case of source preference, in which risk is preferred to uncertainty, as in Ellsberg's examples.[1]

Source sensitivity refers to nonadditivity of decision weights. In particular, the descriptive analysis of decision under risk indicates that the impact of a given event on the value of a prospect is greater when it turns an impossibility into a possibility or a possibility into a certainty than when it merely makes an uncertain event more or less probable [Kahneman and Tversky 1979]. For example, increasing the probability of winning a fixed prize from 0 to 0.1 or 0.9 to 1.0 has a greater impact than increasing the probability from, say, 0.3 to 0.4 Tversky and Fox [1995] have further shown that this pattern, called bounded subadditivity, is more pronounced for uncertainty than for chance (i.e., for vague than for clear probabilities). In other words, people are less sensitive to uncertainty to chance, regardless of whether or not they prefer uncertainty than to chance. Thus, source preference and source sensitivity are logically independent.

The present experiments show that source preference, unlike source sensitivity, is an inherently comparative phenomenon, and it does not arise in an independent evaluation of uncertain prospects. This suggests that models based on decision weights or nonadditive probabilities (e.g., Quiggin [1982]; Gilboa [1987]; Schmeidler [1989]; Tversky and Wakker [forthcoming]) can accommodate source sensitivity, but they do not provide a satisfactory account of source preference because they do not distinguish between comparative and noncomparative evaluation. One might attempt to model the comparative ignorance effect using a contingent weighting approach [Tversky, Sattath, and Slovic 1988] in which the weight associated with an event depends on whether it is evaluated in a comparative or noncomparative context. The major difficulties with this, or any other attempt to model the comparative ignorance effect, is that it requires prior specification of the

1. Some authors have interpreted as ambiguity aversion the finding that people prefer to bet on a more reliable rather than on a less reliable estimate of a given probability p (e.g., Einhorn and Hogarth [1985]). This demonstration, however, does not establish source preference because it does not also consider the complements of the events in question. Hence, the above finding can be attributed to the fact that the subjective probability associated with the less reliable estimate of p is less extreme (i.e., closer to 0.5) than that associated with the more reliable estimate of p (see Heath and Tversky [1991, Table 4]). More generally, the oft-cited conclusion that people are ambiguity-averse for high probabilities and ambiguity-seeking for small probabilities is questionable because the demonstrations on which it is based do not properly control for variations in subjective probability.

decision-maker's sense of his or her competence regarding the event in question and the salience of alternative states of knowledge. Although these variables can be experimentally manipulated, as we did in the preceding studies, they cannot easily be measured and incorporated into a formal model.

Despite the difficulties in modeling comparative ignorance, it could have significant economic implications. For example, an individual who is knowledgeable about the computer industry but not about the energy industry may exhibit ambiguity aversion in choosing whether to invest in a high-tech startup or an oil exploration, but not when each investment is evaluated independently. Furthermore, the present account suggests that the order in which the two investments are considered could affect their valuation. In particular, the less familiar investment might be valued more when it is considered before rather than after the more familiar investment.[2] In light of the present analysis, recent attempts to model ambiguity aversion in financial markets (e.g., Dow, and Werlang [1991] and Epstein and Wang [1994]) may be incomplete because they do not distinguish between comparative and noncomparative evaluation. In particular, such models are likely to overestimate the degree of ambiguity aversion in settings in which uncertain prospects are evaluated in isolation (cf. Sarin and Weber [1993]). The role of comparative ignorance in economic transactions awaits further empirical investigation.

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2. Unpublished data, collected by Fox and Weber, showed that an unfamiliar prospect was priced lower when evaluated after a familiar prospect than when evaluated before that prospect.

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