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Recent Psychological Studies of Behavior under Uncertainty

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The purpose of this paper is to survey a portion of the experimental psychology literature; viz., reports of experiments concerning choice and decision making under uncertainty. Even within this area the coverage will be far from complete—the idea being to treat only work which is both likely to be of interest to economists and to be unfamiliar to them.

The discussion which follows will be directed towards three main points. First, the behavioral regularities reported by psychologists are real, well documented, and replicatable. Thus, if it is said that "individuals in situation x exhibit behavior y," then in general one can be sure that a large number of people have been placed in the given situation and have performed as indicated. Second, much of this work seems to indicate that the behavioral assumptions employed by economists are simply wrong. For instance, choices between gambles are frequently inconsistent. In gaming situations individuals consistently do not adopt obvious optimal strategies. There are substantial and systematic biases in the perception of uncertainty. Also, individuals use information inefficiently; in particular, Bayes' rule fails as a descriptive model. For a discussion of why economists should be concerned by these results see the author and Charles Plott. Third, while these results in principle could apply to the sorts of choices dealt with in economic models, it is not as yet established that they do. In fact, in some cases close analysis of the experimental setting suggests that the results reported are precisely those predicted by conventional economic theory.

I. Probability Learning Experiments

Of all the work in experimental psychology, probably the work best known to economists is that dealing with "probability learning." Though the details of the experiments vary, the basic idea is standard. A subject is shown a sequence of Bernoulli trials, and prior to each trial the subject is asked to predict the outcome of the next trial. In spite of differences in experimental design the behavior observed is generally the same: given a sequence of trials in which the events occur with probabilities p and $1 - p$, a subject attempting to predict each trial will tend to predict the two events in proportions p and $1 - p$. That is, the relative frequency of the subject's predictions match the probabilities of the events being predicted, though the optimal strategy is to always predict the most likely outcome. (See for example Lee Roy Beach et al.)

Morris Fiorina, who surveys the prior work, notes that in most of the experiments the trials were randomized within blocks, and the observed behavior is quite reasonable once this dependence is taken into account. Thus, the probability learning experiments provide little evidence against optimizing behavior. As Fiorina says, "If anything, subjects' perceptions of the state of the experimental world are more accurate than those of the experimenters" (p. 164).

II. Bayes' Rule and Related Matters

The experiments discussed in this section deal with the way individuals process information concerning uncertainty. One of the major questions studied is whether or not subjects revise their beliefs in accord with Bayes' rule. A large number of experiments have been reported and the general finding is that people either do not revise their opinions in that fashion, or if they do, they do not use the correct "objective" probabilities in their calculations.

Many laboratory experiments of the

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book-bag poker-chip variety have demonstrated what has been called conservatism (see Wesley DuCharme; Beach and James Wise; Ward Edwards; C. R. Peterson, DuCharme, and Edwards). There is a tendency to treat probabilities near zero or one as being too close to one-half while probabilities near one-half tend to be correctly measured. This behavior does not appear to be replicatable outside of laboratory surroundings and many of the rules of thumb and heuristics individuals use seem to have the opposite effect (see Baruch Fischhoff; W. C. Howells, 1971, 1972; Paul Slovic, Fischhoff, and Sarah Lichtenstein).

One of the more striking examples which suggests that Bayes' rule is not a good descriptive model was reported by Daniel Kahneman and Amos Tversky (1973) and Tversky and Kahneman (1974). Eighty-five subjects were given the following instructions:

> "A panel of psychologists have interviewed and administered personality tests to 30 engineers and 70 lawyers, all successful in their fields. On the basis of this information, thumbnail descriptions of the 30 engineers and 70 lawyers have been written. You will find on your forms five descriptions chosen at random from the 100 available. For each description, please indicate your probability that the person described is an engineer on a scale of 0 to 100." [1973, p. 241]

Another group of eighty-six subjects was given identical instructions except that the number of lawyers was changed to thirty and the number of engineers to seventy. Both groups were given the same five descriptions to judge, and then the following: "Suppose now that you are given no information whatsoever about an individual chosen at random from the sample. The probability that this man is one of the 30 [70] engineers in the sample of 100 is ___%" (1973, p. 241).

The results reported certainly do not conform to Bayes' rule. Both groups of subjects gave nearly the same posterior probabilities for each of the five descriptions in spite of the substantial change in the priors. This agreement was definitely not due to conservatism or a tendency to give probabilities equal to the prior probabilities. In fact for one of the five descriptions the median estimate of the probability that the man chosen was an engineer was around .05 for both groups of subjects and, for another of the descriptions, was around .95. In addition both groups made the "correct" response to the question quoted above. Perhaps the strangest result reported was the response to the following: "Dick is a thirty-year-old man. He is married with no children. A man of high ability and high motivation he promises to be quite successful in his field. He is well liked by his colleagues" (1973, p. 242). This description was intended to be neutral and apparently was judged so by the subjects. For both groups the median estimate was .50. Thus these subjects evaluated useless information and no information quite differently.

The hypothesis being explored in this work is that individuals make predictions based upon representativeness, and the descriptions presented were designed to test this idea. For example, one of the five descriptions was: "Jack is a forty-five-year-old man. He is married and has four children. He is generally conservative, careful, and ambitious. He shows no interest in political and social issues and spends most of his free time on his many hobbies which include carpentry, sailing, and mathematical puzzles. The probability that Jack is one of the 30 [70] engineers in the sample of 100 is ___%" (1973, p. 241). The results presented certainly do support the hypothesis that individuals judge by something like representativeness and ignore prior probabilities. The responses to the vacuous description and the fact that the subjects were reminded of the prior odds after each description was given are especially convincing. Nevertheless, this experiment has features that make the applicability of the findings to economic decisions doubtful. First, as is often the case, the subjects are not told the truth about the

random process being examined. Clearly, the thumbnail descriptions were not a random sample from the alleged population. The subjects' responses would agree with Bayes' rule only if they either "played the game" or believed the experimental instructions and thereby badly misperceived what was going on. Second, there is the difficulty of controlling the information given when verbal descriptions or situations are presented. Both of these difficulties could be taken care of by the use of actual balls in urns or book-bag poker-chip set ups.

For example, suppose one has two urns, one with four red balls and two white balls, and another urn with three of each color. A known randomizing device, possibly another urn or a spinner, could serve as a prior for choosing which urn to draw from. Suppose that samples of size six are drawn from one of the urns (with replacement of course). The representativeness hypothesis would seem to indicate that for samples composed of four red balls and two white balls, or three of each color, the estimated posterior odds should favor the indicated urn by more than the correct odds.

Finally there is also the question of incentives; it is not clear that Kahneman and Tversky's subjects had a positive incentive to give "correct" answers. The instructions included the following statement: "The same task has been performed by a panel of experts, who are highly accurate in assigning probability to the various descriptions. You will be paid a bonus to the extent that your estimates come close to those of the expert panel" (1973, p. 241). Thus there was an incentive to behave as the "experts" which may or may not be interpreted as attempting to give the right answer. In the ball-urn experiment, incentives can be handled by asking the subjects to guess which urn produced the sample and paying off if they guess correctly.

In fact I have run these types of experiments using economics students from several universities. The results suggest that the representativeness heuristic describes very well the behavior of financially unmotivated subjects and of financially motivated but inexperienced subjects. On the other hand the behavior of experienced subjects whose payments depend upon their decisions appears to be consistent with Bayes' theorem.

The difficulty of controlling the information conveyed in verbal presentations is shown by M. Hammerton. Ten subjects were given the following information:

> "1. A device has been invented for screening a population for a disease known as psylicrapitis.
> 2. The device is a very good one, but not perfect.
> 3. If someone is a sufferer, there is a 90 percent chance that he will be recorded positively.
> 4. If he is *not* a sufferer, there is a 1 percent chance he will be recorded positively.
> 5. Roughly 1 percent of the population has the disease.
> 6. Mr. Smith has been tested and the result is positive. The chance that he is in fact a sufferer is: ____. . . ." [p. 252]

The median response was 85 percent with an interquartile range of 10 percent. Only one of the ten subjects underestimated the probability (which is around one half). Fourteen groups of eight subjects were given the same information except that the order of statements 3, 4, and 5 was varied and sometimes certain of them dropped. The results of those experiments are summarized in Table 1. While it is not clear just how the subjects are determining their probability estimates, it certainly is clear that they are *not* being conservative and are not using Bayes' rule.

Finally a group of twenty subjects (housewives) was given a reworded version of statements 1 through 6. Statement 1 was changed to read: "A device has been invented for screening engine parts for internal cracks" (1973, p. 253). The remaining statements were altered accordingly. For the group the median ρ was 60 percent, the interquartile range was 40 percent and seven subjects underestimated. Comparing this latter group with the population reported in Table 1 showed that the difference in the median was significant at the .001 level.

TABLE 1

Group	Presentation for Statements 3,4,5	Median ρ Estimate	Number of Underestimates
1	3,4,5	.85	1
2	3,5,4	.86	0
3	4,3,5	.85	1
4	4,5,3	.82	2
5	5,3,4	.80	1
6	5,4,3	.80	1
7	4,5	.75	2
8	3,5	.80	1
9	3,4	.75	0
10	3	.75	1
11	4	.90	2
12	5	.85	2
13		.75	1
14	3,4,5	.85	0

Source: M. Hammerton.

Kahneman and Tversky present additional evidence in favor of the representativeness hypothesis and for other heuristics also, and some quite convincing evidence that many truths of mathematical statistics are not intuitive concepts even to individuals trained in these concepts (see also Tversky and Kahneman, 1971). In particular, regression effects (for example, sampling based upon the value of the dependent variable) and sampling variability are often misunderstood. For a survey of the psychological literature see Slovic, Fischhoff, and Lichtenstein. Louis Wilde provides a survey of the evidence concerning the behavior of consumers.

III. Inconsistency in Choice

There is a substantial amount of evidence that in certain types of situations people make choices which are in some sense inconsistent. For example, though economists almost always assume transitivity of individual preference orderings, psychologists have found experimental setups that lead some individuals to choose intransitively. In a classic paper Tversky demonstrated that certain individuals will persistently demonstrate intransitivity.

Consider the following pair of gambles.

A: with probability .99 win \$4.00;
with probability .01 lose \$1.00.

B: with probability .33 win \$16.00;
with probability .67 lose \$2.00.

Note that the expected values of these gambles differ by only one cent. There is an impressive amount of experimental evidence that suggests that the behavior described below is not only possible but indeed quite common.

An individual is allowed to choose one of the two gambles and knows that he will play the gamble of his choice. In this situation he chooses gamble *A*. Instead of being asked which gamble he "likes the best," he is asked how much he would pay for gamble *A* and how much for gamble *B*. He knows that he will pay the higher of the two bids and then play the gamble he has bought. In this situation his bids will not be "unreasonable," that is, he will not bid more than \$4 for *A* or more than \$16 for *B*, but his bid for *B* will be higher than his bid for *A*. Alternatively, if the individual had been given the rights to play the gambles and had been interrogated as to how much he would sell them for, his responses again would be reasonable and would indicate a preference for gamble *B*. In sum, this person would choose *A* over *B*, pay more for *B* than for *A*, and would be willing to sell *A* at a lesser price than *B*.

Lichtenstein and Slovic presented 173 subjects with twelve pairs of bets similar to that shown above. In each pair one bet had a high probability of winning (*P* bet) a small amount and the other had a smaller probability of winning a large amount (\$ bet). The subjects were asked for each pair which they preferred and later were asked to give selling prices. All bets were hypothetical. For 73 percent of the subjects "for every pair in which the *P* bet was chosen, the \$ bet later received a higher bid" (p. 48). In a second experiment 74 subjects were asked to give their choices and buying prices. The rate of reversals was lower than in the previous case, but still significant. As before, all the bets were hypothetical. In order to verify that the phenomenon was not due to a lack of incentives, a third experiment was conducted in which the bets were played. The subjects (14) made choices and subsequently gave selling prices for the various gambles.

These basic results have been replicated, including once at a Las Vegas casino (Lichenstein and Slovic; Harold Lindman).

Economic theory suggests a number of explanations (income effects, misspecified incentives, etc.) which could explain the observed behavior. It is possible, however, to design experiments that avoid these difficulties. The author and Plott report the results of two such experiments, and to our surprise we replicated the psychologists' results. It should be noted that the gambles used were especially selected to produce the intransitivity observed, and it is not claimed that the behavior applies generally or that it would be persistent in the money pump sense.

In conclusion many of the results reported by experimental psychologists should be of interest to economists. In some cases the results obtained raise serious questions concerning the descriptive validity of a number of the behavioral assumptions used in economic models. In many instances, however, the reported behavior is consistent with economic theory, and much of this literature can be seen as showing the power of the economists' model of economic agents.

REFERENCES

L. R. Beach and J. A. Wise, "Subjective Probability Revision and Subsequent Decisions," *J. Experim. Psychol.*, Sept. 1969, *81*, 561–65.

——— et al., "Probability Learning: Response Proportions and Verbal Estimates," *J. Experim. Psychol.*, Oct. 1970, *86*, 165–70.

W. M. DuCharme, "Response Bias Explanation of Conservative Human Inference," *J. Experim. Psychol.*, July 1970, *85*, 66–74.

W. Edwards, "Conservatism in Human Information Processing," in B. Kleinmuntz, ed., *Formal Representation of Human Judgement*, New York 1968.

M. P. Fiorina, "A Note on Probability Matching and Rational Choice," *Behav. Sci.*, Mar. 1971, *16*, 158–66.

B. Fischhoff, "Hindsight and Foresight: The Effect of Outcome Knowledge on Judgment under Uncertainity," *J. Experim. Psychol.: Hum. Percep. and Learning*, Aug. 1975, *1*, 288–99.

D. M. Grether and C. R. Plott, "Economic Theory of Choice and the Preference Reversal Phenomenon," *Amer. Econ. Rev.*, forthcoming.

M. Hammerton, "A Case of Radical Probability Estimation," *J. Experim. Psychol.*, Dec. 1973, *101*, 252–54.

W. C. Howells, "Uncertainty from Internal and External Sources: A Clear Case of Overconfidence," *J. Experim. Psychol.*, Aug. 1971, *89*, 240–43.

———, "Compounding Uncertainty from Internal Sources," *J. Experim. Psychol.*, Sept. 1972, *95*, 6–13.

D. Kahneman and A. Tversky, "On the Psychology of Prediction," *Psychol. Rev.*, July 1973, *80*, 237–51.

S. Lichtenstein and P. Slovic, "Reversals of Preference Between Bids and Choices in Gambling Decisions," *J. Experim. Psychol.*, July 1971, *89*, 46–55.

———, "Response-Induced Reversals of Preferences in Gambling: An Extended Replication in Las Vegas," *J. Experim. Psychol.*, Nov. 1973, *101*, 16–20.

H. R. Lindman, "Inconsistent Preferences among Gambles," *J. Experim. Psychol.*, Aug. 1971, *89*, 390–97.

C. R. Peterson, W. M. DuCharme, and W. Edwards, "Sampling Distribution and Probability Revisions," *J. Experim. Psychol.*, Feb. 1968, *76*, 236–43.

P. Slovic, B. Fischhoff, and S. Lichtenstein, "Behavioral Decision Theory," *Annual Rev. Psychol.*, 1977, *28*, 1–39.

A. Tversky, "Instransitivity of Preferences," *Psychol. Rev.*, Jan. 1969, *76*, 31–48.

——— and D. Kahneman, "Belief in the Law of Small Numbers," *Psychol. Bull.*, 1971, *76*, 105–110.

——— **and** ———, "Judgment under Uncertainty: Heuristics and Biases," *Science*, Sept. 27, 1974, *185*, 1124–31.

L. Wilde, "Consumer Behavior under Imperfect Information: A Survey of the Evidence," unpublished paper, Calif. Instit. Technology 1977.