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FROM SHAKESPEARE TO SIMON: SPECULATIONS—AND SOME EVIDENCE—ABOUT MAN'S ABILITY TO PROCESS INFORMATION

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Recent experimental evidence is marshalled in support of the position that man's limited memory, attention, and reasoning capabilities lead him to apply simple strain-reducing cognitive strategies for processing information when making judgments and decisions. These strategies portray decision processes in a manner quite different from traditional normative and descriptive models. In some situations, these strategies may produce good decisions; in others, they may lead to serious mistakes. Relevance of these findings for important "real-world" (i.e., non-laboratory) decisions is discussed.

> "What a piece of work is man.
> How noble in reason, how infinite in
> faculties, in form and moving how
> express and admirable, in action
> how like an angel. In apprehension how like
> a god. The beauty of the world,
> the paragon of animals. "
>
> William Shakespeare

I. Introduction

The general question that I wish to discuss today is whether man is capable of the kind of high-level information processing that is required for decision making in today's world.

The title of this paper was suggested by one of my favorite posters. It shows an individual in a gas mask surrounded by a cloud of polluted air, symbolic of the troubles that plague modern man. Adjacent to this picture is the quote from Shakespeare presented above. The poster obviously takes issue with Shakespeare's optimistic assessment of human intelligence—to the effect that we are noble in reason and infinite in faculties. I suspect that the designer of the poster would agree more with the following statement by another student of behavior, Herbert Simon:

> "The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the real world—or even for a reasonable approximation to such objective rationality [Simon, 1957; p. 198]."

Simon has long been skeptical about human intellectual capabilities. More than a decade and a half ago he proposed the principle of bounded rationality to describe man's limited capacity for rational thinking. He said,

> " . . . the first consequence of the principle of bounded rationality is that the intended rationality of an actor requires him to construct a simplified model of the real situation in order to deal with it. He behaves rationally with respect to this model, and such behavior is not even approximately optimal with respect to the real world. To predict his behavior we must understand the way in which this simplified model is constructed, and its construction will certainly be related to his psychological properties as a perceiving, thinking, and learning animal [Simon, 1957; p. 198]."

Simon's thinking about bounded rationality has been stimulated by basic psychological research in such areas as learning, memory, and perception. It is tempting to seek additional support for bounded rationality by pointing to the many catastrophes around us. For example, one can note that urban renewal programs have actually reduced the supply of low-cost housing in the U.S., that flood control measures have led to an increase in the yearly toll of flood damages, or that expressways have often added to traffic congestion instead of reducing it. However, these issues are quite complex and the role that improper information processing plays in the failure of our best-intended decisions remains unclear.

As an experimental psychologist, my own interest is in laboratory experiments that are designed to test various hypotheses about bounded rationality. If these experiments are anything more than mere academic exercises, we should eventually be able to link their results to specific examples of suboptimal decision making in the real world. In this paper, I'll try to describe some of these experiments and speculate about their implications for important decisions.

The research on information processing to be described below is organized around several basic questions of concern to a decision maker. First, he wonders what will happen or how likely it is to happen, and his use of information to answer these questions gets him involved in processes which we call inference, prediction, subjective probability, and diagnosis. He must also evaluate the worth of objects, and this often requires him to combine information from several component attributes of the object into an overall judgment. Finally, he is called upon to integrate his opinions about probabilities and values into the selection of some course of action. What is referred to as "weighing risks against benefits" is an example of the latter combinatorial process.

One discipline that has evolved to help the decision maker answer these basic questions is the field of statistics. However, in most of our judgments and decisions, we bypass formal statistical reasoning and act, instead, as "intuitive statisticians." There have been a number of recent studies pertaining to the adequacy of man's performance as an intuitive statistician. In general, these studies have uncovered some surprising and rather disturbing deficiencies in man's ability to think in probabilistic terms or to balance risks against benefits when making decisions.

II. Biased Judgments of Uncertain Events

Because of the importance of probabilistic reasoning to decision making, considerable effort has been devoted to studying how people perceive, process, and evaluate the probabilities of uncertain events. One basic conclusion from this research is that probabilistic judgments show large and consistent biases that are quite difficult to eliminate.

Understanding Random Sampling

The "law of small numbers." One example of man's inadequacy as an intuitive statistician comes from a study by Tversky and Kahneman (1971a), who analyzed the kinds of decisions psychologists make when planning their scientific experiments. Despite extensive formal training in statistics, psychologists usually rely upon their educated intuitions when they make their decisions about how large a sample of data to collect or whether they should repeat an experiment to make sure their results are reliable.

After questioning a number of psychologists about their research practices and after studying the designs of experiments reported in psychological journals, Tversky and Kahneman concluded that these scientists had seriously incorrect notions about the amount of error and unreliability inherent in small samples of data. They found that the typical psychologist gambles his research hypotheses on small samples without realizing that the odds against his obtaining accurate results are unreasonably high; second, he has undue confidence in early trends from the first few data points and in the stability of observed patterns of data. In addition, he has unreasonably high expectations about the replicability of significant results. Finally, he rarely attributes a deviation of results from his expectations to sampling variability because he finds a causal explanation for any discrepancy.

Tversky and Kahneman summarized these results by asserting that people's intuitions seemed to satisfy a "law of small numbers" which means that the "law of large numbers" applies to small samples as well as to large ones. The "law of large numbers" says that very large samples will be highly representative of the population from which they are drawn. For the scientists in this study, small samples were also expected to be highly representative of the population. Since his acquaintance with logic or probability theory did not make the scientist any less susceptible to these cognitive biases, Tversky and Kahneman concluded that the only effective precaution is the use of formal statistical procedures, rather than intuition, to design experiments and evaluate data.[1]

In a related study, this time using Stanford University undergraduates as subjects, Kahneman and Tversky (in press) found that many of these subjects did not understand the fundamental principle of sampling, namely, the notion that the error in a sample becomes smaller as the sample size gets larger. To illustrate, consider one of the questions used in this study.

> "A certain town is served by two hospitals. In the larger hospital about 45 babies are born each day, and in the smaller hospital about 15 babies are born each day. As you know, about 50% of all babies are boys. The exact percentage of baby boys, however, varies from

day to day. Sometimes it may be higher than 50%, sometimes lower.

"For a period of one year, each hospital recorded the days on which more than 60% of the babies born were boys. Which hospital do you think recorded more such days?

"Check one :

a) The larger hospital ______

b) The smaller hospital ______

c) About the same (i.e., # of days were within 5% of each other) ______."

About 24% of the subjects chose answer a, 20% chose b, and 56% selected c. The correct answer is, of course, b. A deviation of 10% or more from the population proportion is much more likely when the sample size is small.

Kahneman and Tversky concluded that "the notion that sampling variance decreases in proportion to sample size is apparently not part of man's repertoire of intuitions. For anyone who would wish to view man as a reasonable intuitive statistician such results are discouraging."

Judgments of Correlation and Causality

Next, let's look at another facet of statistical thinking—the perception of correlational relationships between pairs of variables. Correlation between two variables means that knowledge of one will enable you to predict the value of the other.

Chapman and Chapman (1969), studying a phenomenon they have labeled illusory correlation, have shown how one's prior expectation of a relationship between two variables can lead him to perceive correlation when it does not really exist. They found that most subjects learned to see what they expected to see even though there were no real correlations in the data they were shown. The Chapmans noted that in many decision situations an expert may be reinforced in his observations of illusory correlates by the reports of his colleagues, who themselves may be subject to the same illusion. Such agreement among experts is, unfortunately, often mistaken as evidence for the truth of the observation.

Several studies have investigated subjects' perceptions of correlation and causality in simple situations involving just two binary variables. Consider a 2 x 2 table in which variable A is the antecedent or input variable and B is the consequent or output variable and the small letters are the frequencies with which the levels of these variables occur together.

	B_1	B_2
A_1	$A_1B_1 = a$	$A_1B_2 = b$
A_2	$A_2B_1 = c$	$A_2B_2 = d$

A correlation or contingency exists between A and B to the extent that the probability of B_1 given A_1 differs from the probability of B_1 given A_2: that is, to the extent that $a/(a + b)$ differs from $c/(c + d)$. If B_1 is as likely to occur given A_2 as it is given A_1, there is no correlation between A and B.

Research indicates that subjects' judgments of contingency are not based on a comparison of $a/(a + b)$ versus $c/(c + d)$. For example, Smedslund (1963) had students of nursing judge the relation between a symptom and the diagnosis of a disease. He found that the judgments were based mainly on the frequency of joint occurrence of symptom and disease (cell a in the matrix), without taking the other three event combinations into account. As a result, the judgments were unrelated to actual contingency. Similar results were obtained by Jenkins and Ward (1965) and Ward and Jenkins (1965). Ward and Jenkins concluded:

> "In general . . . statistically naive subjects lack an abstract concept of contingency that is isomorphic with the statistical concept. Those who receive information on a trial by trial basis, as it usually occurs in the real world, generally fail to assess adequately the degree of relationship present [p. 240]."

A recent example in the newspaper illustrates several of the biases described above. A woman asked Abigail Van Buren the following question: "Dear Abby: Why do so many people say that marijuana is harmless? Our daughter began using it in January. She went on to mescaline in March, and was in a mental hospital in July." Abby replied that marijuana apparently can be destructive to some individuals and there is no way of knowing who can handle it and who cannot.

Thus we see that the woman who asked the question and Abby were both drawing an inference about the relationship between marijuana and later problems on the basis of a very small sample (1 case) that fell in cell <u>a</u> of the 2 x 2 table shown above.

<u>Heuristic Devices for Probability Estimation and Intuitive Prediction</u>

Several recent experiments by Kahneman and Tversky help demonstrate the kinds of heuristic devices for processing information that exemplify the struggle of a bounded intellect to cope with problems of uncertainty.

<u>Availability bias in judgments of probability.</u> The first heuristic is the use of "mental effort" or "mental availability" to evaluate probability. Tversky and Kahneman (1971b) found that one cue that we use when judging the probability of an event is the ease with which relevant instances of that event are imagined. Another cue is the number of such instances that are readily remembered. The availability of instances is affected by factors such as recency and imaginability, which may, but need not, bear any relation to the event's probability. For example, the letter k is three times as likely to appear as the third letter of an English word as the first letter, yet most persons judge it as more likely to be a first letter. Tversky and Kahneman hypothesize that, when people make this judgment, they try to think of words either beginning with k or having k as a third letter. It is easier to think of words that begin with k, and if we use that fact as a cue on which to base our intuitive probability estimates, these words will be perceived as more probable than words with k in

the third position. In general, the harder it is to recall or imagine instances of an event, the lower the judged probability of that event.

Dominance of individuating information in intuitive prediction. A second general heuristic for making judgments about uncertain events is a rather complicated device which Kahneman and Tversky (1972a,b) have called representativeness. Although representativeness manifests itself in many judgmental settings, we shall consider only one example—a problem of intuitive prediction studied by Kahneman and Tversky (1972b). The task was to judge the likelihood that an individual, Tom W. , is a graduate student in a particular field of specialization. The judges in this study were all graduate students in psychology. The only information they had available to them was the following brief description written several years earlier by a psychologist on the basis of some projective tests:

> "Tom W. is of high intelligence. although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally enlivened by somewhat corny puns and by flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to have little feel and little sympathy for other people, and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense.
>
> "Tom W. is currently a graduate student. Please rank the following nine fields of graduate specialization in order of the likelihood that Tom W. is now a student in that field. Let rank 1 be the most probable choice."
>
> ______ Business Administration
> ______ Computer Sciences
> ______ Engineering
> ______ Humanities and Education
> ______ Law
> ______ Library Sciences
> ______ Medicine
> ______ Physical and Life Sciences
> ______ Social Science and Social Work

In this particular study. the representativeness hypothesis predicted that people should rank the graduate programs on the basis of the similarity between the brief description and a typical student in each program. This is exactly what happened. Ratings of similarity and ratings of likelihood coincided almost exactly. What was remarkable here is that the prior probabilities, as determined by the base rates for these graduate programs, had no influence whatsoever upon the judgments. Computer Sciences and Engineering were judged to be the most probable fields for Tom W., even though these fields have relatively few students in them. This is especially surprising considering the fact that the judges recognized the thumbnail personality sketch as having little or no validity. In addition, all of these judges had been exposed to the notion of base-rate prediction in their statistical training, and they used the base rate in a condition where no other information was provided. The important result here is the apparent inability of subjects to integrate the similarity ordering with the base-rate information in a situation where base rate should have been predominant. In other words, the judges knew the description was of low validity and they knew that base rates differed, yet they were unable to put this knowledge into practice. As a result, their judgments did not properly reflect their underlying beliefs.

III. Problems in Integrating Information from Multiple Sources

The study just described illustrates the inability of judges to blend base rate information with individuating information in a problem of prediction. Next, I'd like to consider the integration of diverse sources of information into an overall judgment of worth or a decision about a course of action. Here, too, we find that difficulties in integrating information lead people to make judgments that are inconsistent with their underlying values and opinions.

The failure of one's decisions to appropriately reflect his personal values can be considered one of the most fundamental aspects of non-optimal decision making. One example of this comes from an experiment by Slovic and Lichtenstein (1968a). In this study, subjects were asked to indicate how much they would like to play various gambles. The attributes of the gambles, which had to be integrated into the overall judgment, were the gambles' probabilities of winning and losing and the winning and losing payoffs. The experiment was straightforward. One group of subjects rated the attractiveness of playing each gamble on a ten-point scale. A second group of subjects indicated the attractiveness of these same gambles by a method in which they put a price tag on each to indicate its worth to them. That is, they stated an amount of money such that they would be indifferent between playing the gamble and receiving the stated amount. In addition, some of the subjects in both of these groups indicated their subjective weightings for the four attributes of a gamble (i.e., probability of winning, probability of losing, amount to win, and amount to lose) by distributing 100 points over the set of attributes according to their feelings about the relative importance of each dimension. When subjects rated the attractiveness of a gamble, probability of winning was found to be the most important dimension. When they put a price on a gamble, attractiveness was determined by the gamble's payoffs. Yet subjects in both groups stated that they valued probability of winning as the most important attribute. Apparently, there was a failure to give proper consideration to this value when making the pricing responses.

Two later experiments (Lichtenstein & Slovic, 1971; 1972), one of which was conducted on the floor of the Four Queens Casino in Las Vegas, demonstrated a similar response-mode effect. Consider the following pair of gambles used in the Las Vegas experiment:

<u>Bet A</u>	<u>Bet B</u>
11/12 chance to win 12 chips	2/12 chance to win 79 chips
1/12 chance to win 24 chips	10/12 chance to lose 5 chips

where each chip could represent either 10¢, 25¢, $1, or $5.

Notice that Bet A has a much better chance of winning but Bet B offers a higher winning payoff. Subjects were shown many such pairs of bets. They were asked to indicate, in two ways, how much they would like to play each bet in a pair. First they made a simple choice, A or B. Later they were asked to assume they owned a ticket to play each bet, and they were to state the lowest price for which they would sell this ticket.

Presumably these selling prices and choices are both governed by the same underlying quality, the subjective attractiveness of each gamble.[2] Therefore, the subject should state a higher selling price for the gamble that he prefers in the choice situation. However, the results indicated that subjects often chose one gamble, yet stated a higher selling price for the other gamble. For the particular pair of gambles shown above, Bets A and B were chosen about equally often. However, Bet B received a higher selling price about 88% of the time. Of the subjects who chose Bet A, 87% gave a higher selling price to Bet B, thus exhibiting an inconsistent preference pattern.

What accounts for the inconsistent pattern of preferences among almost half the subjects? We have traced it to the fact that subjects use different cognitive strategies for setting prices than for making choices. Subjects choose Bet A because of its good odds, but they set a higher price for B because of its large winning payoff. Because the responses are inconsistent, it is obvious that at least one kind of response does not accurately reflect what the decision maker believes to be the most important attribute in a gamble.

A "compatibility" effect seems to be operating here. Since a selling price is expressed in terms of monetary units, subjects apparently found it easier to use the monetary aspects of the gamble to produce this type of response. Such a bias did not exist with the choices since each attribute of one gamble could be directly compared with the same attribute of the other gamble. With no reason to use payoffs as a starting point, subjects were free to use any number of strategies to determine their choices. In many cases, they relied primarily on the probabilities of winning and losing. When faced with their inconsistent decisions, many subjects had a very hard time changing either of their conflicting responses. They felt that the different strategies they used for each decision were appropriate. However, strict adherence to an inconsistent pattern of prices and choices can be termed irrational, since the inconsistent subject can be made to become a "money pump," easily led into purchasing and trading gambles in such a way that he continually loses money.

The overdependence on payoff cues when pricing a gamble suggests a general hypothesis to the effect that the compatibility or commensurability between a dimension of information and the required response affects the importance of that information in determining the response. This hypothesis was tested in a recent experiment (Slovic & MacPhillamy, 1972) in which we predicted that dimensions common to each alternative in a choice situation would have greater influence upon decisions than would dimensions that were unique to a particular alternative. We asked subjects to compare pairs of students and predict which would get the higher college Grade Point Average. The subjects were given each student's scores on two cue dimensions (tests) on which to base their judgments. One dimension was common to both students and the other was unique. For example, Student A might be described in terms of his scores on Need for Achievement and Quantitative Ability, while Student B might be described by his scores on Need for Achievement and English Skill. In this example, since Need for Achievement is a dimension common to both students, it should be weighted heavily. That is, a comparison between two students along the same dimension should be easier, cognitively, than a comparison between different dimensions, and this ease of use should lead to greater reliance on the common dimension. The data strongly confirmed this hypothesis. Dimensions were weighted more heavily when common than when they were unique attributes. Interrogation of the subjects after the experiment indicated that most did not wish to give more weight to common dimensions and were unaware that they had done so.

The message in these experiments is that the amalgamation of different types of information and different types of values into an overall judgment is a difficult cognitive process. In our attempts to ease the strain of processing information, we often resort to judgmental strategies that do an injustice to our underlying values.

IV. A Search for General Principles

Concreteness

Thus far, I've been describing some specific mechanisms that decision makers use to reduce the strain of integrating information. At present, we are searching for some more general principles to describe information-processing strategies. One such principle is the concept of "concreteness." Concreteness represents the general notion that a judge or decision maker tends to use only the information that is explicitly displayed in the stimulus object and will use it only in the form in which it is displayed. Information that has to be stored in memory, inferred from the explicit display, or transformed tends to be discounted or ignored.

The work on cue commensurability described above is congruent with this hypothesis. There is evidence from the literature on problem solving that also suggests it, see Bruner, Goodnow, and Austin (1956, p.237), for example.

The tendency to avoid transforming information prior to using that information is illustrated in the context of risk-taking decisions by two recent experiments. The first study, done by Slovic and Lichtenstein (1968b), was designed to test the hypothesis that the variance of outcomes in a gamble is an important determinant of the gamble's attractiveness. Specially-constructed gambles were used to manipulate variance without changing the probabilities and payoffs that were explicitly displayed to the subject. To illustrate this, Figure 1 shows a duplex bet and a standard bet that are termed parallel because they have the same stated probabilities and payoffs, namely .6 chance to win $2 and .4 chance to lose $2. Imagine that the circular discs in Figure 1 have spinners attached to them. When the spinner points to a section of the disc you win or lose the amount indicated adjacent to that section. To play a duplex bet, one must spin a pointer on both discs. Thus, one can win and not lose, lose and not win, both win and lose, or neither win nor lose. The duplex and its parallel standard bet differ in variance. If the subject plays the standard bet, he will either gain or lose $2. If he plays the duplex bet, he has a fairly high probability of breaking even. The duplex bet, therefore, has much less variance. We have found that most subjects perceived duplex bets and their parallel standard bets as equally attractive. This suggests that the judgments are based only upon the explicitly stated probabilities and payoffs. The characteristics of the underlying distribution for the duplex bet are apparently too subtle to exert any significant influence.

An experiment by Payne and Braunstein (1971), outlined in Figure 2, nicely complements the study just described. They used pairs of duplex gambles designed to have equal underlying distributions but different explicit probability values. Subjects had definite preferences for one member of such pairs over the other, again demonstrating the dominance of explicit information over information that must be transformed before it can be operated upon.

Anchoring and Adjustment

A second general notion that seems useful in describing how humans ease the strain of integrating information is a process called anchoring and adjustment. In this process, a natural starting point is used as a first approximation to the judgment, an anchor so to speak. This anchor is then adjusted to accommodate the implications of the additional information. Typically, the adjustment is a crude and imprecise one which fails to do justice to the importance of additional information.

One example of anchoring and adjustment comes from the experiment described earlier in which people had to attach monetary values to gambles to indicate the attractiveness of those gambles. We have found that, in making these judgments, people who find a gamble basically attractive use the amount to win as a natural starting point. They then adjust the amount to win downward to take into account the less-than-perfect chance of winning and the fact that there is some amount to lose as well. Typically, this adjustment is insufficient and that is why large winning payoffs lead people to set prices that are inconsistent with their choices.

A second example of anchoring and adjustment comes from studies by Alpert and Raiffa (1968) and by Tversky and Kahneman (1972). In both of these studies, subjects were given "almanac questions" such as the following:

> "How many foreign cars were imported into the U.S. in 1968?
>
> (a) Make a high estimate such that you feel there is only a 1% probability the true answer would exceed your estimate.
>
> (b) Make a low estimate such that you feel there is only a 1% probability the true answer would be below this estimate."

In essence, the subject is being asked to estimate an interval such that he believes there is a 98% chance that the true answer will fall within that interval. The spacing between his high and low estimates is his expression of his uncertainty about the quantity in question. We cannot say that this single pair of estimates is right or wrong. However, if he were to make many such estimates or if a large number of persons were to answer this question, we should expect the range between upper and lower estimates to include the truth about 98% of the time—if the subjective probabilities were valid. What is typically found, however, by Alpert and Raiffa and by Tversky and Kahneman, is that the 98% confidence range fails to include the true value from 40% to 50% of the time, across many subjects answering many kinds of almanac questions. In other words, subjects' confidence bands are much too narrow, given their state of knowledge. Alpert and Raiffa observed that this bias persisted even when subjects were given feedback about their overly-narrow confidence bands and urged to widen the bands on a new set of estimation problems.

These studies indicate that people believe they have a much better picture of the truth than they really do. Why this happens is not entirely clear. Tversky and Kahneman tentatively hypothesize that people approach these problems by searching for a calculational scheme or algorithm by which to estimate a best guess which they then adjust up and down to get a 98% confidence range. For example, in answering the above question, one might proceed as follows:

> “I think there were about 180 million people in the U.S. in 1968; there is about one car for every three people thus there would have been about 60 million cars; the lifetime of a car is about 10 years, this suggests that there should be about 6 million new cars in a year but since the population and the number of cars is increasing let's make that 9 million for 1968; foreign cars make up about 10% of the U.S. market, thus there were probably about 900,000 foreign imports; to set my 98% confidence band, I'll add and subtract a few hundred thousand cars from my estimate of 900,000."

Tversky and Kahneman argue that people's estimates assume the validity of their computational algorithms. However, there are two sources of uncertainty that plague these algorithms. First, there is uncertainty associated with every step in the algorithm and there is uncertainty about the algorithm itself. That is, the whole calculational scheme may be incorrect. It is apparently quite difficult to carry along these several sources of uncertainty and translate them intuitively into a 98% confidence band. Once the "best guess" is arrived at as an anchor (e.g. , the 900,000 figure above), the adjustments fail to do justice to the many ways in which this estimate could be in error.

Another recent study by Tversky and Kahneman (1972) demonstrates quite nicely the fact that adjustments tend to be insufficient. They asked subjects almanac questions such as "What is the percentage of people in the U.S. today who are age 55 or older?" They gave the subjects starting percentages that were randomly chosen and asked the subjects to adjust these starting points until they reached their best estimate. Because of insufficient adjustment, those whose starting points were too high ended up with higher estimates than those who started with a value that was too low.

An anchor serves the function of a register in which we store our first impressions or the results of our earlier calculations. Thus, anchoring is a natural strategy for easing the strain that information processing places upon our memory. Why adjustments from the anchor are typically insufficient is presently unclear. One possibility is that people stop adjusting too soon because they tire of the mental effort involved in adjusting. Another possibility is that the anchor point takes on a special salience and people feel that there is less risk in making estimates close to it than in deviating far from it.

V. Are Important Decisions Biased?

Experimental work, such as that just described, documents man's difficulties in weighing information and judging uncertainty. Do these difficulties persist outside the confines of the laboratory when the subject resumes the task of using familiar sources of information to make decisions that are personally important to him?

While there is little systematic evidence bearing on this question, there are reasons to believe that man's cognitive limitations will lead him to simplify the process of integrating information when making even the most important decisions.

The first argument in support of this statement is based upon the pervasiveness of the evidence on cognitive biases, across a wide variety of tasks, where intelligent individuals served as subjects, often under conditions designed to maximize motivation and involvement. For example, the subjects studied by Tversky and Kahneman (197la) were scientists, highly trained in statistics, evaluating problems with which they were familiar. Likewise, Alpert and Raiffa (1968) found it extremely difficult to reduce the biased confidence intervals in their subjects who were students in the advanced management program at a leading graduate school. In many of the experiments reported above, extreme measures were taken to maximize the subjects' motivation to be unbiased. When Lichtenstein and Slovic (1971) observed inconsistent patterns of choices and prices among college student subjects gambling for relatively small stakes, they repeated the study, with identical results, on the floor of a Las Vegas casino. It should be noted that their experiments involving selling price responses employed a rather elaborate procedure devised by Becker, De Groot, and Marschak (1964) to persuade the subject to report his true subjective value of the bet as his lowest selling price; any deviations from this strategy, any efforts to "beat the game," necessarily resulted in a game of lesser value to the subject than the game resulting when he honestly reported his subjective valuations. Tversky and Kahneman have also resorted to extreme measures to motivate their subjects to behave in an unbiased manner. The belief that man can behave optimally when it is worthwhile for him to do so gains little support from these studies. The sources of judgmental bias are cognitive, not motivational. They have a persistent quality not unlike that of perceptual illusions.

Furthermore, there are some hints, at least, of the consequences of man's information-processing limitations in many important decision situations. For example, Kates (1962) and Burton and Kates (1964) present data showing that overly simple judgmental processes and misperception of the probabilistic nature of the environment contribute to massive losses due to floods and other natural hazards. Examination of business decisions and governmental policy making suggests that, whenever possible, decision makers avoid uncertainty and the necessity of weighting and combining information or integrating conflicting values. For example, Woods (1966, p. 95) summarizes his observations of one business firm's investment strategy as follows:

> "In estimating the value to their company of a potential investment, the managers in the organizations studied are preoccupied with searching for a comparable prior investment rather than identifying the relevant variables and forecasting the underlying uncertainty. Uncertainty is avoided like the plague, while the certainty of historical information is accorded such a premium that it dominates the managers' mental processes completely."

Cyert and March (1963, p. 120) have also written about the avoidance of uncertainty by business firms:

> "Our studies, however, lead us to the proposition that firms will devise and negotiate an environment so as to eliminate the uncertainty. Rather than treat the environment as exogenous and to be predicted, they seek ways to make it controllable.
>
> ". . . one conspicuous means of control is through the establishment of an industry-wide conventional practices.
>
> "For example, prices are frequently set on the basis of conventional practice. With time, such variables as the rate of mark-up, price lines, and standard costing procedures become customary within an industry. The net result of such activity . . . is that an uncertain environment is made quite highly predictable."

Lindblom (1964) came to similar conclusions on the basis of his analysis of governmental policy making. He noted that administrators avoid the difficult task of taking all important factors into consideration and weighing their relative merits and drawbacks. Instead, they employ what he calls "the method of successive limited comparisons." This method simplifies decisions by comparing only those policies that differ in relatively small degree from policies already in effect. Thus it is not necessary to undertake fundamental inquiry into an alternative and its consequences: one need study only those respects in which the proposed alternative and its consequences differ from the status quo.

The decision makers studied by Cyert and March and Lindblom were also found to avoid long-range planning and forecasting. They preferred to take small steps and to monitor short-run feedback rather than to try to predict the consequences of a long-range move. Quite often, it took a crisis to force them to make new decisions. The avoidance of uncertainty, the avoidance of "weighing relative merits and drawbacks," crisis orientation, and the avoidance of long-range forecasting are just what one would expect, given what the laboratory studies indicate about our cognitive limitations.

The anchoring and adjustment mechanism that is so evident in experimental studies seems to crop up in many interesting real-world decisions as well. For example, a procedure frequently used by retail businessmen to set prices is to use the wholesale price of an item as an anchor and then add a fixed percentage mark-up to this base. In the area of budget making, it is common knowledge that the largest determining factor of the size of this year's budget is last year's budget, which essentially serves as an anchor. Wildavsky (1964, p. 15) makes the following comment:

> "Budgeting is incremental, not comprehensive. The beginning of wisdom about an agency budget is that it is almost never actively reviewed as a whole every year in the sense of reconsidering the value of all existing programs as compared to all possible alternatives. Instead, it is based on last year's budget with special attention given to a narrow range of increases or decreases. Thus the men who make the budget are concerned with relatively small increments to an existing base."

The anchoring and insufficient adjustment that Tversky and Kahneman observed with their almanac questions could well contribute to errors that plague projected cost estimates. For example, a recent congressional study team has noted that the cost of major weapons systems is running nearly 50% ahead of original estimates. In one case, the original estimate for 6 submarine rescue vehicles was 18 million dollars. The actual cost was close to 460 million dollars—a value that most certainly would have been viewed as impossible when the original estimates were made. This gigantic overrun, like many others, was blamed on a failure to foresee development problems. The moral seems to be that there are many ways our estimates can go wrong, and it is difficult to incorporate our uncertainty about these possible sources of error into our actual judgments.

Finally, I'd like to point out a particularly painful example of anchoring and insufficient adjustment from my own experience. A few years ago a colleague and I agreed to write a chapter for a book. After the project was completed, we were rummaging through our correspondence with the book's editor and were rather dismayed to note the string of optimistic projections and broken promises that is illustrated below:

History of the Chapter

On this date:	We promised it for this date:
Sept. 16, 1968	June 1969
May 1969	end of July 1969
Dec. 1969	end of Jan. 1970
Jan. 1970	April 1970
April 1970	end of June 1970
But we finally sent the first draft:	July 24, 1970

I'm sure many of you have had the same experience and we can take some small comfort in a study by Kidd (1970) showing that a similar thing happens when the Central Electricity Generating Board in England and Wales attempts to estimate how long it will take to overhaul its equipment.

VI. Some Concluding Comments

I'd like to conclude with some speculations about the implications of research on human cognitive limitations. Although the paper began with a quote from Shakespeare, Francis Bacon was perhaps more foresightful. He said, "We do ill to exalt the powers of the human mind, when we should seek out its proper helps." The research I've been describing certainly documents the urgent need for such proper helps, or decision aids as they are now called, but it also indicates that the development of such aids will not necessarily come easily. For example, the key element of many suggested procedures for aiding decision making is their emphasis on decomposing a decision problem into a number of more elementary problems. The decision maker is asked questions about specific probabilities and utilities and his subjective judgments form the input to a normative model which then tells him what decision to follow. But what is the best method of assessing these probabilities and utilities? We have observed that serious biases can creep into even the most elementary judgments. Knowing how these biases operate, however, will undoubtedly help us determine the most unbiased ways to elicit the decision maker's knowledge and beliefs.

It is interesting to speculate about why we have such great confidence in our intuitive judgments, in the light of the deficiencies that emerge when they are exposed to scientific scrutiny. For one thing, our basic perceptual motor skills are remarkably good, the product of a long period of evolution, and thus we can process sensory information with remarkable ease. This may fool us into thinking that we can process conceptual information with similar facility. Anyone who tries to predict where a baseball will land by calculating its impact against the bat, trajectory of flight, etc. will quickly realize that his analytic skills are inferior to his perceptual-motor abilities. Another reason for our confidence is that the world is structured in such a complex, multiply-determined way that we can usually find some reason for our failures, other than our inherent inadequacies—bad luck is a particularly good excuse in a probabilistic world. In many situations we get little or no feedback about the results of our decisions and, in other instances, the criterion for judging our decisions is sufficiently vague that we can't tell how poorly we are actually doing. Finally, when we do make a mistake and recognize it as such, we often have the opportunity to take corrective action—thus, we may move from crisis to crisis but, in between crises, we have periods of fairly effective functioning.

Man has faced decisions of great consequence, like those involving nuclear energy, only within his recent history. It might be argued that he has not had enough opportunity to evolve an intellect capable of dealing conceptually with information and uncertainty. He is essentially a trial-and-error learner and there is little evidence that he can change his ways even when errors will be quite costly (see, for example, Schrader, 1971). How does such a creature learn by experience, yet avoid catastrophe? A pessimist might advise him to take very small steps—small enough so that he can recover from the inevitable miscalculations. An optimist would reply that the technology of decision making will undoubtedly advance rapidly within the next decade. Perhaps an awareness of our limitations, coupled with sophisticated methods of decision analysis, will enable us to minimize many of the judgmental biases discussed in this paper.

I'm an optimist.

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Notes

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1. People are not always incautious when drawing inferences from samples of data. Under somewhat different circumstances they become quite conservative, responding as though data are much less diagnostic than they truly are (see Edwards, 1968).

2. Considerable effort was made to insure that the selling prices, like the choices, reflected only the attractiveness of the gambles and not extraneous motivational factors. For details, see the reports of the experiments.

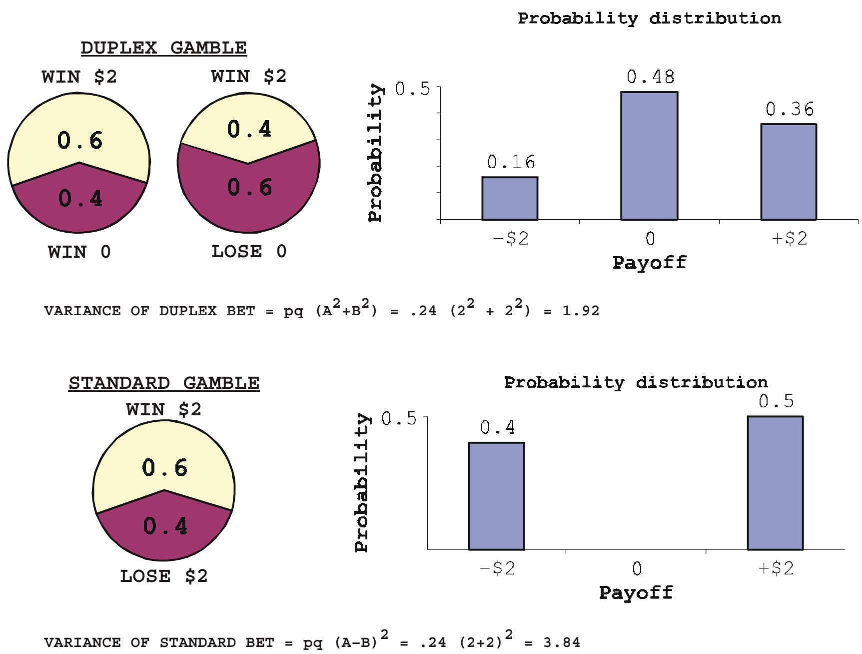

Figure 1. Comparison between parallel duplex and standard gambles.

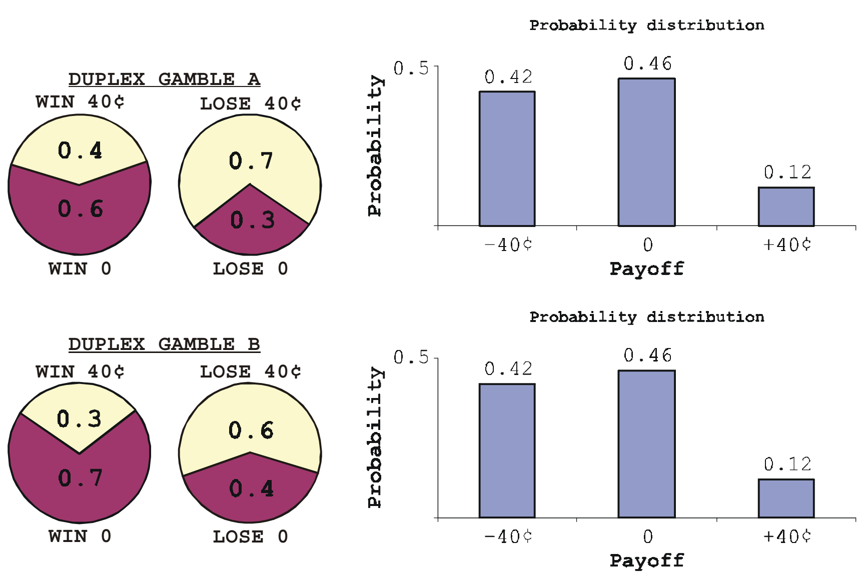

Figure 2. Comparison between pairs of duplex gambles by Payne and Braunstein.