TWELFTH RESEARCH CONFERENCE ON SUBJECTIVE PROBABILITY, UTILITY AND DECISION MAKING

MOSCOW, USSR
21 – 25 August

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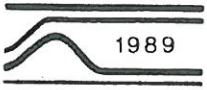

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P R O G R A M

TWELFTH RESEACH CONFERENCE ON SUBJECTIVE PROBABILITY, UTILITY AND DECISION MAKING

MOSCOW, USSR

1989

21-25 August

SPUDM is an international, interdisciplinary conference committed to improving the theory and practice of decision making. It is open to those who believe that schemes prescribing how people should make decisions need to incorporate knowledge about the way people actually do make decisions. Conversely, descriptive studies are believed relevant in so far they offer suggestions for making better decisions. The increased demand for practical methods to tackle complex decision problems requires careful examination of theoretical conceptions and hypotheses employed for justifying any method. The SPUDM conference attempts to do this in meetings held every second year in a different European city.

The conference in largely conducted in plenary sessions in order to discourage division of the field into narrow specialities, and to encourage participants to discover the relevance of others work to their own activities. Apart from (invited) special lecture and major papers, the conference will consist of presentations of specific papers, five different workshops, and some social events.

Katrin Borcherding
Istvän Kiss
Oleg I. Larichev
David M. Messick
Werner H. Tack
Stephen R. Watson

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Organizer: Baruch Fischhoff, USA

B. Modeling knowledge for intelligent decision support — room 8
Organizer: Patrick Humphreys, England and Helen Moshkovich, USSR

C. Process tracing and process models — room 9
Organizer: Ola Svenson, Sweden

D. Structuring decision analysis: Statistical and psychological consideration — room 356
Organizer: Peter Politser, USA

E. Negotiator cognition and rationality — room 357
Organizer: Margaret Neale, USA

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Organizer: Baruch Fischhoff, USA

B. Modeling knowledge for intelligent decision support — room 8
Organizer: Patrick Humphreys, England and Helen Moshkovich, USSR

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D. Structuring decision analysis: Statistical and psychological consideration — room 356
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E. Negotiator cognition and rationality — room 357
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X Wilma Otten & Charles Vlek, The Netherlands.
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Vladimir M. Ozernoy, USA.
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12.45 Closing of the Conference

13.00-14.30 Lunch

DECISION-MAKING THEORY AND REAL WORLD

J.M.Gvishiani
(Institute for Systems Studies, USSR)

Abstract

The value of conferences on subjective probability, utility and decision-making is determined to a large degree by their multidisciplinarity, attempts to regard decision-making problems from both descriptive and normative points of view. The interdisciplinary approach is suited to optimally reflect the specifics of the real world where lots of decisions that influence the destinies of thousands and millions of people are made every day.

In what degree can the modern theory and methodology of decision-making be useful to decision-makers - policy-makers, businessmen, administrators? The answer to this question is important to those engaged in both theory and practice.

My long experience as a man making responsible decisions and as a scientist developing the methodology of systems research helps me formulate my answer as follows. There exist tools of preliminary analysis of decision-making problems. These include both the systems approach methodology based on common sense and numerous mathematical techniques of data analysis and evaluation of alternative decisions. These tools are undoubtedly useful and one may feel sorry that not many of the decision-makers are aware of their utility.

The preliminary analysis may serve as the first application of decision-making methods. Throwing a critical glance over these techniques, one can point out that not many of them are consistent with the demands placed by real life. This critical look may help define the lines of future development of decision-making theory and methodology that should operate with both formalizable and nonformalizable factors reflecting the complexity of real decision-making processes.

Ambiguity and Confidence in Choice under Uncertainty

Amos Tversky and Chip Heath

Stanford University

Abstract

Action and belief are mediated by confidence: the willingness to bet on an uncertain event increases with the confidence in the assessment of the relevant context. Although confidence is correlated with belief or subjective probability, there are factors that influence confidence without affecting belief. In general, confidence is reduced by emphasizing relevant information that is not available to the decision maker, especially if it is available to others, and confidence is enhanced by personal knowledge of the relevant context, even if it does not improved predictive accuracy.

The confidence hypothesis is tested in a series of studies in which people can bet on the validity of their judgments or an equiprobable chance event. As predicted, people favored the chance bet when confidence was low, and they favored the judgment bet when confidence was high. This pattern was observed for general-knowledge as well as for the prediction of future political and sport events. Furthermore, people preferred to bet on their judgment in an area in which they considered themselves experts, and they preferred to bet on chance in an area in which they are less knowledgeable.

The confidence hypothesis can also explain the observed preference for betting on a chance event whose probability is known rather than unknown, on the future rather than on the past, and on skill rather than on chance. These observations, however, are at variance with the standard normative theory in which the choice between uncertain prospects depends on the degree of uncertainty, but not on its source.

Paper prepared for the twelfth research conference on subjective probability, utility and decision making, Moscow, August 1989.

The uncertainty we encounter in the world is not readily quantified. We may feel that our favorite football team has a good chance to win the championship match, that the price of gold will probably go up, and that the incumbent mayor is unlikely to be re-elected, but we are normally reluctant to assign numerical probabilities to these events. However, to facilitate communication and enhance the analysis of choice, we are sometimes asked to express our beliefs in numerical form. This task requires a mapping of an impression or a mental state into the language of chance. When we say that the chance of an uncertain event is 30%, for example, we express the belief that we consider this event to be as probable as the drawing of a red ball from a box that contains 30 red and 70 green balls. Does this thought experiment provide an adequate method for measuring belief or subjective probability? What tests can be performed to ensure the meaningfulness of these numbers?

Aside from reliability and internal consistency, proper subjective probabilities must satisfy an additional assumption, which may be called *source independence*. This condition says that if the judged probability of an uncertain event E is P, then the decision maker should be as willing to bet $X on the occurrence of E or on the drawing of a red ball from a box in which the proportion of red balls is P. Consequently, preferences between risky prospects depend on the degree of uncertainty but not on its source, at least for neutral events. (This need not hold for non-neutral events such as the victory of one's favorite football team.) The assumption of source independence is implicit in the work of Ramsey (1931) and Savage (1954) that provides the foundation for the modern theory of utility and subjective probability.

Source independence has been challenged by Daniel Ellsberg (1961; see also Fellner, 1961) who constructed a compelling demonstration of what has come to be called an ambiguity effect. The simplest demonstration of an ambiguity effect involves two boxes: one contains 50 red balls and 50 green balls, whereas the second contains 100 red and green balls in unknown proportion. You draw a ball blindly from a box and guess its color. If your guess in correct, you win $20, otherwise you get nothing. On which box would you rather bet? Ellsberg argued that people prefer to bet on the 50/50 box than on the box with the unknown composition, even though they have no color preferences so they are indifferent between betting on red or on green in either box. This pattern of preferences, which has been later demonstrated in many experiments, violates the additivity of probability assumed in expected utility theory because it implies that the sum of the probabilities of red and of green must be higher in the 50/50 box than in the unknown box.

Ellsberg's work has generated a great deal of interest for two reasons. First, it violates source independence, and provides a compelling counter-example to expected utility theory within the context of games of chance. Second, it suggests the general hypothesis called ambiguity aversion, that people prefer to bet on clear than on vague events, at least for moderate and high probability. Most decisions in the real world depend on uncertain events whose probabilities cannot be precisely assessed. This is especially true for probabilities based on intuitive judgment that are generally approximate and vague. If expected utility theory cannot accommodate vague probabilities, its applicability is severely limited. Indeed, several authors have extended the theory by invoking nonadditive measures of belief, and second-order probability distributions in order to account for the effect of ambiguity. The normative status of these models is a

subject of a lively debate. Several authors, notably Ellsberg (1963), maintain that aversion to ambiguity can be justified on normative grounds, although Raiffa (1961) has shown that it can lead to incoherence.

Ellsberg's example and most of the experimental demonstrations that followed his work are confined to chance processes, such as drawing a ball from a box. The potential significance of this phenomenon, however, stems from its relevance to the evaluation of inconclusive evidence. This raises the question of whether ambiguity aversion hold for judgmental probabilities that reflect an evaluation of evidence rather than considerations of symmetry or total ignorance. We found no direct test of this hypothesis, but there are three lines of evidence indicating that aversion to ambiguity may not apply to judgmental probabilities.

First, Budescu, Weinberg, and Wallsten (1986) compared the cash equivalents of gambles whose probabilities were expressed numerically, graphically, or verbally. In the graphical display, probabilities were presented as the shaded area of a circle. In the verbal form, probabilities were described by expressions such as "very likely" or "highly improbable". Because the verbal and the graphical forms are more ambiguous than the numerical form, ambiguity aversion implies a preference for the numerical over the other displays. This prediction was not confirmed. Subjects priced the gambles roughly the same in all three displays. Second, Cohen and Hansel (1959), and Howell (1971) investigated subjects' choices between compound gambles involving both skill and chance components. For example, the subject has to hit a target with a dart (on which the subject's hit rate = 75%) and spin a roulette wheel so that it will land on a marked section comprising 40% of the area. This bet involves a 75% skill and 40% chance with an overall probability of winning of $.75 \times .4 = .3$. Howell (1971) varied the skill and

chance components of the gambles, holding the overall probability of winning constant. Because the chance level was known to the subject whereas the skill level was not, ambiguity-aversion implies that subjects would shift as much uncertainty as possible to the chance component of the gamble. In contrast, 87% of the choices reflect a preference for skill over chance. Cohen and Hansel (1959) obtained essentially the same results. Further evidence against ambiguity-aversion hypothesis comes from studies of calibration (see, Lichtenstein, Phillips & Fischhoff, 1982, for a review), which compare people's stated probability in the validity of their predictions with their actual hit rate. In order to validate the numerical prediction, a few investigators offered subjects an opportunity to bet either on the validity of their predictions or on a chance event with the same probability. Because the intuitive estimates are vague, ambiguity-aversion implies a preference for betting on the box than on one's estimate. The data do not confirm this prediction and the two types of bets are selected equally often (see, e.g., Dunning, Milojkovic and Ross, 1989).

The Confidence Hypothesis

The preceding results indicate that the aversion to ambiguity observed in a chance setup (involving aleatory uncertainty) is not readily applicable to judgmental probabilities (involving epistemic uncertainty). Furthermore, the data suggest that the willingness to bet on an uncertain event depends on factors other than ambiguity. In this article, we investigate an alternative account, which applies to both chance and evidential contexts. Belief and action, we submit, are mediated by confidence. We are willing to act on beliefs that are held with confidence and we are reluctant to bet on propositions in which we have doubt. In general, confidence reflects

belief or subjective probability but the correlation between them is not perfect. There are factors that increase or decrease confidence without affecting the assessment of likelihood. Ellsberg's example is a case in point. Although the probability of drawing a red ball is one-half for both boxes (by symmetry), people feel more confident in their assessment when the composition of the box is known. More generally, confidence is reduced by emphasizing relevant data (e.g., the proportion of red balls in the unknown box) that is not available to the decision maker. People are particularly reluctant to act in situations where others have information that they do not have. The fact that the composition of the box is known to the experimenter but not to the subject reduces the subject's confidence and makes the 50/50 box even more attractive. This hypothesis is consistent with the finding of Curley, Yates and Abrams (1986) that the aversion to ambiguity is enhanced by the anticipation that the content of the unknown box will be shown to others.

The confidence hypothesis can also explain the preference for betting on future rather than on past events. Following a hypothesis attributed to Beveles, Rothbart and Snyder (1970) asked subjects to roll a die and bet on the outcome either before the die was rolled or after the die was rolled but before the result was revealed. The subjects who predicted the outcome before the die was rolled expressed greater confidence in their guesses than the subjects who postdicted the outcome after the die roll. The prediction group also bet significantly more money than the postdiction group. The authors attributed this phenomenon to magical thinking, the belief that the subjects can exercise some control over the outcome before, but not after, the roll of the die. However, the preference to bet on future rather than chance events is observed even when magical thinking is unlikely, as illustrated by the following problem in which subjects were presented with a choice between the two bets:

a) A stock is selected at random from the Wall Street Journal. You guess whether it will go up or down tomorrow. If you're right, you win $5.

b) A stock is selected at random from the Wall Street Journal. You guess whether it went up or down yesterday. You cannot check the paper. If you're right you win $5.

Sixty-seven percent of the subjects (N=184) preferred to bet on tomorrow's closing price than on yesterday's closing price. (Ten participants, selected at random, actually played their chosen bet.) The confidence hypothesis implies that people have more confidence in prediction than in postdiction (even though they do not know more about the future than about the past in this case) because the past -- unlike the future -- is knowable. There are more ways of being wrong in postdiction than in prediction. The same applies to Ellsberg's example. In the 50/50 box, a guess could turn out to be wrong only after drawing the ball. In the unknown box, on the other hand, the guess may turn out to be mistaken even before the drawing of the ball -- if it turns out that the majority of balls in the box are of the opposite color.

The confidence hypothesis can also account for the preference to bet on skill rather than on chance observed by Cohen and Hansel (1959), and by Howell (1971). Confidence is determined by one's knowledge and competence. The more skillful and knowledgeable we feel, the greater our confidence in our action. As a consequence, people prefer to bet on their skill or knowledge if they consider themselves competent, and they prefer to bet on chance if they feel they do not have the relevant knowledge or skill. (The preference to bet on one's knowledge is reminiscent of the observation of March and Shapira (1987) that many top managers do not regard their decisions as gambles, even though they are surely aware of many potential risks. Evidently, people feel more confident when they act on their judgment, in the area of their expertise, than on a matched chance bet.)

The present account may be summarized as follows: (a) the willingness to act on an uncertain belief increases with the confidence people have in their assessment of the situation, (b) confidence and belief are not perfectly correlated, and there are factors that influence confidence without affecting belief, (c) confidence is reduced by emphasizing relevant information that is not available to the decision maker, especially if it is available to others, (d) confidence is enhanced by personal knowledge of the situation, especially if it is not available to others, even when it does not improve predictive accuracy. This account is tested in the following series of studies that employ an uncertainty-preference paradigm. In this paradigm, subjects first assess the probability of various events and are then offered a choice between betting on the validity of their judgments or on a matched chance lottery, which offers the same probability of getting the same reward.

Study 1: Betting on Knowledge

Subjects answered 30 knowledge questions in two different categories, such as, history, geography, sport. Four alternative answers were presented for each question, and the subject first selected an answer and then rated his or her confidence in the answer on a scale from 25% (pure guessing) to 100% (absolute certainty). Participants were given detailed instructions about the definition of the scale and the idea of calibration. Specifically, they were told to use the scale so that a confidence rating of 60%, say, will correspond to a hit rate of 60%. They were also told that these ratings would be the basis for a money-making game, and warned that both underconfidence and overconfidence would reduce their earnings.

After answering the questions and assessing confidence, subjects were given an opportunity to choose between betting on their answers or on a lottery in which the probability of winning was equal to their stated confidence. For a confidence rating of 75%, for example, the subject was given the choice between (i) betting that his or her answer was correct, or (ii) betting on a 75% lottery, defined by drawing a numbered chip in the range 1-75 from a bag filled with 100 numbered poker chips. For half of the questions, lotteries were directly equated to confidence ratings. For the other half of the questions, subjects chose between the complement of their answer (betting that an answer other than the one they chose is correct) or the complement of their confidence rating. Thus, if a subject chose answer "A" with confidence of 65%, the subject could choose between betting that one of the remaining answers "B", "C", or "D" is correct, or betting on a 100% – 65% = 35% lottery.

Two groups of subjects participated in the study. One group (N=29) included psychology students who received course credit for participation. The second group (N=26) was recruited from introductory economic classes and performed the experiment for cash earnings. To determine the subjects' payoffs, ten questions were selected at random, and the subjects played out the bets they had chosen. If subjects chose to gamble on their answer, they collected $1.50 if their answer was correct. If subjects chose to bet on the chance lottery, they drew a chip from the bag and collected $1.50 if the number on the chip fell in the proper range and nothing otherwise. Average earnings for the experiment were around $8.50.

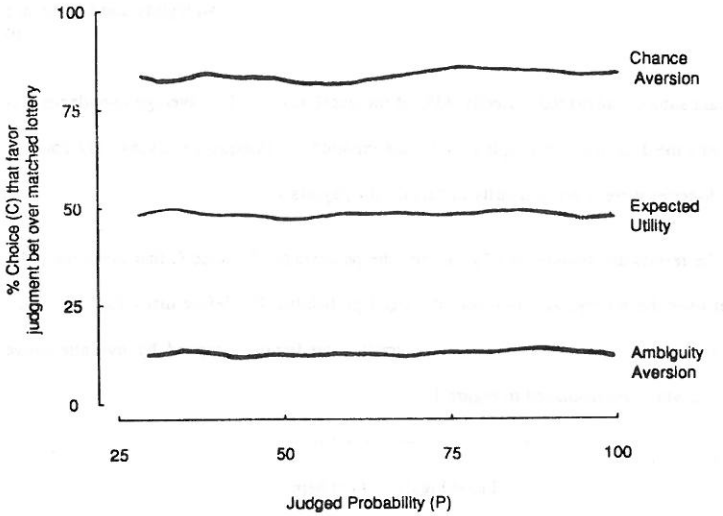
Paid subjects took more time than unpaid subjects in selecting their answers and assessing confidence; they were slightly more accurate. Both groups exhibited overconfidence: the paid subjects answered correctly 47% of the questions and their average confidence was 60%.

The unpaid subjects answered correctly 43% of the questions and their average confidence was 53%. (Only the data from the simple lotteries are reported in subsequent analyses. The complementary lotteries were added primarily to balance the payoffs.)

The results are summarized by plotting the percentage of choice C that favor the judgment bet over the lottery, as a function of judged probability P. Before discussing the actual data, it is instructive to examine several contrasting predictions, implied by five alternative hypotheses, which are displayed in Figure 1.

Insert Figure 1 about here

The upper panel of Figure 1 displays the predictions of three hypotheses in which C is independent of P. According to expected utility theory, decision makers will be indifferent between betting on their judgment or betting on a chance lottery, hence C should equal 50% throughout. Ambiguity aversion implies that people will prefer to bet on a chance event whose probability is well defined than on their judged probability, which is inevitably vague, hence C should fall below 50% everywhere. The complementary hypothesis, called chance aversion, predicts that people will prefer to bet on their judgment than on a matched chance lottery, hence C should exceed 50% for all P. In contrast to the flat predictions displayed in the upper panel, the two hypothesis in the lower panel imply that C depends on P. The regression hypothesis states that the decision weights, which control choice, will be regressive relative to stated probabilities. Thus, C will be relatively high for small probabilities, and relatively low for high proba-



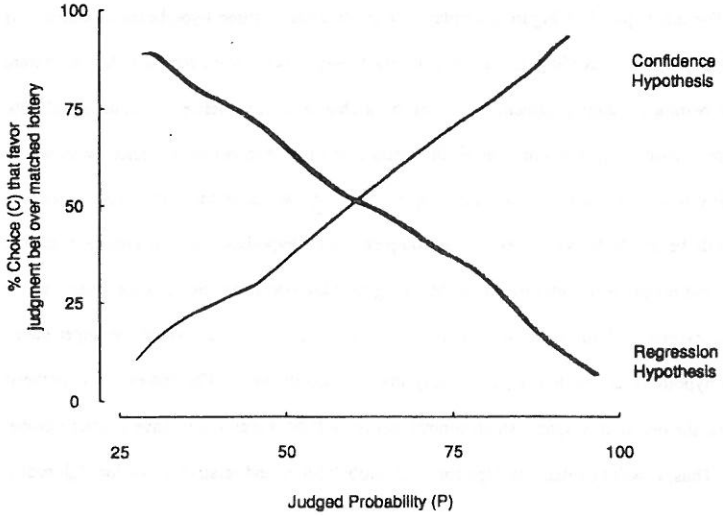


Figure 1. Five contrasting predictions of the results of an uncertainty preference experiment.

bilities. This prediction also follows from the theory put forth by Einhorn and Hogarth (1985). These authors hypothesized a particular process model based on mental simulation, adjustment and anchoring but their predictions coincide with the regression hypothesis. Finally, the confidence hypothesis, introduced in this paper, implies that people will tend to bet on their judgment when their confidence is high, and on the chance lottery when their confidence is low. As a consequence, C will be an increasing function of P, except at 100% where the chance lottery amounts to a sure thing.

Insert Figure 2 about here

Insert Table 1 about here

The results of the study are summarized in Table 1 and Figure 2. Table 1 presents, for three different ranges of P, the percentage of paid and non-paid subjects who bet on their answers rather than on the matched lottery. Recall that each question had four possible answers so the lowest confidence level is 25%. Figure 2 displays the overall percentage of choices C that favored the judgment bet over the lottery as a function of judged probability P. (In this and all subsequent figures, we plot the isotone regression of C on P. That is, the best-fitting monotone function in the least squares sense, see Barlow, Bartholomew, Brimmner & Brunk, 1972). The graph shows that the subjects chose the lottery when P was low or moderate (below 65%), and

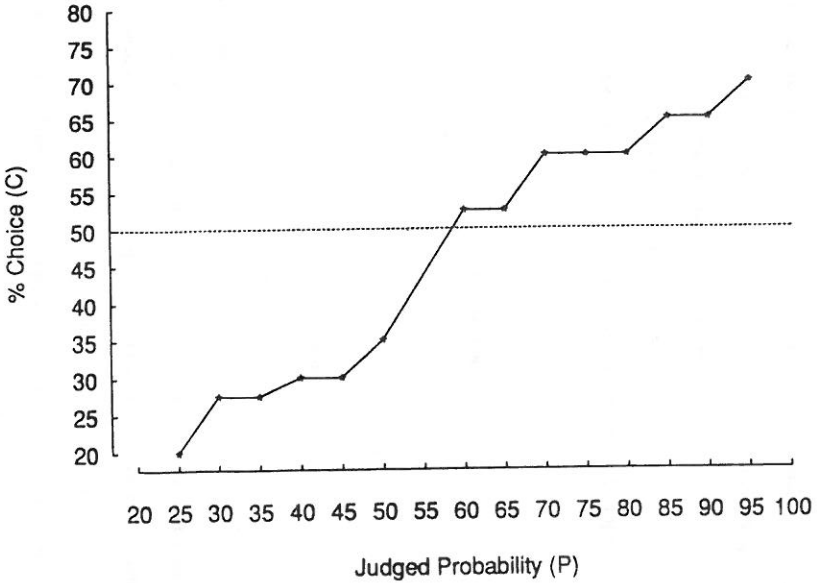


Figure 2. Percentage of choices C that favor a judgment bet over a matched lottery as a function of judged probability P (Study 1).

Table 1. Percentage of paid and non-paid subjects who preferred the judgment bet over the lottery for low, medium and high P. The number of observations are given in parenthesis.

	$25 \leq P \leq 50$	$50 < P < 75$	$75 \leq P \leq 100$
Paid	29 (278)	42 (174)	55 (168)
Non-paid	22 (394)	43 (188)	69 (140)

that they chose to bet on their answers when P was high. The pattern of results was the same for the paid as for the non-paid subjects but the effect was slightly stronger for the latter group. These results confirm the confidence hypothesis and reject the four alternative accounts, notably the ambiguity aversion hypothesis, implied by second-order probability models (e.g., Gärdenfors and Sahlin, 1982), and the regression hypothesis, implied by the model of Einhorn and Hogarth (1985). We shall discuss these models further in the last section.

To obtain a statistical test of the confidence hypothesis we computed, separately for each subject, the binary correlation coefficient (ϕ) between choice (judgment bet vs. lottery) and judged probability (above .65 vs. below .65). Seventy-two percent of the subjects yielded positive coefficients and the average ϕ was .30, ($t(54) = 4.3$, $p < .01$). To investigate the robustness of the observed pattern, we replicated the study with one major change. Instead of constructing chance lotteries whose probabilities matched the values stated by the subjects, we constructed lotteries in which the probability of winning was either 6% higher or 6% lower than the subjects' judged probability. For high-knowledge questions ($P \geq 75\%$), the majority of responses (70%) favored the judgment bet over the lottery even when the lottery offered a (6%) higher probability of winning. Similarly for low confidence questions ($P \leq 50\%$), the majority of responses (52%) favored the lottery over the judgment bet even when the former offered a lower (6%) probability of winning.

Insert Figure 3 about here

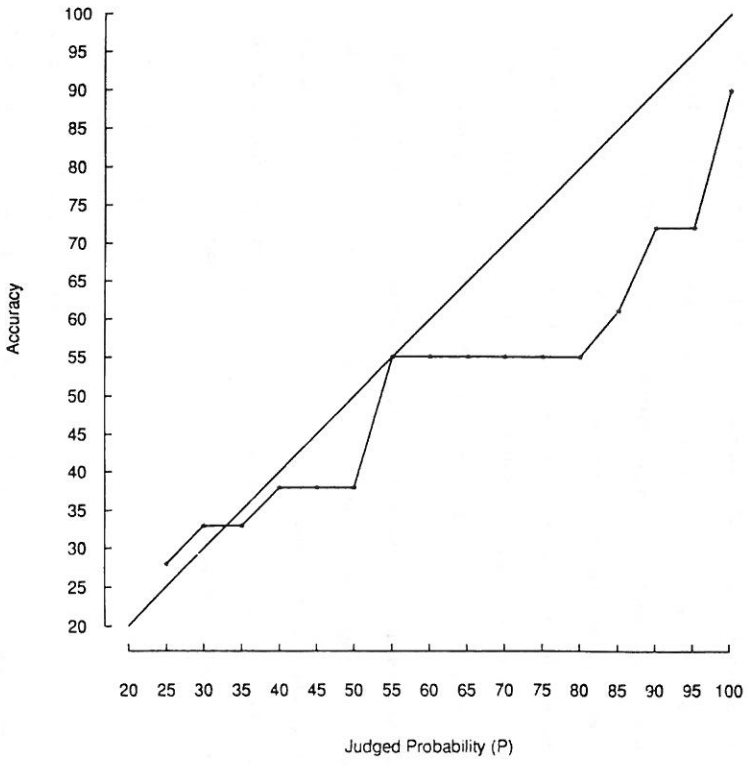


Figure 3. Calibration curve for Study 1.

Figure 3 presents the calibration curve for the data of Study 1. The figure shows that people are well-calibrated for low probability, but exhibit substantial overconfidence for high probability. Hence, the preference for the judgment bet over the lottery for high probability cannot be justified on an actuarial basis.

Study 2: Football and Politics

Our next study differs from the previous one in several respects. First, it concerns the prediction of real-world future events rather than the assessment of general knowledge. Second, it deals with binary events so that the lowest level of confidence is .5 rather than .25 as in the previous study. Finally, in addition to the judgments of probability and the choice between the matched bets, subjects also rated their level of knowledge for each one of the predicted items.

In the first part of the study, a group of 20 students predicted the outcomes of 14 football games each week for 5 consecutive weeks. For each game, subjects selected the team that they thought would win the game and assessed the probability of their chosen team winning. The subjects also assessed, on a 5-point scale, how knowledgeable they are with respect to each game. Following the rating, subjects were asked whether they preferred to bet on the team they chose or on a matched chance lottery. The results summarized in Figure 4 support the confidence hypothesis. For both high and low knowledge (defined by a median split on the knowledge rating scale), C was an increasing function of P. Moreover, C was greater for high knowledge than for low knowledge at any $p > .5$. Only 5% of the subjects produced negative correlations between C and P, and the average ϕ coefficient was .33, ($t(77) = 8.7$, $p<.01$).

Insert Figure 4 about here

We next took the confidence hypothesis to the floor of the Republican National Convention in New Orleans during August of 1988. The participants were mostly student volunteers who worked at the convention. They were given a one-page questionnaire that contained instructions and an answer sheet. Thirteen states were selected to represent a cross-section of different geographical areas as well to include the most important states in terms of electoral votes. The participants (N=112) rated the probability of Bush carrying each of the 13 states in the November election on a scale from 0 (Bush is certain to lose) to 100 (Bush is certain to win). As in the football study, the participants rated their knowledge of each state on a 5-point scale and indicated whether they would rather bet on their prediction or on a chance lottery. The results, summarized in Figure 5, show that C increased with P for both levels of knowledge, and that C was greater for high knowledge than for low knowledge at all levels of P. When asked about their home state, 70% of the participants selected the judgment bet over the lottery. Only 5% of the subjects yielded negative correlations between C and P, and the average ϕ coefficient was .42, ($t(99) = 13.4$, $p<.01$).

Insert Figure 5 about here

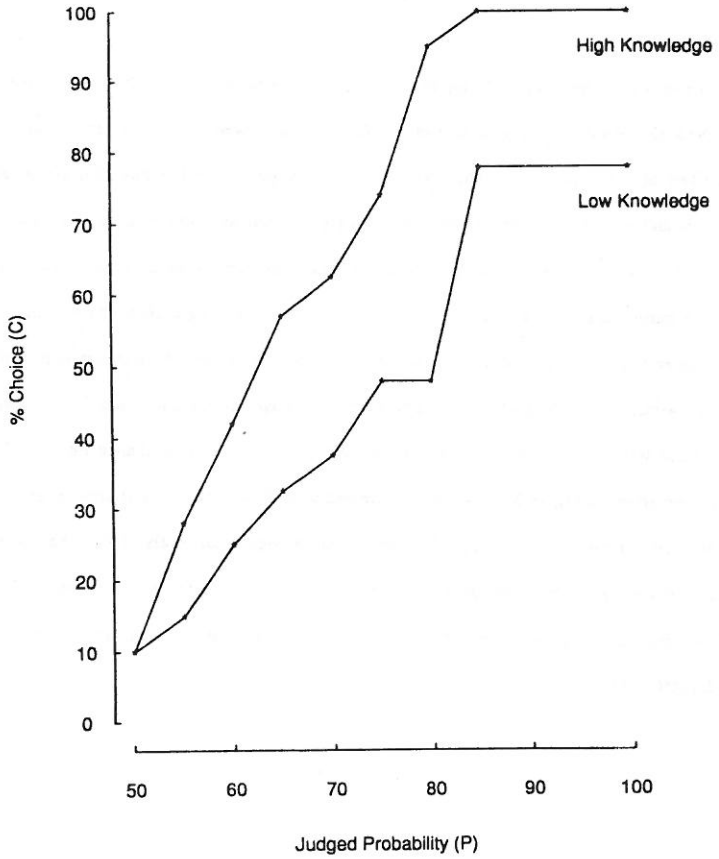


Figure 4. Percentage of choices C that favor a judgment bet over a matched lottery as a function of judged probability P, for high- and low-knowledge items. (Football forecast, Study 2).

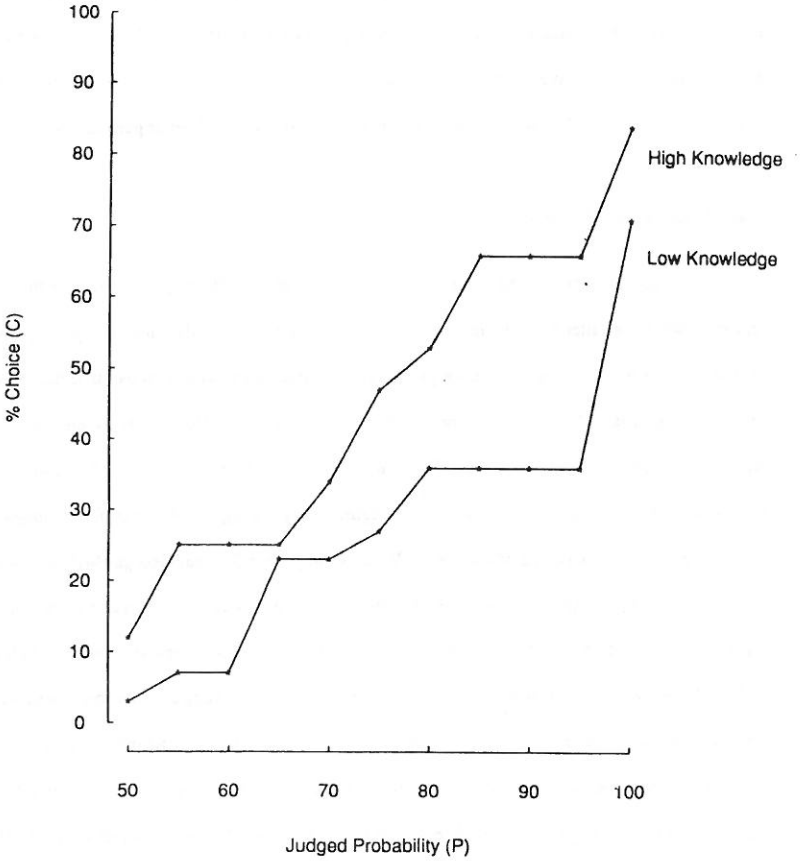


Figure 5. Percentage of choices C that favor a judgment bet over a matched lottery as a function of judged probability P, for high- and low-knowledge items. (Election forecast, Study 2).

The results displayed in Figures 4 and 5 support the confidence hypothesis in the prediction of real-world events. In both tasks C increases with P as well as with rated knowledge. It is noteworthy that the strategy of betting on judgment was less successful than the strategy of betting on chance in both data sets. The former strategy yielded hit rates of 64% and 78% for football and election, respectively, whereas the latter strategy yielded hit rates of 73% and 80%. The observed tendency to select the judgment bet, therefore, does not yield better performance.

Study 3: Confidence Premium

The preceding experiments showed that subjects preferred the judgment bet over the lottery even when the latter had a higher expected value. The present study employs a pricing procedure in order to assess the confidence premium that subjects are willing to pay in order to bet on their judgment. The confidence premium is defined as the difference between the cash equivalent of the judgment bet and the cash equivalence of the matched lottery. The subjects in this study performed two tasks: probability judgment and pricing. In the first phase, subjects were presented with questions of the form, "What is the probability that George Bush was born before (after) 1920?" Subjects were told that the true quantity was always greater or less than the stated value (Bush was born in 1924). Half of the subjects answered the version "before 1920" and the other half answered the version "after 1920". Other subjects were presented with a bet defined by the same event. That is, they were asked to consider the bet that would pay $15 if Bush was born before (after) 1920. Subjects were asked to state their cash equivalence for each bet. Different subjects gave different cash equivalence for the two (complementary) bets. To test the confidence hypothesis, we constructed pairs of high-knowledge and low-knowledge

items. For example, we assumed that subjects have more knowledge about birth year of George Bush than that of Franklin Pierce (the 14th president of the U.S.). Ten such pairs of items were used in the experiment. Each subject made 12 pricing responses and 12 probability judgments in that order. No subject saw the same question in more than one format.

The subjects (N=86) were students in a decision-making class at Stanford. They were informed that a few students, selected at random, would be given an opportunity to play one of their bets. They were told that a pair of items would be selected at random and they would play the bet for which they stated a higher cash equivalence. For the high-knowledge bets, the probabilities of the complementary events were nearly perfectly additive (M=101.7%) across both subjects and problems. The sum of the probabilities for the low-knowledge bets were slightly subadditive (M=95.2%). The difference between the average sums is statistically significant ($p<.05$). As expected, the difference between the high-knowledge and the low-knowledge condition was much more pronounced in the pricing task. Subjects were willing to pay on average \$7.12 for the high-knowledge bet and only \$5.96 for the low-knowledge bet. This difference is highly significant ($p<.01$). Thus, people were paying in effect a confidence premium of nearly 20% in order to bet on the high-knowledge category. Recall that for a risk-neutral subject, the average price should be \$7.50 in both conditions because both sides of each bet were presented to the subjects. Regressing the stated prices against judged probability, separately for the high and low knowledge items, yielded two parallel lines indicating that the difference between them is not due to variation in P.

Study 4: Expert Prediction

Recall that in Study 1, probability and confidence were perfectly correlated, hence, the data could be explained by the hypothesis that in the assessment phase subjects overestimated low probabilities and underestimated high probabilities. This hypothesis, however, does not apply to Studies 2 and 3, which compared C for high-knowledge and low-knowledge items for the same level of P. A stronger test of the confidence hypothesis may be obtained by comparing subjects' responses in an area in which they are experts to their responses in an area in which they are not. To create such a comparison, we asked 110 students in an introductory psychology class to assess their knowledge of politics and of football on a 9-point scale. Subjects who rated their knowledge of the two areas on opposite sides of the mid-point were asked to take part in the study. Twenty-five subjects met this criterion and all but two agreed to participate. They received course credit for participation and were informed that, on average, they are expected to win an additional $10. The participants included 12 political "experts" and 11 football "experts" defined by their strong area. To induce the subjects to give careful responses, we gave them detailed instructions including a discussion of calibration, and we employed a proper scoring rule (Lichtenstein et. al, 1982) designed to motivate subjects to reveal their best estimates.

The experiment consisted of two sessions. In the first session, each subject made predictions for a set of 40 future events (20 political events and 20 football games). All the events were resolved within five weeks of the date of the initial session. The political events concerned the winner of the various states in the 1988 presidential election. The 20 football games included 10 professional and 10 college games. For each contest (politics or football), subjects

chose a winner by circling the name of one of the contestants, and then assessed the probability that their prediction would come true (on a scale from 50% to 100%).

Using the results of the first session, 20 triples of bets were constructed for each participant. Each triple included three matched bets with the same probability of winning generated by (i) a chance device, (ii) the subject's prediction in his or her expert category, (iii) the subject's prediction in his or her non-expert category. In the second session, subjects ranked each of the 20 triples of bets. The chance bets were defined as in Study 1 with reference to a box containing 100 numbered chips. Subjects were told that they would actually play their choices in each one of the triples. To encourage careful ranking, subjects were told that they would play 80% of their first choices and 20% of their second choices.

Insert Table 2 about here

Insert Figure 6 about here

The data are summarized in Table 2 and Figure 6, which plots the attractiveness of the three types of bets (inverse mean rank) against judged probability. The results show a strong preference for betting on the expert category. Across all triples, the mean ranks were 1.68 for the expert category, 2.08 for the chance lottery, and 2.23 for the non-expert category. The difference among the ranks is highly significant ($p<.001$) by the Wilcoxen rank sum test. These

Table 2. Ranking data for Expert Study.

Rank:	1st	2nd	3rd	Mean Rank
High-Knowledge Bet	192	85	68	1.64
Chance Bet	74	155	116	2.12
Low-Knowledge Bet	79	105	161	2.23

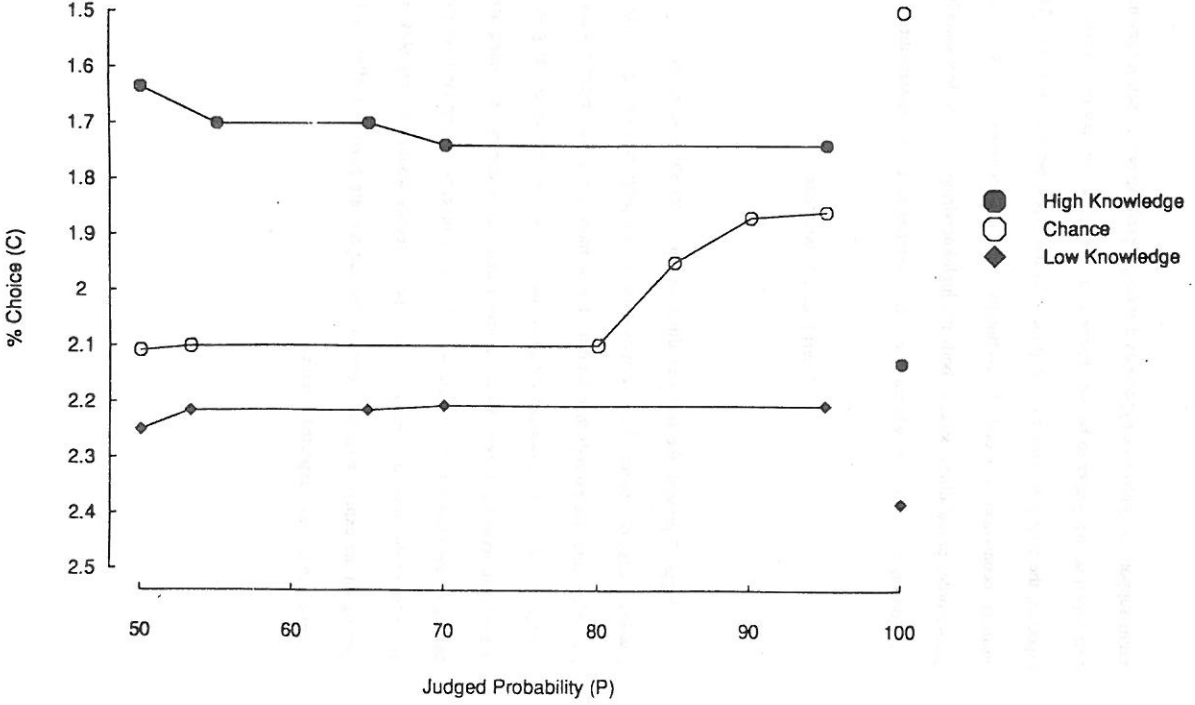


Figure 6. Ranking data for high knowledge, low knowledge and chance bets as a function of P.

results support the confidence hypothesis that people prefer to bet on their judgment in an area of their expertise, but prefer to bet on chance in an area in which they do not feel confident. As expected, the lottery became more popular than the expert bet only at 100%. This pattern of result is inconsistent with both the ambiguity-aversion hypothesis and the standard theory of second-order probabilities because both the high-knowledge and the low-knowledge bets are based on vague probabilities whereas the chance lotteries have clear probabilities.

Insert Figure 7 about here

Figure 7 presents the average calibration curves for Study 4, separately for the high- and low-knowledge categories. These graphs show that the judgments were generally overconfident: people's confidence exceeds their hit rate. Furthermore, the overconfidence was even more pronounced in the high-knowledge category than in the low-knowledge category. As a consequence, the ordering of bets did not mirror judgmental accuracy. Summing across all triples, betting on the chance lottery would win 69% of the time, betting on the novice category would win 64% of the time and betting on the expert category would win only 60% of the time. By betting on the expert category, therefore, the subjects are paying, in effect, a 15% confidence premium in terms of expected earning.

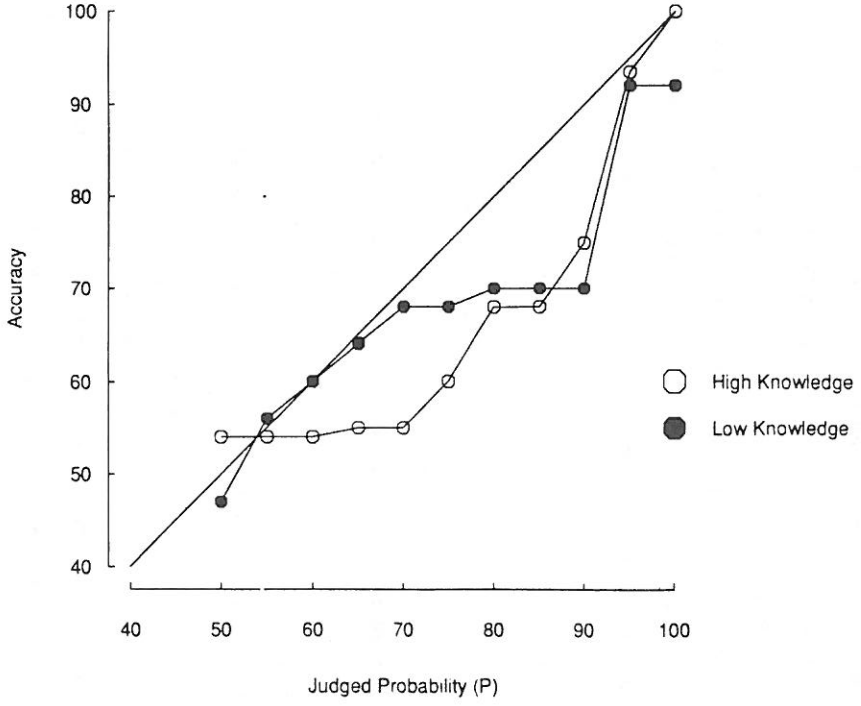


Figure 7. Calibration curves for high- and low-knowledge categories. (Study 4)

Discussion

The experiments reported in the preceding section provide strong support for the confidence hypothesis, according to which the willingness to bet on an uncertain event depends not only on its probability but also on one's confidence. People prefer to bet on their knowledge and skill when they consider themselves knowledgeable and skillful, and they prefer to bet on chance when their knowledge or understanding is limited.

The present account can explain the aversion to vagueness in a chance setup, as well as other phenomena such as the preference to bet on the future rather than on the past (Snyder & Rothbart, 1971), the preference for skill over chance (Cohen & Hansel, 1959; Howell, 1971), and the enhancement of ambiguity aversion in the presence of knowledgeable others (Curley, Yates, & Abrams, 1986). In the present section we discuss two related phenomena: probabilistic loss aversion and regressive priors.

Probabilistic Loss Aversion

The preference for sharp over vague symmetric bets in a chance setup can be produced by the lower confidence associated with the vague event. It can also be produced by loss aversion (Kahneman & Tversky, 1984; Tversky & Kahneman, 1989). According to this principle, which has been confirmed in many studies, losses loom larger than the corresponding gains. If we include probabilities among the consequences of an action, then many forms of ambiguity aversion can be viewed as instances of loss aversion. For example, Viscusi, Magat, and Huber

(1986) asked consumers to state the price they would be willing to pay for a product (e.g., a pesticide, a cleaning agent) if the risk it entails were increased or decreased by a fraction of a percent. The subjects were willing to pay a few dollars for a reduction in risk, but were unwilling to accept an increase in risk at any price. This observation represents probabilistic loss aversion: an undesirable increase in probability has considerably more impact than a comparable decrease in probability. Treating probability as a consequence is especially compelling in this example because the consumer has to live with the small risk he or she had accepted, and there is no definite point in time in which the gamble is realized.

The following problem presents another example of uncertainty preferences (based on an unpublished problem of Kahneman and Tversky) consistent with the confidence hypothesis that can also be interpreted as an instance of probabilistic loss aversion.

> PROBLEM 1 (N=73). You enter the hospital and are diagnosed as being in the beginning stages of a new type of flu that has been spreading around the country. The flu is quite painful and normal recovery time is around three weeks.
>
> Two strains of the flu have been discovered. They have been labeled "alpha" and "beta". Each strain accounts for 50% of the total flu cases that have been diagnosed. The symptoms associated with the strains are the same but the strains respond differently to different treatments. No procedure has yet been devised to tell the strains apart before treatment is undertaken.
>
> *Drug K* is very effective against the flu type alpha, giving immediate recovery to 85% of the patients with alpha flu. However, they are not very effective with beta flu. Only 15% of the people with beta flu recover immediately when given K-series drugs.
>
> *Drug L* is better at treating beta flu: 60% of the patients with beta flu recover immediately. Of the patients with alpha flu, 40% recover immediately when treated with L-series drugs.
>
> *Drug M* may be used to treat the disease as well, but this drug operates exactly the same for both types of flu. About 50% of the people with either alpha or beta flu recover immediately when treated with M-series drugs.

Your doctor has asked you to choose one of the treatments. You will only have a chance to undergo one treatment before the disease runs its natural course, so if the treatment is not immediately effective, you won't have a chance to try another.

Insert Table 3 about here

Note that the probability of immediate recovery is .5 for all three drugs. Drug M, however, is equally appropriate for either type of flu. Drugs K and L are more suitable for alpha and beta, respectively. Because subjects do not know whether they have alpha flu or beta flu, they prefer Drug M whose effectiveness does not depend on the unknown information (see Table 3). Thus, people prefer to avoid making a guess that might turn out to be wrong. The pattern observed in this problem was replicated using a choice involving positive rather than negative outcomes. In that problem, subjects chose between three advertising campaigns that had differential effectiveness against two potential products released by a competitor. Again, people preferred the policy that was equally effective against both releases, even though their actual probability of success were exactly the same.

Judgmental vs. Preferential Biases

There is evidence that when the probability of winning a prize is relatively small, people prefer to bet on a vague rather than on a sharp event. Conversely, when people face a high probability of a loss they prefer a vague event over a sharp one (Gärdenfors & Sahlin, 1982; Einhorn & Hogarth, 1985; Hogarth & Kunreuther, 1989). These observations suggest that

Table 3. Ranking data for Problem 1.

Rank:	1st	2nd	3rd	Mean Rank
Drug M	51	11	11	1.45
Drug L	15	47	11	1.95
Drug K	7	15	51	2.60

people overweight vague events whose probability is low and underweight vague events whose probability is high. This is the main prediction of the ambiguity model of Einhorn and Hogarth (1985). However, this model or more generally the regression hypothesis implies the opposite pattern than that observed in Studies 1-4. How can we reconcile the evidence that seems to support the regression hypothesis with the present data that appear to refute it?

To answer this question, it is essential to distinguish between preference and judgment, and more specifically between decision weights and subjective probabilities. In order to demonstrate either ambiguity aversion or ambiguity seeking, it is essential to construct a problem in which the ambiguous and the less ambiguous event are subjectively equiprobable. Ellsberg has shown how to satisfy this condition for 50/50 bets. For probability values other than 1/2, however, it is not easy to establish that the vague and the clear events are subjectively equiprobable. Einhorn and Hogarth (1985), for example, told two groups of subjects that the probability of receiving a prize is .001. One group was told that the estimate is very reliable whereas a second group was told that the estimate is unreliable. These authors observed that the second group found the gamble more attractive than the first group, and interpreted this result as an indication of ambiguity seeking. This inference, however, is not valid if the second group perceived the event as more likely than the first group. An unreliable estimate of .001 may well be taken as .002. Thus, the evidence for the regression hypothesis may reflect (justified or unjustified) variations in the subjective probability of the target event, which cannot be interpreted as an ambiguity effect. Naturally, extreme estimates (near 0 and 1) are likely to regress toward the middle, resulting in a pattern of prediction that mimics the regression hypothesis, or the ambiguity model of Einhorn and Hogarth.

Insert Table 4 about here

This interpretation has been confirmed in an unpublished study by Parayre and Kahneman conducted in 1985. Their results are summarized in Table 4, which presents both choice and likelihood data for three probability levels: low, medium and high. For each probability level, the investigators compared a sharp event, defined by the proportion of red balls in the box, with a vague event defined by the range of balls of the designated color. For high probability, for example, the vague event was generated by informing the subject that the percentage of red balls could be anywhere between 80% and 100%, compared with 90% for the sharp event. The choice data show that subjects preferred the ambiguous box when the probability of winning was low and when the probability of losing was high, as observed by other investigators. The novel feature of the Parayre and Kahneman study lies in the use of likelihood rating. Using a perceptually-based (non-numerical) rating scale, these investigators showed that the vague low-probability event was judged as more probable than the clear event, and the vague high-probability event was judged as less probable than the sharp event. No significant difference in the likelihood rating of the medium probability was observed. The same results were obtained when the likelihood rating was obtained in the context of a positive gamble, a negative gamble or a neutral comparison. These data demonstrate that the preference for the ambiguous event observed at the low end for positive bets and in the high end for negative bets is attributable to variations in the perception of probability rather than willingness or unwillingness to bet on uncertain events.

Table 4. (Data from Parayre and Kahneman). Percentage of subjects who selected the sharp event and the vague event in rating of likelihood and in direct choice. The sum of the two values in each condition is less than 100%; the remaining responses expressed equivalence. Significant differences at the .05 level are denoted by an * near the larger value. In the likelihood rating task, the low values were .05 and [0,.1].

	Probability (Win/lose)	Choice		Likelihood Rating
		Win $100	Lose $100	
Low	.075	12	66*	26
	[0,.15]	74*	12	55*
Medium	.5	60*	60*	37
	[0,1]	26	21	25
High	.9	50	22	55*
	[.8,1]	34	47*	22

Other Accounts

The pattern of results observed in the present studies, and particularly the preference for betting on one's judgment rather than on chance, rules out most common models based on second-order probabilities. Although people prefer sharp probabilities over vague ones within a chance setting, they don't do so elsewhere. Another plausible explanation of ambiguity effects concern the role of regret. It is noteworthy that to apply the regret interpretation, one needs to assume some version of probabilistic loss aversion. Furthermore, an experiment by Curley, Yates and Abrams (1986) showed that the aversion for ambiguity for symmetric bets in a chance setup was not reduced when the content of the box was not revealed, contrary to the prediction of the regret hypothesis.

Finally, it could be argued that the choice between bets may be taken as a more adequate measure of probability than subjects' stated values. According to this interpretation, the present finding may demonstrate the inadequacy of verbal methods for measuring subjective probability. But since the confidence effect was not reduced by the use of a proper scoring rule, the present results cannot be attributed to the absence of incentives. Rather, it appears that subjective probabilities do not coincide with the respective decision weights and that the latter reflect people's confidence over and above the perceived likelihood of the events in question.

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Figure Captions

Figure 1. Five contrasting predictions of the results of an uncertainty preference experiment.

Figure 2. Percentage of choices (C) that favor a judgment bet over a matched lottery as a function of judged probability (P) in Study 1.

Figure 3. Calibration curve for Study 1.

Figure 4. Percentage of choices (C) that favor a judgment bet over a matched lottery as a function of judged probability (P), for high- and low- knowledge items in the football prediction task (Study 2).

Figure 5. Percentage of choices (C) that favor a judgment bet over matched lottery as a function of judged probability (P), for high- and low- knowledge items in Study 2 (Election data).

Figure 6. Ranking data for high knowledge, low knowledge and chance bets as a function of P in Study 4.

Figure 7. Calibration curves for high- and low-knowledge categories in Study 4.

REFLECTIONS ON ARTIFICIAL INTELLIGENCE

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For the last thirty years human sciences generated a great deal of new notions and concepts which resembled (especially in the context of national stagnation) dressed up ladies and gentlemen cropping up amid tired sloggers. The notions quickly became fashionable and as quickly perished leaving behind material traces in the form of well supplied laboratories with rapidly exhaustible research capability but steadily increasing funds. Then new notions evolved placing demand for new much higher priority laboratories. This kaleidoscopic period is not yet over, moreover, not in human sciences alone: a spontaneous succession of costly fashions dominates music, painting, literature, TV, daily life, etc. This is apparently a distinguishing characteristic of the modern phase in computer age, for instead of a stepped up evolution, expected at its outset, we are witnessing an accelerated involution in different branches of culture given a complete lack of at least vague ideas as to what should replace its wretched short-lived substitutes.

The fate of the term "Artificial intelligence" that originated with the USA in 1956, outwardly resembles that of the fashionable notions. Indeed, it did not have a chance to become a rigorously scientific notion, and many specialists point out to its conditional and metaphorical nature for they experience vexatious inconveniences in applying it in concrete situations, when comparing artificial intelligence with natural one. New terms are suggested whose lot cannot be predicted by anybody. As applied to artificial intelligence, however, one should not identify the fate of a lame term with the reality it signifies. The latter enraptures some people (primarily, engineers and Philistines), puzzles others (psychologists and philosophers), and frightens still other people (humanitarian futurologists). One cannot but marvel at the successes in robot engineering, expert systems for medical diagnosis, economic computations, design, geological prospecting, solution of mathematical problems, education. Problems arise when comparing philosophical and psychological theories of human knowledge with different

concepts of artificial intelligence put forward as models of natural intelligence or methodological base for future technical designs. The scepticism and warnings about the hazard of some current and future trends in artificial intelligence development stem from humanization of technological change and the necessity of its subordination to the principle of harmonious development of personality. Each of the three types of reaction to a new phenomenon of social life, which the artificial intelligence actually is,(for the time being we'll use this conventional term) has its own underpinnings, and not only emotional but also parti cularly rational, though the latter can far from always be treated as strictly scientific. It is one thing, however, when this is a local phenomenon affecting only individual aspects of social life. But it is an entirely different thing when it goes beyond the bounds of laboratories, gradually comes to bear upon the entire production, and becomes a substantial component of human culture. Given a fully spontaneous transformation of local social phenomena in global ones, initially latent and undisco vered due to narrowness and laziness of mind, the problems show up as a lasting tragedy following a short-term triumph of msses. There are numerous examples to this end in different countries. On acquiring an opportunity, for the first time ever, to relati vely quickly render some or other phenomenon mass, we encountered an as yet unknown dialectics of local good transformation in global evil. The realization of this fact helps understand the suspicious and sceptical reaction to artificial intelligence leading one to answer a far from idle question concerning its present and future status in the life of society and individual.

Technical literature defines artificial intelligence (of course, not in terms of logically strict notion) as a capacity of the computer system to solve intellectual problems. The latter are usually stated by man (system user). It is worth noting that each system is rather narrowly specializized and is considerably inferior in this respect to even the most narrow professional. The system's specialization is determined by a totality of hard- and software built in it back at the development stage. An integral component of the intelligent system software, distingui

shing them from unintelligent ones, is a cognitive potential comprising knowledge base and data base. "The knowledge base contains information reflecting the laws of the given subject area and making it possible to predict and derive new facts... The data base comprises factual, quantitative data characterising the subject area. The partitioning of the cognitive potential into two bases makes sense. The point is that one and the same relations (including natural ones) may connect quite diverse facts, and vice versa, one and the same facts may enter into different relations with one another. In order to elicit new knowledge about a fact, we ought to either perceive it in new environments, featuring new relations of this fact with other facts, or given its mental image, incorporate it (deliberately or involuntarily) in a new relation (perceived or imagined) with which we never before associated this fact. In other words, a prerequisite for eliciting new knowledge boils down to separation of the given relation from the fact forming it. The human being given relation from facts forming it. The human being has a lot of opportunities for meeting this requirement: abstraction from the actually perceived situation may, depending on specific circumstances, take form of ideas, expressive movements, subject values, verbal designations and notions. In a much the same unconscious way man comes back to reality, and his cognitive potential keeps in touch with concrete life. The individual activity of man is a material manifestation of the dialectics of abstract-concrete interactions without which man turns either into a slave of the current situation, or a carrier of dead abstractions ignoring the living diversity.

The content of the cognitive potential determined by the specific purpose of the intelligent system is closely linked with the form of knowledge presentation. There are three forms: logical (such as propositional calculus or predicate calculus), network (semantic or frame network), and linguistic (three types of artificial languages: for processing symbolic information, for search of solutions and demonstration of theorems, for presentation of general purpose knowledge). These diverse forms have one common feature: they contain the description of symbols

and rules of their application. As for the subject value of these symbols, it exists only in the consciousness of their creator and users of the intelligent system. Thus, what we refer to as a cognitive potential of intelligent system should not be treated as knowledge in the general sense of the term, for following the transfer of human knowledge to computer, it loses its relationship with the subject, its substantive meaning. The computer stores a mere sign of the knowledge, its symbols. Here we face an unprecedented situation:knowledge is a reflection of reality produced by the cognitive activity of human being, and the cognitive potential of computer results from reflection of the human knowledge which is the second order reflection.

Why do we treat this situation as unprecedented? The point is that the developed forms of cognitive activity cannot do without a symbolic representation of the cognized reality. One of the products of the cognitive activity is materialized knowledge, i.e. potential knowledge contained in oral and written speech, works of literature, painting, music, cinema, and other means of communication. This knowledge is actualized only following it assimilation by man. The book can be referred to as a source of knowledge but as such it is not knowledge but a mere publication. The same holds true of any other works of culture. The cognitive resource of the computer is a kind of knowledge materialized by man. Its peculiarity, however, lies in the fact that this mate rialized knowledge may be not only static but also dynamic which was ruled out prior to the evolvement of intelligent machines. The book is unable to handle and modify the material printed in it. Nothing new can appear in the picture after an artist painted it. In a movie picture we can watch only what has been imprinted on the film. As for the computer, it can not only store informa-tion but also modify it in the process of interaction with the user, i.e. manipulate information, accumulate, and correct it.

This capability, however, still cannot be considered innovative in the true sense of the term, and not only because it was built in the machine by man. The intelligent systems' capaci ties to handle information are limited by both the nature of symbols and rules of their manipulation general, as they may be.

One may elicit new knowledge with the aid of some or other formal system but only within the limits bounded by the established formal laws. Thus, the formal-logical deductions sometimes lead us to substantively new inferences, but the formal logic, like any other formal system is, first, not the only tool of creative process and, second, it often hampers creativity and even kills it should it infringe upon dogmas. The formal thinking is useful and necessary to a certain extent as an adjunct to other types of activity, but when it comes to be the only, unlimited, and mass-scale we witness transformation of the local good in the global evil - a medieval scholasticism or bureaucratism of our time. And if we do not want the currently unique intelligently packed expert systems to turn into the dominant system of bureaucratic examination assisted by the fail-safe computer technology, then it is necessary, already now, to find out what is knowledge and what is a far from harmless tool thereof.

There are two points of view in artificial intelligence research concerning its relationships with human intelligence The proponents of one of them believe that the successes in the development of machine intelligence are fully dependent on the understanding of the substance and principles of human knowledge application. Others hold that the structure and principles of data manipulation in artificial intelligence systems should not at all be analogous to the psychological structure of human knowledge. If the first point of view is true at least to some extent then the second one seems absurd.

Technology develops by its own laws though in the context of human culture. The cultural context, in some or other measure (depending on the society maturity) determines the contents and prospects of technological change. Their practical implementation largely depends on the attained level of material and technical base of society. The sophisticated computers are capable of performing some functions which were earlier the prerogative of man. This is far from purely engineering accomplishment, however. It is necessitated by the need to find a practical and effective solution to problems which were brought about by an accelerated growth of human knowledge and much faster differentiation

thereof. All these problems are engendered by a comparatively new conflict in the cognitive activity, notably, a contradiction between the volume of potential (materialized) knowledge and traditional forms of its storage, assimilation, and application. Hardly is there a specialist in some or other branch of science who could confidently claim to have mastered the complete, or at least the major part of the relevant information, let alone relative disciplines. One is lucky to acquire at least scrappy knowledge. As a result, for example, the psychologist specializing in the field of perception has at best superficial knowledge of personality psychology or social psychology. And vice versa, a programming expert may be ignorant of automatic control system theory, etc. The superficialness and fragmentary nature of human knowledge, the incessant and stronger appeals to restore its integrity are indicative not so much of the laziness of mind and degradation of morale (that is the case too, though) as intensification of the aforementioned conflict. Under the circumstances, the attempts to develop intelligent systems by analogy with human intelligence seem untenable: first,despite the sophistication of the advanced computers, their characteristics are, and will long be inferior to the essential characteristics of human intelligence for all its weaknesses; second, simulation of human intelligence will hardly promote resolution of the above cognition conflict; third,the development of artificial analogues of human intelligence will cost society much more than the more pleasant and less expensive business of the natural reproduction of homo sapiens.

At the same time, the orientation at a radical distinction of intelligent systems from human intlligence cannot be viewed as a reasonable alternative either. First, nature has not created anything better than human intelligence (we mean intelligence making good). Second, human cognition and knowledge of it (epistemology) have a long history involving not only understand ing of the truth but of errors too. Reiteration of the past truths is not an honourable business, but the repetition of conscious errors is equivalent to stupidity. Besides if in the past, errors of the reason concerned destinies of only individual

scholars or, in extreme case, of small social groups, then nowadays they may turn into tragedies of much larger scale. The engineers' nihilism toward philosophical and psychological theories of knowledge as well as a superficial acquaintance with them, resembles a slighting attitude of a student to mathematics only because he does not like the math teacher. The imperfection of modern epistemology, its inability to solve crucial problems of human knowledge increment cannot serve as a basis for ignoring it in designing intelligent systems, moreover that, as experience shows and epistemology holds, there are no perfect theories altogether. Finally, third, it is difficult to imagine an intelligent system used by a man which was developed without due account of the nature of human intellect. This resembles a phantastic encounter of hominoid with an Earth's creature.

On explaining the necessity of appealing to the nature of human knowledge in designing intelligent systems, let us turn back to the problem of knowledge desubjectivization following its transfer to the cognitive resource of the computer. In mastering knowledge man is assumed to subjectivize it. The formation of full-fledged mental activities, and thinking in general, starts with objects' manipulation, and this subject relevance of an ideal action is retained at all subsequent stages of its formation and functioning including the very abstract levels of intelligence. Note that human knowledge is desubjecti vized and subjectivized with one and the same tool, notably, speech. A great deal of interesting papers of the Soviet and foreign psychologists are devoted to the control functions of speech in human activities, so we shall not elaborate. We men tioned it just to pre-empt an undesirable (due to its formality) association between the fundamental role of speech in the develo pment of intelligence, recognized in the theory of knowledge, and the ever increasing efforts on the development of speech communi cation interfaces between man and machine. Great hopes are pinned on speech interfaces, for in the near future they will considera bly simplify and reduce (and may be eliminate altogether) the programmer mediation between user and computer. There is no reason for delusion, however. The speech interface converts the

oral (or symbolic) speech into a machine code followed by a reverse conversion. This is nothing short of a well-known procedure (technically more complicated than the preceding ones, though) of coding and decoding the symbol information which can be successfully carried out given a complete abstraction from the subject content of speech utterance. Thus, the speech interface does not solve the problem of subjectivizing the cognitive resource of the computer either.

We have arrived at the only conclusion, not very comforting though in the light of the aforelisted problems, that the subjectivization function may be exercised only in human activity or, as he is often referred to now, - computer user. If materialization, i.e. desubjectivization of the new knowledge, is a necessary prerequisite for transmitting it to other people, then subjectivization of the materialized forms of knowledge assumes its assimilation and application. Computer is one of the instruments (apparently, the most perfect at present) of such double conversion of knowledge, but it cannot act as its subject, for it is only the subject that can generate, assimilate, and apply knowledge.

In summary, we would like to touch upon a possible way of resolving the conflict between the growing volume of knowledge and traditional methods of its assimilation. Throughout the larger part of human history, the knowledge transmission and assimilation were dominated by speech (oral or written) communication. The advantages of speech as compared to other means of communication are well known, especially when knowledge is required to be as objective as possible. Probably every speaking person has experienced shortcomings of speech communication. Should it be necessary to express the subjective aspects of knowledge, people turn to mimicry, gestures, movements, i.e. to the means of communication which precede the speech communication and were traditionally considered rudimentary and limited. We believe that the above contradiction exposes one more drawback of speech conditioned by its successive nature - its consecutive development in time (oral form) and in space (written form). The growth of the substantive volume of knowledge leads to an increa

singly longer time of its oral transmission and an excessively larger space for knowledge storage. The latter gave rise to a problem of search for the necessary knowledge whose solution often takes much more time and effort than that required for assimilation of the found knowledge. True, computers and new information media are of great help here as they considerably reduce the size of book depots. But as before, the generation of knowledge outstrips the possibilities of its assimilation, and the time gap will increase with time. Is there any way out? An intuitive answer, not claiming the scientific rigor, is that it is necessary to revise our undeservedly slighting attitude toward the prespeech forms of communication, especially the ones of simultaneous character (e.g. visual images), moreover that a high intelligence of modern man has penetrated not only his reason, but a misterious world of images and movements.

RISK EVALUATION AND THE CAUSES OF ACCIDENTS

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Abstract

Is misperceived risk or consciously accepted risk a major source of accidents? And will it help to tell people who may be involved in accidents about these risks, so that they will be in a better position to avoid them? From an analysis of studies on driving behavior, on the use of dangerous products, and of accidents at sea, it emerges that most accidents are consequences of routine behavior, which is preprogrammed to such an extent that it occurs without any consideration of risk. The normative model of human decision making, which assumes an exploration of alternatives and consequences, is not applicable to the actual behavior of people about to be engaged in accidents. People are running risks, but that does not mean they are aware of these risks, or are consciously taking them. The risks people are running are created higher up in organizations and society, at a level where knowledge-based problem solving occurs. At these levels it can be assumed that exploration of alternatives and consequences take place, and that risks, when realized, may be considered. Therefore my answer is: No, people engaged in accidents did not misperceive or consciously accept the risks; Yes, many accidents are the ultimate consequence of decision processes in which risks were wrongly omitted, underestimated, or willfully accepted. I conclude that risk communication should be aimed, not at those individuals who may cause accidents at the 'shop floor', but at those individuals in organizations and society who take decisions that create the situations in which the routine behavior of others will appear to be unsafe.

The question addressed in this paper is whether misperceived risk, or consciously accepted risk, is a major source of accidents. The question originates from my experience that frequently in accident reports, or in law

suits that follow accidents, the actors in the drama are accused of underestimating or accepting grave risks in an irresponsible manner. My own impulse, after reading hundreds of accident histories, is that those who are running risks, cannot always be said to have taken those risks. The following pages contain a less impulsive analysis of this problem.

The study of risk perception and its logical successor, risk communication, seems to be based on the simple assumption that undesired outcomes occur because people, when considering alternatives and consequences, accept risks they should not accept. Thus it is assumed that people do not stop smoking because they do not appreciate the associated risk, and refuse to use seat belts because they are not aware of the blessings of seat belts. Telling people about all this would then lead to a reduction of risky behavior.

This notion of risk acceptance as a result of a conscious analysis may have emerged from a normative model of decision making, in which all available alternatives are considered, their consequences evaluated with respect to probability and utility, and in which some expression for the attractiveness of the expected outcome is obtained. Within the framework of such models much attention was paid to the ways in which people conceptualize alternative choices, the ways in which probabilities can be inferred from related indicators, the

ways in which utilities are derived and handled. Less attention was paid to the question whether and in what conditions people will engage in such analyses, instead of acting automatically, following their gut feeling, of accept the first choice that is offered. Still the wide-spread interest in risk-taking behavior is based upon this notion that people accept the risks they are running after completing detailed analyses, simple and limited to the probability or size of one possible loss, or extremely complicated and encompassing the distribution of all possible consequences. There is a wealth of literature on misperception of risks, indicating that these prior evaluations may result both in underestimation and overestimation of risk, suggesting that the acceptance of excessive risks and the emotional overreaction to in principle very small risks, are both to be attributed to some sort of cognitive illusion. This notion was widely applied to the problem of societal and public acceptance of novel technologies, such as vaccination, DNA-manipulation, and nuclear energy production. It has been argued that "those who promote and regulate health and safety need to understand the ways in which people think about and respond to risk" (Slovic, 1987, p.280). I would argue that, even when it is shown that people underestimate risks in our laboratory tasks, it still must be proven that this underestimation is the only, or the major reason why they are running those risks.

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The last question becomes extremely relevant when we consider the next step, which has to do with changing risk behavior by affecting some 'erroneous' risk perceptions through a process of risk communication. This attempt looked especially attractive in those cases in which the general public was seen to underestimate risk, and to refuse the acceptance of safety measures that help to reduce the risks. Good examples are the almost worldwide campaigns against smoking and drinking, and in favour of wearing seatbelts. Many of such programs have been utter failures (cf. Slovic's review of seatbelt campaigns; Slovic, 1985). One explanation of these failures is that individual behavior is not always preceded by conscious risk evaluations, and is therefore not necessarily the result of a misperception. However, the logic that risky behavior follows a consideration of those risks, is extremely compelling, and has lead to an even larger step: the assumption that most accidents occurring to people are the result of some sort of faulty risk perception. This then leads to campaigns promoting 'safety awareness' in industrial environments. Again, the logic behind such campaigns is compelling, especially because accident scenarios usually look very silly; it is often hard to believe that the actors in the drama did not consider the risk of the approaching doom that in hindsight is seen by everyone. Hence, since the actors could not have failed to consider the negative consequences of their actions, they

must have misperceived the risk. This notion of mishap following a consciously considered risk is not limited to scientists alone; Hovden and Larsson (1987) reported that in a representative sample of Swedes between 18 and 70 years of age, 90% agreed that risk-taking is the major source of accidents.

The notion of actions being preceded by considerations of risk is also exemplified by the frequent application of the Fischbein-Ajzen model to risk problems (cf. Midden, 1986, Verplanken, 1989). The Fischbein-Ajzen model postulates that behavior results from attitudes, and that in turn attitudes are determined by beliefs. Attitude change through the introduction of new beliefs would automatically lead to changes of individual behavior. Evaluations of industrial safety campaigns based on risk communication only (cf. Heinrich, 1931; Kletz, 1985; Planek, 1982), do not suggest that presentation of information may lead to the avoidance of risky behavior.

Societal and individual decision making. The possibility that people engage in most of their everyday behavior without a conscious consideration of the associated risks, and that therefore many accidents cannot be attributed to erroneous perception of risk, is worth investigating. But it will be necessary to distinguish here between societies and organizations on one hand, and individual people on the other. Societies and organizations may be involved in decision processes that

contain an organized investigation and evaluation of risks. Risk evaluation might even be enforced by statutory law. But this does not mean that individuals, engaging in risky activities, will also consider the risks prior to their actions, nor even that individuals feel that risk evaluations ought to be made in such cases. Some evidence about this may be obtained from two studies by Slovic, Fischhoff, and Lichtenstein (1985), and Slovic, Lichtenstein, and Fischhoff(1984), both referenced in Slovic (1987). These studies considered the factor-analytic representation of subjective risk, which tends to contain two major factors: 'Dread Risk', which stands for the perceived lack of control, catastrophic potential, and inequitable distribution of fatal consequences; 'Unknown Risk', which stands for hazards that are unobservable, unknown, new, and that have delayed effects. In the third quadrant of this plane there are risks that score low both on 'dread' and 'unknown'. Typical examples are riding bicycles, recreational boating, down-hill skiing, home swimming pools, use of chainsaws, smoking, drinking. Compared to the other three quadrants, where we find water fluoridation, diagnostic X-rays, DNA-technology, Starwars, nuclear reactors, general aviation, and large dams, it can be said that the third quadrant represents more individual behavior, the other quadrants more societal behavior. This dissociation is further exemplified when we look at two other factors

emerging from the analyses: desire for strict regulation to reduce risk, and signal potential, defined as "the degree to which an accident involving that hazard was judged to serve as a warning signal for society". It appears that hazards in the third quadrant load low on these factors, whereas hazards in the other quadrants load high on them. Apparently people make a distinction between individual and societal hazards. They seem to feel that risk considerations apply to societal issues, but not to individual activities.

The discussion in this paper will be restricted to the notion that accidents are caused by the faulty risk considerations of the individual actors in an accident scenario, and that risk communication could help to improve these considerations, and therefore to reduce accident rates.

Conscious decisions vs. Action schemata

The general model of actions being preceded by risk considerations is not psychologically plausible, when we talk about individuals instead of organizations, and when we talk about everyday behavior instead of the taking of once-in-a-life decisions. It is widely accepted that much of our everyday behavior is automatized, and runs without a continuous attentional control (cf. Shiffrin and Schneider, 1977). Possibly this automated behavior is controlled by a hierarchy of stored schemata (cf. Norman,

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1981). My schema for going home after work contains the following steps: leaving the office, finding my car, getting on the road, following the way home, parking the car, entering home. Each of these steps in this 'mother schema' is itself a 'daughter schema'. Getting on the road involves opening the car, putting my things in the car, getting seated, belting myself, get the engine started, back out of the parking lot, joining the traffic stream. These steps are again 'granddaughter schemata': starting the engine involves finding the car key, entering it, turning it, waiting till the engine is heated (I drive a Diesel), turn the key again, listen whether the engine catches on, (eventually repeating some of the previous steps). Each of the steps involves a finely tuned perceptual-motor programme, e.g. inserting the car key without really looking. On an ordinary day no step in this hierarchical organization involves a decision based on risk considerations. Reason's GEMS model (Reason, 1989) describes how the transition from automatic control to conscious problem solving takes place when exceptional circumstances arise. Problem solving activities might involve risk considerations, but in ordinary conditions these considerations will rarely occur. The overtaking of other cars, or the crossing of intersections are guided by pre-arranged schemata with build-in decision criteria that have evolved on the basis of experience, and that are not subjected over and over again to conscious risk analyses.

Risk-taking in traffic. Risk-taking in traffic has been modelled in various ways. The most debated model is Wilde's Theory of Risk-homeostasis (e.g. Wilde, 1982), which postulates that drivers maintain a constant level of perceived risk. Any measure that is seen to reduce the risk of driving will automatically be counteracted by a change of behavior resulting in a partial or full compensation of the reduction. Such a theory is quite discouraging and seems to lead to a total governmental non-involvement. Without taking a stand on this issue, I like to point out that the theory assumes a continuous risk evaluation on the part of the drivers. It is not surprising that the competing theory in this area is called 'Zero-risk theory' (Näätänen and Summala; 1974, 1976). It assumes that critical actions such as decreasing your speed in dangerous places, keeping distance to the car in front of you, deciding to overtake other traffic, are not at all guided by risk assessments, but are executed on the basis of preprogrammed routines. In a recent debate the following arguments were put forward. "Whilst the risk of an accident may be very much in the mind of the accident researcher, it may not be in the mind of participants in the activity being studied. Most people who engage in activities with some level of associated risk will have successfully and safely carried out these activities on hundreds and perhaps thousands of previous occasions. Under these circumstances, it seems more likely

that their behaviour will be directed by task-related events and goals, which have a much higher frequency of occurrence than accidents" (McKenna, 1988, p. 479). "Automatization of the driving task and avoidance learning make it possible that most of driving eventually becomes a habitual activity based largely on automatized control of safety margins in partial tasks. No consideration is normally given to risks" (Summala, 1988, p. 497). This issue is further illustrated by the two examples in the next section.

Traffic lights and crossing children

A demonstration of my tenet is Jorgensen's analysis of jumping the red lights. If, at the moment a traffic light turns yellow, you are close to the light and driving fast, you would not brake, but assume the light can be passed before it turns red. If you are distant and driving slowly, you would stop, knowing that you cannot pass the light on time. In a plot of speed versus distance these two regions are separated by a straight line, because speed and distance can be traded off in a linear fashion. However, the braking characteristic of a car is curvelinear: the necessary stopping distance increases exponentially with speed. The result is that there exists a zone, called the dilemma zone, in which you could brake and stop before the crossing line, or continue and cross before the light turns red. Jorgensen used this feature in

a simple experiment on an intersection with signals controlled by a pedestrian-actuated button. When a car approached with a sufficient speed to be in the dilemma zone, the experimenter pushed the button and observed the driver's reaction. Out of 50 cars, no driver attempted a braking manoeuvre. This indicates that in a situation in which there is sufficient freedom to allow a decision, apparently a fixed routine is applied. Carstensen (1983; cited by Jorgensen, 1988) suggested that accidents at traffic signals are to a large extent due the fact that many road users rely exclusively on behavioral rules that assume the proper functioning of signals and the respect of other road users for the signals, making no attempt to evaluate the risk themselves.

Another illustration of fixed behavior schemata is provided by a group of traffic researchers at the University of Nottingham (cf. Howarth, 1988). They studied the interaction between the behavior of childeren crossing an intersection, and drivers approaching that intersection. Their tenet was that drivers are aware of the fact that child pedestrians are less predictable than adults, and that drivers, knowing this, would therefore take special care in the presence of children. In reality they found that less than 10% of the drivers take any action at a time that would allow avoidance of the child if it would step from the curb unexpectedly. Those who took action would still not be able to stop their cars in

time, because their actions were insufficient. When the car reached the ultimate point at which action could be taken by the driver, 80% of the children had already taken an avoidance action. Statistics show that in the remaining stage of the encounter an additional 19.999% of the children take action, while only 0.001% do not. Thus, the entire responsibility for accident avoidance is borne by the children. Likewise, it was shown that in a school area drivers maintained the same average speed, irrespective of the presence or absence of child pedestrians waiting to cross the road. They simply continued with an average of 60 kph, leaving a distance to the curb of 1.2 meters.

What do these data mean? Are all drivers murderous fanatics, lusting for the blood of innocent children? Or should we assume the alternative, which is that drivers are not using any subjective considerations of risk, despite all exhortations of safety education and propaganda; that they maintain a routine behavioral pattern based on the experience that only once in 100,000 encounters with a child intending to cross the road, the child fails to take appropriate action? The propaganda about children's unpredictability is at odds with their actual behavior. The subjective risk is not reflected by actual risk numbers, and it seems that drivers' behavior reflects the routine shaped by reality, rather than some conscious risk evaluation that would take into account the propagated unpredictability and vulnerability of children.

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The only hole in this argument is that drivers may not believe that children on the road require extra caution. Howarth gives the counter argument that after an accident it is often claimed that the child 'was running heedlessly into the road so that there was nothing the driver could do to avoid the accident'. Such an excuse, if accepted, proves, according to Howarth, that people generally believe the propaganda and not the factual statistics which, if expressed in a similar way, would say: "There was nothing the driver could do to prevent the accident because our contention that this child behaved heedlessly is backed by the well-established fact that five-year-old children only succeed in avoiding 99.999% of potential accidents." (p. 531)

The interesting aspect of Howarth's studies is that they are not restricted to accidents. The apparently reckless behavior of drivers is not only present in a few fatal encounters; conscious risk evaluation seems to be lacking all the time. Thus it appears that accidents are not atypical occurrences in which risk was handled in manner totally different from all other cases in which nothing happened. The difference between safe crossings and accidents resides in the behavior of the children. The only way in which a theory of conscious risk evaluation could account for these data is by arguing that the theory is meant to apply to children, not to adults.

Dangerous products

Another illustration of the dissociation between risk attitude and risky behavior is the effectiveness of warnings on labels. Our group at Leiden University has conducted a number of studies on the design and use of warning labels on dangerous products used by professionals (Souverijn, 1989) and lay persons (Venema, 1989). The Dutch National Centre for Information on Poison receives about 4000 queries a year about acute poisoning by cleaning fluids and do-it-yourself products. Probably there are many more cases. This is why we were asked to study the effects of warning labels on these products. We interviewed 779 people in the age range of 12 to 79 years. Ninety-seven percent claimed that they read warnings on dangerous products, although 40 percent added that they read warnings only if the product is new to them. Similar percentages were found for professional vermin-killers and farmers.

Such outcomes indicate only that people are generally aware of the dangers of certain chemicals, and that it is socially desirable to read warning labels. However, in an observation study it transpired that people are not behaving in accordance with such beliefs. In a home-economics fair we organized a stand in which new products were introduced. We invited visitors to try the new products. The products were Green-Free (a vermin-killer for plants), Texatok (a vermin-killer for

unpainted wood), Verf-Fix (a paint remover), and Candle-Light (a fuel for fondue sets). The participants were asked to try the newly designed bottles and cans through actual use, such as spraying a plant, and refuelling the burner. The instructions included the use of gloves, not sniffing at the bottle, closing the can after usage, extinguishing the fire before refuelling. The environment was a simple kitchen mock-up, that provided all the necessary tools, such as apron, gloves, etc. The observed behaviors are portrayed in Table 1.

Table 1. Behavior of visitors trying out new products in a home-economics fair.

Product	N	Reading label	Following instructions Without reading	After reading
Green-Free	104	31%	22%	60%
Texatok	104	13%	45%	70%
Verf-Fix	180	39%	24%	54%
Candle-Light	166	29%	87%	98%

Despite people's expressed attitudes towards reading labels on new products, they were in fact reading labels in a minority of the cases. Reading of labels lead to a significant increase of following the instructions, but the effects were far from maximal. Why did our subjects not read the labels? Fifty-five percent of those not reading the labels said they forgot. Habit was mentioned

by 8 percent. Not seeing the label was mentioned by 14 percent. Thus in 77 percent of the cases not reading the labels had nothing to do with conscious decisions, but rather with routinized behavior. Not using gloves, or not extinguishing the open fire of the burner, was explained by routine behavior (it's never necessary, I forgot, I never do that, I hate gloves) in 57 percent of the cases.

The relation between beliefs, attitudes and behavior is apparently weak. This has been noted before (e.g. Nuttin, 1975; Midden, 1986). It is easier to change attitudes than behavior. If perceptions of risk, revealed by attitudes, are used in a conscious risk evaluation that precedes behavior, this lack of relationship is hard to explain. However, if behavior is mainly determined by pre-arranged routines, it is easy to understand that a change of risk-attitudes would only result in behavioral change if the existing routines are broken down, and replaced by new routines.

Once a certain degree of dissociation between attitudes and behavior is assumed, another question emerges: how can we be certain that these attitudes existed prior to the investigation, instead of being the product of the investigation? Attitude measurement and the assessment of subjective risk share this problem of engaging subjects in questions that might be totally new to them. Most subjects are very much willing to oblige the experimenters, and will therefore reply to questions as

good as they can. But this does not mean that they have considered such questions before, and even less that their replies constitute a psychological reality. What evidence is there that people do of their own account engage frequently (or at all) in the type of risk evaluation prescribed by normative theories? Most of the experiments we have been conducting in the past 20 years bring subjects in situations in which their responses, no matter what they are, cannot be interpreted in another way than to mean that risk evaluation takes place. This constraint is true for the old choice-among-gambles situation, for the heuristics and biases studies, for the risk-factor investigations, and even for process-model experiments. None of these paradigms guarantee that the type of process proposed by our theories does really occur outside our experimental settings. In the next section I will therefore look more closely at some accident histories, to disclose whether risks considerations are found in the descriptions of how the accident happened.

Accident histories

Accidents are usually studied retrospectively, i.e. the situations in which accidents may occur, are represented by the subset of those situations in which accidents did actually occur. Retrospective studies have as a general disadvantage that it is impossible to control for confounding variables, of which there usually is an

abundance. On top of that accident studies have the disadvantage that there is no control group of situations in which no accidents occurred. This is unfortunate, because it is quite possible that there is a fundamental difference between those dangerous situations that developped into an accident, and those that did not. The difference might even be in the amount or type of risk consideration that took place. The distinction between at least two modes of operation, the routine application of fixed behavioral patterns, and the conscious consideration of risk, leads to the prediction that perceived risk (or subjective risk) and actual accident rates (objective risk) are unrelated, or even inversely related. "Perceived risk is likely to generate awareness of danger and avoidance of accident involvement, whereas danger which is not perceived will tend to result in accidents" (Jorgensen, 1988, p.660). Thus, if in everyday life people are avoiding risks that therefore rarely materialize, while they are hit by risks they never really considered, the study of accident histories will reveal that people generally fail to analyse the risks that are facing them. One could argue that for this reason accident histories are not the appropriate material for the study of risk evaluation. The counterargument is exemplified by Howarth's study of child-car encounters. The unresponsiveness of drivers is universally present, in safe and fatal encounters alike. The subset of fatal

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encounters studied as accidents would not cast a false light upon the population of all encounters. Another counterargument is that the study of behavior that leads to accidents is valuable, even if that behavior is exceptional. If routine behavior is the major source of accidents, then it is still true that measures for the prevention of accidents should not assume a continuous assessment of risks.

The Herald of Free Enterprise. A much discussed accident in Europe was the capsizing of the Herald of Free Enterprise, a roll-on roll-off ferry boat sailing between Zeebrugge and Dover. One hundred eighty people died in the accident because the ship toppled over within a few minutes. At the inquest it transpired that the bow doors, through which the cars enter the ship, had been left open, so that sea water had free access to the car decks. It was the assistant-bosun's task to close these doors, but this functionary had taken a nap, and did not wake up in time. There were no alarm lights, signalling the open bow door on the bridge. The captain had applied for such lights, but the request had been turned down with the argument that a senior officer should monitor the closing of the doors, and that therefore there was no possibility of the doors staying open. In fact the ship's crew had adopted a 'negative checking' system: functionaries did not control one another, but assumed all was well as long as there

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were no alarms. The first officer, responsible for the supervision of the assistant-bosun, had left the car deck before the closing of the door could take place, because he had some more urgent duties. This urgency was again due to a chronical shortage of staff.

Another aspect of the accident had to do with the question why the water entered through the open doors, which were several meters above sea level. Here it appeared that the Herald was originally designed for the connection Dover-Calais. The ramp in Zeebrugge differed from the ramp in Calais; at high tide it was not possible for the cars to reach the upper deck. Therefore the nose of the ship had been lowered a few meters through the filling of the ballast tanks. The ballast pumps did not have a sufficient capacity for emptying the tanks in a short time. The Herald had docked in Zeebrugge five minutes late, but was requested to arrive in Dover 15 minutes early. Therefore there was no time for waitng till the ballast tanks were empty. Instead, the Herald left the harbor with the nose three meters down, and at full speed, which created a high bow wave. And so the Herald capsized, in perfect weather, and on a practically waveless sea.

Enter Figure 1

A summary of the events is presented in Figure 1. Each branch of the tree is an event, and each lense-shaped

figure a logical AND. Some of the events that were discussed above are identified in the tree. The interesting aspect of the accident is that the actions immediately preceding the capsizing were, although extremely dangerous, not the result of a deliberate acceptance of risks. The assistant-bosun failed to wake up, but not because he thought the risk was acceptable. The captain failed to notice the open bow doors, but not because he thought he could risk it. The first officer applied the negative control operation without consideration of the risk that the whole ship might perish. On the contrary, the accident scenario is so complicated, stretches out over such a long period of time, and involves so many actors, from the car deck to the upper management levels of the company, that no one could have predicted that on this particular day this specific accident would happen. If interviewed about the possible causes of major accidents with ferries, even the experts would only list such conditions as storm, collision with other traffic, grounding, fire, shifting cargo, explosion, and the like. Nobody would include a sleeping assistant-bosun. Accidents like the one with the Herald have been called 'Inconceivable events' (Oestberg, 1984) or 'Impossible accidents' (Wagenaar and Groeneweg, 1987). The disturbing aspect of impossible accidents is that, since they cannot be foreseen, they are never considered as possible risks. Here we encounter again the

mechanism noted by Jorgensen (1988): accidents that are reckoned to belong to the possible outcomes may be avoided, impossible accidents are not, and are therefore bound to occur. It is quite likely that major accidents in comparatively sophisticated systems will all be of the impossible type, that follow a scenario that was never envisaged, and definitely not considered by those making the last fatal steps at the sharp end of the system. Our main question, are accidents the result of misperceived risk, could be rephrased as: are there other than impossible accidents?

Fifty-seven accidents at sea. Our group in Leiden studied a large number of histories of accidents that happened at sea (Wagenaar and Groeneweg, 1987); police shooting accidents (Groeneweg and Wagenaar, 1986); accidents in oil exploration and production (Groeneweg and Pleit-Kuiper, 1987); accidents in electricity transport (Van de Roovaart, 1987). All accidents were represented by means of event trees, such as the one presented in Figure 1. The role of risk taking was specifically studied in an analysis of 57 accidents at sea that were presented to the Dutch Shipping Council, the legal authority dealing with the judiciary investigations of accidents at sea (Hagenzieker and Wagenaar, 1987). Each accident was described in an elaborate report to the Council, sometimes covering well over 100 pages. The rationale of our

analysis was that risk evaluation presupposes a number of successive subprocesses. First the relevant information is sought or received. Then the status quo is analyzed, in order to establish whether there is a problem that requires a decision. If a decision needs to be taken there is an investigation of the available choices, their possible consequences, and how these consequences are to be valued. Finally there is a stage in which, following some decision rule, risks are accepted or rejected. Accident histories with the level of detail as present in the reports of the Dutch Shipping Council allowed us to ascertain with some degree of confidence in which stage of the decision process things went wrong. The outcome of this analysis is presented in Table 2.

Table 2. Where errors occurred in 57 accidents at sea presented to the Dutch Shipping Council in the years 1984 and 1985.

Stage	Errors	
Seeking or receiving information	17	21%
Evaluation of status quo	21	27%
Listing of choices	12	15%
Investigation of consequences	16	20%
Evaluation of consequences	13	16%
Acceptance of risk	1	1%

The total adds up to more than 57, because in some accidents more errors were included in the analysis. It

was not always evident in which category an error belonged, and some rather arbitrary decisions had to be taken. The ambiguity is reflected by a separability score, which was obtained by subtracting from 1.0, the number of times there was doubt which of two categories should be chosen, divided by the total number of classifications in the two categories. The resulting scores are presented in Table 3. The lowest separability existed between the investigation and evaluation of consequences. Not considering a consequence at all was hardly distinguishable from underestimating the severity of a consequence. Here are some examples of errors that were classified in the various categories.

Seeking or receiving information: The light on the telegraph was broken; Maps were obsolete; Danger warning was not received because the radar was switched off.

Evaluation of status quo: The captain assumed he would not need a pilot.

Listing choices: The rules specified that no extra man was required on the bridge; hence this option was never considered.

Investigation and evaluation of consequences: Captain says that rules were silly; Skipper claims it is alright to

predict encounters without plotting; Captain says the probability of an accident was negligable.

Acceptance of risk: Captain says the risk of a collision was smaller than the risk of a grounding.

Table 3. Separability of the process stages in the the analysis of 57 accidents at sea.

	Evalu. status quo	Listing choices	Invest. of conseq.	Evalu. of conseq.	Accept. of risk
Seeking or receiving inf.	1.00	1.00	1.00	1.00	1.00
Evaluation of status quo		0.79	0.97	0.97	1.00
Listing choices			0.96	0.96	1.00
Investigation of consequences				0.20	0.94
Evaluation of consequences					0.85

The reason for classifying the mentioned errors under 'Investigation of consequences' and 'Evaluation of consequences' was that the negative consequences were either denied or their likelihood belittled. Only in the one case classified under 'Acceptance of risk' there was a full analysis and understanding of the negative result that finally came out. The risk was accepted because the alternative choice was judged to be riskier. In the end the Council decided that this judgment had been wrong.

This inventory lends little support to the notion that accidents occur because risks are evaluated and accepted by those directly involved. In 21 percent of the cases the information about the immanent danger was not even available. In another 27 percent the information was received, but the situation was not recognized as problematic. In still another 15 percent the error was in not considering the alternative that would have solved the problem. Thus, in 63 percent of the cases there was definitely no decision preceded by a conscious analysis of the relevant risks. In a further 36 percent of the cases it is not totally clear what happened. The consequences were either not foreseen, or the likelihood of disaster underestimated. In case the consequences were not at all foreseen, it is quite possible that action was taken on a routine basis, again without consideration of any risk. A skipper who even at the inquest claims that encounters between ships can be predicted without plotting the positions would probably also not have considered the risk during the actual manoeuvre. Therefore I will assume that those errors classified under 'Evaluation of consequences' represent cases that were handled without a conscious analysis of the risks. Hence, in a total of 83% of the cases errors were not due to a calculated acceptance of risk.

Levels of operation. The errors as listed above raise questions with respect to the locus of decision making.

The employment of out-of-date maps prevents a captain from being warned against wrecks that have recently gone down. Thus, on the spot, the captain cannot evaluate the risk of sailing near wrecks. However, the use of out-of-date maps might itself also be the result of a decision, taken much earlier in the process. This decision might have been based on risk considerations. The broader issue, hidden behind this problem, is the definition of levels of operation. The routine behavior of drivers, captains, operators, and all those who cause accidents at the sharp end of the system, is often preceded by some less routine-like planning. Van der Molen and Boetticher (1988) distinguish in their model of driving behavior three levels. The operational level, which describes the ongoing behavior during actual driving. The tactical level, describing incidental decisions such as overtaking, stopping at traffic lights. The strategical level, at which long-term decisions are taken, such as route choice, and choice of average speed.

A similar distinction among levels of operation was introduced by Rasmussen (1982, 1983). He distinguished skill-based behavior, which runs mostly automatically; Rule-based behavior, which operayes through the application of consciously chosen but fully pre-programmed rules; Knowledge-based behavior, under which all sorts of conscious problem solving are grouped. This subdivision is

also at the basis of Reason's GEMS model (Reason, 1989), which is illustrated in Figure 2.

Insert Figure 2

It is tempting to combine these two tripartitions by equating the operational level with skill-based behavior, the tactical level with rule-based behavior, the strategical level with knowledge-based behavior. One rationale of this equation would be that in both systems risk evaluation is absent at the bottom level, and fully present at the top level. The two systems differ with respect to the amount of risk evaluation that takes place at the middle level. Van der Molen and Boetticher assume some sort of quick-and-dirty risk assessment, while Rasmussen excludes any type of risk assessment that is not incorporated in fixed rules. A possible reconciliation is obtained by assuming that any amount of risk assessment at the tactical level operates through the application of fixed decision rules, such as rules for overtaking other traffic, based on perceived distances and velocities. The adaptation of such rules would then occur at the top level.

The distinction among levels of operation can be applied upon accident histories, such as the capsizing of the Herald of Free Enterprise. The routine actions of the assisitant-bosun, the deck-officer, and the captain, are

represented at the bottom level. Decisions such as to leave with the nose down in order to gain 20 minutes are taken at the intermediate level. Decisions such as the adoption of a negative checking procedure, the understaffing, the use of a ship not designed for that route, the use of the ballast tanks for levelling with the ramp, the chronic acceptance of too short turn-around times, are taken at the top level. The three levels of operation are in this manner spread across time, and across levels of the organization. The top level has to do with management decisions high up in the organization, a long time before accidents occur. The bottom level has to do with operator decisions taken at the work floor shortly before the accident. Our initial question: 'Are accidents caused by faulty risk assessments?' is possibly answered differently for the various levels of an organization. There is little evidence that risk assessment occurs at the bottom level; hence inadequate risk considerations of the actors directly involved are rarely among the causes of accidents. At the intermediate level the actors in the drama apply rules of the if...then type, which means that the application is dictated by the circumstances. A specific assessment of the risk involved does not take place every time the rule is applied. But the generation and maintenance of these if...then rules is under the control of conscious deliberations at the top level. In this way if...then rules may embody faulty risk

assessments, even when the rule is thereafter applied without any consideration of the risks involved. Finally, at the top level, there are many deliberations that may well involve a consideration of risk, trade-off between safety and costs, and willful acceptance of calculated risks.

It is obvious that the accident histories described in accident reports, and considered in our analysis of accidents at sea, will contain almost exclusively behavior at the two lower levels. Behavior at the top level is localized in entirely different sections of an organization, and occur at a time that may antedate the accident by many years. It is therefore no surprise that so little conscious risk taking was observed. But this does not mean that the outcome is trivial or meaningless, because the tenet that risk taking rarely occurs at the operational level is not universally accepted. Many industrial organizations attempt to improve their accident statistics by advertizing safety awareness to employees on the shop floor. Our conclusion that consideration of risk occurs mostly at the strategical level means that risk communication, as a means to prevent accidents, could most profitably be directed at those levels of an organization where strategical planning is executed. Only knowledge-based behavior can be modelled by consideration of risk.

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The capsizing of the Herald of Free Enterprise yields many examples of useful targets for risk communication.

- The captain's decision to leave at full speed is a less promising target for improvement than the tight time schedules that prevail in most ferry lines. It should be possible to convince the ship owners, the harbor authorities, or the national governments, that the turn-around time of ferry boats should be made longer. This will probably require the construction of more berthes, but that is easier to achieve than a change of behavior in all those instances in which a crew may under time pressure adopt dangerous procedures.
- Banning the irresponsible use of the ballasting facility will save fewer lives than forcing top management to monitor on a regular basis the practices that result from their decisions. Shipowners must realise that a regular audit of operational procedures is needed, because otherwise they cannot know the side effects of their managerial decisions. Technical safety audits are by now almost universally accepted for nuclear power plants. There is no reason to exempt ferry boats, with their considerable killing potential, from such obvious practices. The lack of regular audits is a more serious flaw than the adoption of a negative checking routine.

- Adopting international rules about the closing of bow doors will have less effect than adopting rules about the quality of organizations that are licensed to operate public transport systems. Risk communication efforts could be directed at national governments, in order to convince them that safety requirements should extend to those levels in the organization at which the actual risk management takes place. Bus drivers, train drivers, and ship masters, are selected and thereafter examined according to strict rules. But their managers, who may cause much greater havoc, are not.

Conclusion

Are accidents caused by faulty risk evaluations? My answer is no, not at the level of those directly involved at the sharp end of systems. The behavior of people walking in the streets, driving their cars, doing their regular jobs on a routine basis, may be among the causes of almost all accidents. But these people do rarely consider these accidents in advance; they run risks, but they do not take them. Much more risk evaluation occurs at the blunt end of the system, where the planners are, the designers, the managers, the authorities that make decisions in lieu of millions of others. But these evaluation processes are rarely considered in accident histories, rarely adapted after the occurrence of

accidents, and rarely the target of risk communication programmes, possibly because the illusion that most risks originate at the operational level is too strong.

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Figure 1

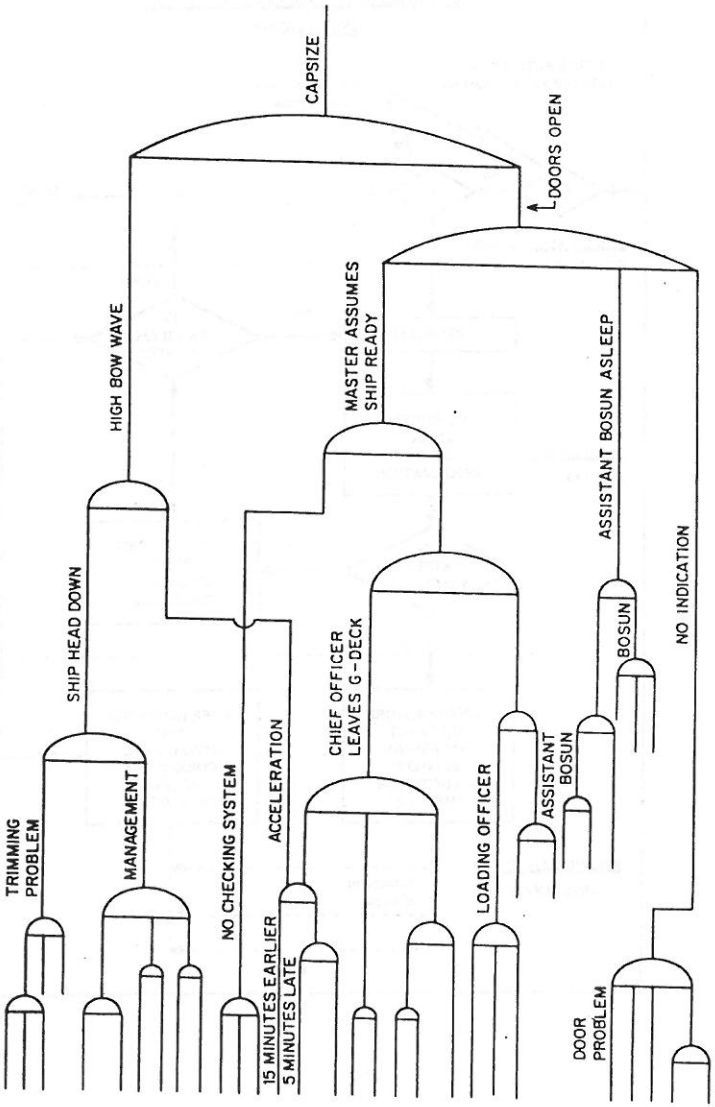
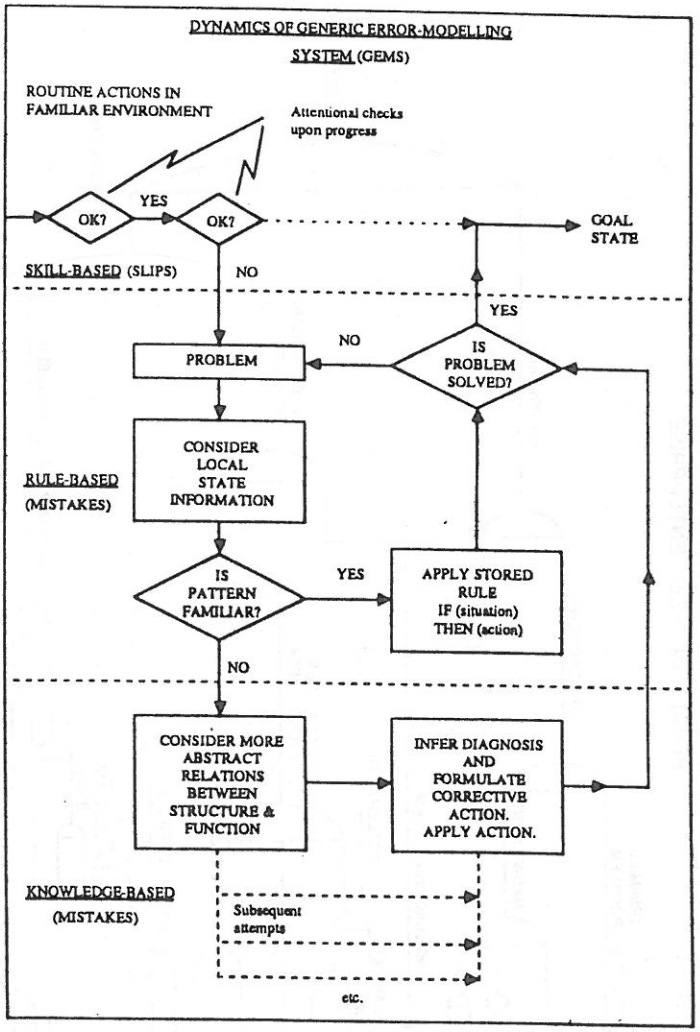

HERALD OF FREE ENTERPRISE
CAPSIZE
DOORS OPEN
HIGH BOW WAVE
SHIP HEAD DOWN
TRIMMING PROBLEM
MANAGEMENT
NO CHECKING SYSTEM
15 MINUTES EARLIER
5 MINUTES LATE
ACCELERATION
MASTER ASSUMES SHIP READY
CHIEF OFFICER LEAVES G-DECK
LOADING OFFICER
ASSISTANT BOSUN
ASSISTANT BOSUN ASLEEP
BOSUN
NO INDICATION
DOOR PROBLEM

Figure 2


DYNAMICS OF GENERIC ERROR-MODELLING SYSTEM (GEMS)
ROUTINE ACTIONS IN FAMILIAR ENVIRONMENT
Attentional checks upon progress
OK?
YES
OK?
GOAL STATE
SKILL-BASED (SLIPS)
NO
YES
NO
PROBLEM
IS PROBLEM SOLVED?
CONSIDER LOCAL STATE INFORMATION
RULE-BASED (MISTAKES)
IS PATTERN FAMILIAR?
YES
APPLY STORED RULE IF (situation) THEN (action)
NO
CONSIDER MORE ABSTRACT RELATIONS BETWEEN STRUCTURE & FUNCTION
INFER DIAGNOSIS AND FORMULATE CORRECTIVE ACTION. APPLY ACTION.
KNOWLEDGE-BASED (MISTAKES)
Subsequent attempts
etc.

A. Workshop on Institutional Management of Risk.

Convenor: Baruch Fischhoff, Carnegie-Mellon University, USA.

The proliferation of technological hazards, and the accompanying pressure for accountability, has prompted the development of various institutions for risk management. At times, this development has been planned; at times, it has been an impromptu response to political or physical crises. In this workshop, we will examine the current state of institutional risk management, and the role of SPUDM participants in it.

Crisis Risk Management

Joanne Linnerooth, IIASA: "The international response to Chernobyl: Prospects for an international safety regime"

James Reason, University of Manchester: "Managing the managerial contribution to risk in hazardous technologies"

Nicholas Pidgeon, Birkbeck College: "Crisis and routine: Learning the lessons of (near) disasters"

Distributive Risk Management

Zur Shapira, New York University: What managers say about organizing for risk managment.

Daniel Kahneman, University of California, Berkeley: Agency theory in risk management.

Jennifer J. Halpern, University of California, Berkeley: "Cognitive factors influencing decision making in a highly reliable organization"

Management of Financial Risks

Werner De Bondt & Richard Thaler, Cornell University: "Are security analyst forecasts rational?"

Richard Gonzalez & Amos Tversky, Stanford University: "The effect of others' decisions on stock selection"

Thomas Russell, Santa Clara University: "Portfolio choice for agents who fail to maximize expected utility"

B. Workshop on modeling knowledge for intelligent decision support.

Convenors: Helena Moshkovich, Institute for Systems Studies, USSR and Patrick Humphreys, London School of Economics, U.K.

Synopsis

This workshop aims both to go beyond the once popular and now largely discredited idea that a decision maker may be aided (rather than replaced) merely through capturing relevant knowledge in declarative form, formalising it in a 'knowledge base' and then applying this knowledge in a similar way as would an unaided decision maker. We will emphasise issues relevant to the provision of fully interactive support for decision makers facing higher level problems which are initially unstructured (or partially or poorly structured) and where the decision maker has considerable discretion in the selection of methods to formulate and implement a policy for action.

First session (two hours).

(i) Overview: Scope of the workshop and issues to be addressed.

Helena Moshkovich, Institute for Systems Studies, USSR.

(ii) Presentations on Techniques and problems in eliciting and structuring knowledge from stakeholders in decision problems:

Knowledge elicitation methodologies: The good, the bad, and what is needed.

Willy Cats-Baril, University of Vermont, USA.

Mutual conversion of information and knowledge.

Yuri Schrader, Institute of Science and Technical Information, USSR.

Structuring opinions in conflict resolution.

Anna Vari and Klara Farago, Hungarian Public Opinion Research Institute, Budapest.

(iii) Workshop discussion.

Second session (two hours)

(i) Presentations on Knowledge representation, systems logic and conceptual modeling:

Generating conceptual models in support of decision making
Patrick Humphreys and Dina Berkeley, London School of Economics.
Systems logic for problem formulation and choice.
Eric Nappelbaum, Institute for Systems Studies, USSR.
Knowledge representation for policy designing
Peter Neijens and Jan A. Ridder, University of Amsterdam

(ii) Workshop discussion

Third session (two hours)

(i) Presentations on Support system design and implementation:

ARIADNE: The knowledge elicitation support system
V.K. Morgoev, Institute for Systems Studies, USSR
Model-based decision support for large and complex issues.
Elizabeth Weigkricht, International Institute for Applied Systems Analysis, Austria.
Developing CHESS: a community-wide decision support system.
David Gustafson *et al.*, University of Wisconsin-Madison, USA.

(ii) Workshop discussion

(iii) Conclusion: Some issues and themes of the workshop
Helena Moshkovich, Institute for Systems Studies, USSR.

C. Workshop on Process Tracing and Process Models.

Convenor: Ola Svenson, University of Stockholm, Sweden.

In future process studies of decision making at least two lines of research need to be developed further. The first of these is represented by work on models or theories for decision processes and the second by studies of the effects of interesting independent factors on decision processes. Therefore, the development of more strictly defined and yet general models of decision processes will be one theme of this workshop. The other theme will treat the application of process tracing techniques in studies of factors which may affect these processes (like information overload, stress, motivation, depression, etc.). The workshop will treat decision making only and not include judgement this time.

D. Workshop oh Stucturing Decision Analysis:
Statistical and Psychological Consideration.

Convenor: Peter Politser, Harvard University, USA

This workshop will investigate some important practical questions of how to do Decision Analysis, including the stucturing and evaluation problems.

E. Workshop on Negotiator Cognition and Rationality: Extending the Domain of Negotiation Research

Convenor: Margaret Neale, Northwestern University, USA

Workshop Overview

This workshop is organized around negotiation research which specifically integrates existing prescriptive and descriptive approaches to negotiation. From this perspective, rational models of negotiation provide descriptive researchers with a necessary anchor from which to describe systematic deviations and illuminate a goal state that the negotiator is trying to achieve. Behavioral theory and research clarify deviations from rational behavior that a focal negotiator can expect from an opponent and provide indications of cognitive barriers that limit a negotiator's ability to follow prescriptive advice.

The research presented in this workshop extends negotiation research beyond the study of novice negotiators in a single, dyadic negotiation to the study of common, yet unrepresented, contexts of negotiation. Specifically, this workshop will focus on the following four areas:

1. The Role of Expertise in Negotiator Performance. The impact of experience and expertise on negotiator performance. These studies examine the descriptive impact of expertise and explore the factors which influence the development of negotiator expertise. ***Presenters: Margaret Neale and Gregory Northcraft***

2. Group Negotiations. Group negotiation is a mixed-motive task. Previous research has typically assumed that groups are either purely cooperative or purely competitive. As such, the usefulness of much of the previous research on groups and group decision making is limited. In this presentation, the impact of group negotiation on the vulnerability to judgmental biases and the impact of negotiation within a larger social context will be examined. ***Presenter: Elizabeth Mannix***

3. Market Negotiations. While most negotiation studies have been studies in two-person contexts, this presentation will focus on the relatively rare negotiations that take place in market settings. From this perspective, negotiators in a market have a two-dimensional task. They must first determine the specific identify of their negotiating opponent and then negotiate the actual agreement. ***Presenters: Harris Sondak and Max Bazerman***

4. Negotiating through Intermediaries. This portion of the workshop will emphasize negotiations which occur though intermediaries such as agents, mediators, among others. The results of the studies will illustrate differences in the impact on the negotiation outcome and process of various types of intermediaries. ***Presenters: Max Bazerman and Margaret Neale***

First session

Introduction.
Margaret Neale, Northwestern University, USA

The role of expertise in negotiator performance.
Margaret Neale, Northwestern University, USA

Cognitive characteristics of negotiators, structure of negotiation tasks, and the potential for optimal settlements.
Jeryl Mumpower, State University of New York, USA

Second session

Improving negotiator cognitions.
John S. Carroll, Massachusetts Institute of Technology, USA

Adaptive reference points in decision making and negotiation.
William P. Bottom, Washington University, USA

Negotiating through intermediaries.
Max Bazerman and Margaret Neale, Northwestern University, USA

Discussant: Zur Shapiro, Hebrew University, Israel

Third session

Introduction.
Elizabeth Mannix, University of Chicago, USA

Group negotiations.
Elizabeth Mannix, University of Chicago, USA

Market negotiations.
Harris Sondak, Northwestern University, USA

Workshop summary.
Max Bazerman, Northwestern University, USA

A MORE ROBUST DEFINITION OF SUBJECTIVE PROBABILITY

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Ramat–Aviv, Israel

January, 1989

Although their goal is to separate a decision maker's underlying *beliefs* (his or her subjective probabilities of events) from properties of their *preferences* (his or her attitudes toward risk), existing choice–theoretic derivations of subjective probability all rely upon some form of the von Neumann–Morgenstern 'independence axiom' or the Savage 'substitution principle,' which is equivalent to assuming that the decision maker's preferences over lotteries conform to the expected utility hypothesis. This paper presents a choice–theoretic development of classical subjective probability* which neither assumes nor implies that the decision maker's preferences over lotteries necessarily conform to the expected utility hypothesis.

* That is, a probability measure satisfying all of the Kolmogorov properties

We are grateful to Peter Fishburn and David Kreps for helpful discussions on this material. Responsibility for errors and opinions is our own.

A proper scoring rule for eliciting inter-subjective information

Dražen Prelec

The paper addresses the problem of eliciting information from a group of experts, when there is no external criterion for scoring judgments (because the events that make the judgments true or false are not known). This problem arises, for example, in interpreting the political significance of documents or treaties, appraisal of art objects, evaluation of complex commodities, such as wines, etc.. The proposed solution consists of a mutual but *competitive* proper scoring rule, in which two or more experts attempt to outguess each other's responses. It is proved that optimal play requires each expert to fully reveal all private information about the issue being considered, and that his or her long-run score will equal the statistical information transmitted (in the Shannon-Weaver sense). The procedure is illustrated with some experimental results, obtained from an interactive three-person game, in which the information is elicited in the form of subjective probability judgments for true-false propositions (constructed by the players themselves).

Fuzzy Sets Theory and Decision Making

Ilian Tchorbadjiev, Vladimir Antikarov

1. Introduction

Traditional mathematic and logic provide no methods for representing the meaning of vague information. This kind of formal systems are not suitable for making decisions in ill-structured environment and especially in purely subjective tasks. This paper propose an operational method for evaluating uncertainty situations. The method is based on the fuzzy set approach - so called fuzzy sets with interval membership function. In general such approach is quite powerful to be used in a lot of applications - standard decision theory, risk analyses, hierarchical analysis and decision trees, fuzzy optimization task, evaluation of verbal models, etc. The method is demonstrated by using Decision Support System SupREme, especially designed for these purposes.

2. Fuzzy set basis

Standard fuzzy set is a set of couples ‹x. (x)›, where x U and normally :U-› [0.1]. This means that fuzzy set is a normal Kantor set distinguish only by extended membership function, i.e. in standard case membership relation is defined over [True,False] set. The fuzzy set with interval membership function extended - mapping over subsets of [0,1] or P([0.1]).And the assignment [b.a] has to be interpreted as 'Confidence factor or degree of belief in x is not more than a and not low than b'. Geometrical image of this assignment is an convex area in I or II quadrant of Dekart space and it is not a curve like standard fuzzy sets assignment. All standard fuzzy set operations can be extended over interval based fuzzy sets. The only way to do this is to used interval arithmetic and logic. Each set is represented as a system of interval levels (parametrification using degree of belief) and after that interval operations are applied over each

member of the system. Practically this is the computation core of DSS SupREme.

3.Applications study

Finally DSS SupREme is used to solve following problems:

3.1 Decision Theory. The decision maker (DM) must choose some action Ai without knowing beforehand the state of nature. The DM wishes to maximize the payoff and thus the 'best' action Ai is Ai={Pij/Sj}j, where Sj is a state of nature and Pij is payoff if occur Ai and Sj. In uncertainty case Pij or Sj may be fuzzy variables. Therefore, an action could be fuzzy variable too.

3.2 Evaluation of Verbal Models. If it is necessary to make a truth estimation on the proposition 'X is F', where F is a fuzzy subset of U, the truth value is defined to be the degree of consistency with some observed data.

3.3 Generalizing Evidences. The decision maker must collect and generalize different evidences with different confidence.

3.4 Hierarchical Analysis. The A={Ai} is alternative set and C={Ck}k is criteria set. The overall objective is to choose the best alternative satisfying the criteria.

A logic of decision making

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April 1988

Abstract

Traditional numerical frameworks for decision making, such as the classical maximisation of subjective-expected utility, are often too restrictive for developing realistic decision models or applications. The principal group of restrictions inherent in numerical decision theories is that they make no provision for reasoning about the decision process itself. Classical decision processes cannot reflect on what the decision is, what the options are, what methods should be (or have been) used in making a decision, and so forth (Fox, 1983). We argue that recent quarrels about the "correct" way of representing and propagating uncertainty and belief have distracted from these deeper problems and limited progress on theories of decision making. We present an approach which accomodates classical concepts but extends them with non-numerical methods. These include non-monotonic schemata for proposing decision options and propagating beliefs about them; for arguing the merits of options using knowledge of causality, structure, function and so on; and for reasoning about ways of aggregating evidence and arguments which reflect practical or procedural constraints.

Illinois interdisciplinary workshop on decision making
University of Illinois, Urbana, Champaign, June 1988

DRAFT

Evaluating Money: Temporal Influences on Context.

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Abstract submitted for SPUDM 12

Much recent research in decision making has focussed on the effects of contextual factors on judgments and choices. Kahneman & Miller's (1986) article has attempted to integrate much of this work and to provide a conceptual foundation for such effects. The central idea of this article, namely that a stimulus may evoke its own norms or context, was examined in a social context in which experimental subjects were paid for participation. In two different experiments, subjects were told, unexpectedly, that they were going to be paid one dollar for their participation. The dollar, they were told, was the allocation of another subject who had been randomly chosen to determine how much of $6 that had been made available for the *pair* would be given to the other subject. The allocator kept $5. Subjects could either accept the dollar, permitting the other to keep the $5, or could reject the dollar and thereby deprive the other of the $5.

An evaluative context that focuses only on the money should induce subjects to keep the dollar since one dollar is preferred to nothing, all else equal. A context that focuses on fairness, however, could lead subjects to reject the dollar since it falls below the $3 that an equal division would allocate. Our experiments were designed to determine if the salience of these two contexts could be manipulated by varying the temporal order in which they were invoked. In the first experiment, subjects were given information about the allocation procedure but for one third of these subjects they were given the dollar at the same time (money plus information). The others were given the dollar later. We hypothesized that the dollar would evoke a money context that would interfere or compete with the fairness context, leading more subjects to keep the money more often in that condition than in the others. As expected, 74% of the subjects kept the money in that condition compared to 47% in the other two. In the second experiment, we gave one third of the subjects the dollar and told them that we would explain the allocation procedure to them shortly (money before information). For these subjects, the money context should be maximal since it would be evoked prior to a fairness context. We also included the money plus information condition from the first study, and one of the money after information conditions from that study. Seventeen of the twenty subjects (85%) in the money before information condition kept the money, whereas only 50% of the money plus information and 45% of the information before money kept it. This experiment again demonstrated the impact of the temporal order of context evocation, although it failed to replicate the first experiment. Judgments of the importance of different evaluative dimensions (e.g., fairness, making sure both subjects get something) suggest that the weights associated with the choice dimensions may be constructed *after* the decisions are made, not before.

12th European Conference on Subjective Probability, Utility and Decision Making, Moscow, 21-25 August 1989.

ABSTRACT

Eliciting knowledge for intelligent decision support

by

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Developing intelligent decision support systems raises a number of fundamental issues familiar to researchers in artificial intelligence (AI). In particular there often exists a need to model the decision processes and knowledge structures of domain experts and potential system users as a prerequisite to system development. The paper focuses upon the use of AI techniques of knowledge elicitation in identifying and representing individuals' knowledge for intelligent decision support. Knowledge elicitation involves the processes of obtaining, analysing, and agreeing with the expert an initial representation of the core knowledge deemed relevant to the development objectives of the proposed decision support system. Experience in the field of AI has shown that close attention to all aspects of knowledge elicitation is an essential prerequisite for building intelligent knowledge-based systems. It is argued that knowledge elicitation can be characterised fundamentally as a creative, interpretative activity, which often involves the analysis of qualitative forms of data (e.g. interview transcripts, verbal protocols). A number of current techniques for knowledge elicitation are outlined, focusing primarily upon psychometric and observational/interviewing approaches; these include multidimensional scaling, the repertory grid, protocol analysis, grounded theory and discourse analysis. The importance of deriving explicit, and appropriate, methods for the practical analysis of data obtained from human expert sources will be discussed.

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Knowledge Acquisiton Methods: A Computer-Aided Approach

by

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We employed four approaches to acquiring knowledge for an expert system to support business and economic forecasting. These included a review of the relevant empirical literature, a survey of experts in forecasting, direct assessment, and protocol analysis as forecasters solved forecasting problems. A decision support system was developed to support the protocol analysis. The four approaches were compared. Particular emphasis was given to the process aspects of the protocol analysis. The benefits of the various approaches are described as well as their costs. The importance of the decision support system in reducing the costs of protocol analysis is examined. Suggestions are made for selecting among these approaches, dependent upon the types of knowledge required.

BASIS OF KNOWLEDGE SYSTEM

A.Yu.Terekhina (USSR)

In this paper, the process of knowledge structuring in the memory is studied by multidimensional scaling methods. The focus is on how the knowledge structure is organized in the memory, what affects this process, what it reflects, the relationships between the knowledge structure and skills, experience, and nature of activities.

Knowledge of an unskilled person is in correspondence with a multidimensional fuzzy semantic space. Domain is perceived as a set of unconnected concepts. It is only for a skilled specialist that the entire set is described with a small combination of generalized attributes. The degree of attribute generalization is a function of learning. It is easy to distinguish a skilled specialist from unskilled one by the character of semantic space.

Since knowledge is stored in memory in the form of an organized system and can be represented graphically, semantic space is a convenient tool for monitoring and communicating knowledge. It considerably facilitates realization, assimilation and memorizing of new material.

The principle of representing conceptual systems in the form of geometrical structure with a basis of independent attributes is universal. It was tested on a wide range of areas and has a number of practical implications. This method makes it possible to present structures of knowledge in a form convenient for analysis, easily test and communicate it, and all this opens up opportunities for programmed development of knowledge structures.

CONSTRUCTION OF ARTIFICIAL SYSTEMS IMITATING EXPERTS'KNOWLEDGE

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Abstract

One of the most difficult problems in decision support systems and in expert systems is the problem of constructing a knowledge base generating a lot of difficulties of psychological, mathematical and computational nature. The authors have developed a new approach to knowledge base construction solving the following expert classification problem: there are attributes characterizing the object under study; each attribute has an ordinal scale of possible values; it is necessary to assign each possible combination of attribute values to one or several decision classes.

The approach developed by the authors creates certain possibilities. One may: a) structure the problem and find a set of attributes; b) construct a full knowledge base; c) check the expert knowledge for contradictions and create conditions for their elimination; d) find natural explanations for expert decisions.

The authors have developed instrumental systems making it possible to construct in a short time full knowledge bases quite precisely imitating human judgment.

BUSINESS CASE STUDY ON THE VALUE OF MARKET RESEARCH

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One of the world's largest multi-national corporations is evaluating how much money to spend on research on its potential markets, how to spend it and what its economic value will be. This case study highlights more general issues of prescriptive decision research, balancing the need for methodology to be logical sound, feasible to implement and useful to the decision maker.

The company is providing a test-bed for decision and inference methodology being developed by DSC with funding from the National Science Foundation.

GROUP DECISION-MAKING

IN ECONOMIC ORGANIZED SYSTEMS

WITH THE HELP OF MAN-MACHINE PROCEDURES

I.A.ERMAKOVA (USSR)

In a complex economic organized system such as an enterprise or a branch of industry we have to pay attention to an area of responsible decisions. These decisions are made by a group of professionals. There is a need for examining different aspects of a problem under decision. For this purpose it is necessary to have a preliminary period when the experts prepare a kind of decision and appreciate it. This process is described with a help of a network model taking into consideration the interaction of elements and hierarchy of organized structure.

The preliminary period is nessesary but sometimes is inadequate. In this case it is necessary to discuss problem by a group of professionals simaltaneously to find out an unexpected method of resolving a problem. One of the form of such method is a business game that meets the demand of flexibility and novelty but efficiency expressed in terms of quantity.

In the course of economic reform sequentail preparation of decision-making together iterative process of coordination and expedite search of group decision-making with help of man-machine procedures for finding out the best version can be used in practice of strategic policy and operative planning very widely.

DECISION MAKING IN FREE CLASSIFICATION TASK: A PSYCHOLOGICAL VIEW

Rebecca M. Frumkina (Moscow)

Free classification paradigm (FCl) without a feedback was used to study typical behaviors depending on stimuli number, stimuli dimensionality, Ss' ways of task interpretation and E's attitudes.

Experiments reported deal with various types of stimuli, such as real objects (coins, other artefacts), words (color names, names of artefacts and non-artefacts), graphic patterns.

Our main tenet is stated as following: S in a FCl task is not "free" unless we deliberately force him make a really free choice. Notwithstanding any standard instruction, many variables interact to restrict S' freedom, namely: a) number of stimuli presented; b) the proportion of stimuli with certain dimensional features; c) S' interpretation of the task as "common sense" problem vs some test of his intellectual abilities or personal traits; d) S' attitudes toward the E and his goals; e) S' pattern of behavior in any new context.

Types of strategies observed in experiments with 500 Ss are highly correlated not only with stimuli properties but also with personal traits of participants.

Main types of cognitive behaviors in decision making process under FCl conditions are: "rational" S; "zealous" S, a "simple-minded" and an"outsmarter".

Verbal protocols as indicators of typical decision making techniques are discussed in detail.

The naive ontology of a FCl problem space turns out to differ strikingly from rationalistic reasoning, the latter being nothing more than a well-known carthesian belief.

A Process-Tracing Analysis of Consumer Choice for Non-Durables

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ABSTRACT

Over the past two decades the dominant paradigm for describing purchase decisions has shifted from utility maximization to an adaptation to the purchase environment. As future theories of consumer choice will almost certainly be more complex than utility maximization, and more closely tied to the actual process of choice, there is a need is for a sound and sufficiently detailed empirical base.

The goal of this work is a data-driven description of the choice process for consumer non-durables. We examine the choices of forty-seven housewives in three such products categories using eye fixations and verbal protocols as process-tracing methods. As an attempt to remedy the lack of external validity of laboratory studies, the data were collected in a simulated supermarket using real products, prices and shelf-arrangements.

Results include global statistics (viz., time, number of fixations, number of alternatives fixated), the role of the habitual brand in the choice process and the size of the active consideration set (i.e., all alternatives fixated but not yet eliminated). Two major themes of the results are the evidence for distinct stages in the choice process, and the role of direct product comparisons. We find three stages in the choice process: orientation, evaluation and verification, with specific processing operations occurring in each stage. We also find that more than fifty percent of the fixations in the evaluation stage are devoted to comparisons among two or three alternatives and that more than half of these comparisons involve the chosen brand. Analysis of the verbal protocols reveals the frequency of use of product attributes and specific operations such as information acquisition, evaluation, comparison and elimination, including usage trends over the course of the decision process.

We conclude that at least in this specific environment, a choice does not necessarily reflect a concluded decision but is an action forced by time limits. That is, a tentative decision becomes the choice when the decision maker terminates the consideration process, presumably because it is no longer worth more time and effort.

Effort-quality analysis of decision behavior under conditions of sequential information display

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Payne (1982) proposed effort-quality principles to explain the finding that decision behavior is highly contingent upon task demands. Subsequently, Johnson and Payne developed effort-quality analysis by simulation and empirical studies. The basic idea of this approach - i.e., that a decision maker's processing adapts to task demands in such a way that a compromise is reached between the opposite goals of minimizing cognitive effort and making a good decision - is incorporated in the well known criterion-dependent choice models. Within this general framework, it is assumed that processing is only continued until an evidence criterion in favor of an alternative is exceeded. By calculating effort and quality for varying criteria, effort-quality tradeoff functions can be constructed (Schmalhofer, 1987) and used for a comparison of different processing strategies which have been specified in the general framework.

Effort-quality analysis was used to investigate under what conditions alternative-based processing may be employed. Starting from Tversky's conjecture that alternative-based strategies are used if the alternatives are displayed sequentially, different conditions of sequential information display were analyzed with respect to the effort and quality of alternative-based vs. dimension-based strategies. The simulation results support Tversky's conjecture. The predictions of these analyses were thus compared to the data of several experiments in which sequential vs. simultaneous information display and task complexity were varied. Though the empirical results are generally compatible with the predictions of the effort-quality analysis, the tendency towards dimensional processing was stronger than predicted. Alternative-based operations may require considerably more computational effort than dimension-based operations which should be taken into account by further analyses.

References: Johnson & Payne (1985), Management Science, 31; Payne (1982), Psych.Bull., 92; Payne, Bettman & Johnson (1988), JEP: LMC, 14; Schmalhofer (1987), in Uppuluri et al., Expert judgment and expert systems; Tversky (1969), Psych. Rev., 76.

PERCEIVED CONTROL, NATURE OF RISK INFORMATION AND LEVEL OF RISK TAKING; An experimental test of a simple taxonomy of uncertainty

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In a recent paper we have discussed a fourfold taxonomy of uncertainty or risk, based upon two dimensions (Vlek & Hendrickx, 1988). The first dimension concerns the nature of the available risk information: frequentistic information refers to the outcomes of similar situations in the past ("how often did an accident happen?"), while non-frequentistic information refers to the process(es) or scenario(s) resulting in a future accident ("in which way might an accident occur?"). The second dimension refers to the outcome-determining factors: outcomes may entirely depend on external, uncontrollable ('chance') factors, or they may be (co)determined by internal, controllable factors (e.g., knowledge and/or skills).

To study actual risk taking under each of the four resulting types of uncertainty, a computer-implemented experimental task was developed. In each of 60 successive trials subjects had to stop a moving symbol before it passed a target line on the screen. Succes yielded a small gain, while failure led them into a 'penalty task' in which they could incur a considerable loss. On each trial subjects could choose among ten 'risk-levels' (varying symbol speeds), low risk levels resulting in small but almost sure gains, while higher levels yielded larger but less probable gains. Different groups of subjects were presented with task variants differing with regard to three characteristics of the penalty task: (1) probability of loss, (2) either external or internal (chance versus skill) determination of outcomes, and (3) type of risk information made available (frequentistic versus non-frequentistic).

Main findings were: (a) subjects largely ignored frequentistic risk information, while the availability of non-frequentistic (process) information resulted in a significantly lower level of risk taking; (b) internal outcome determination (perceived control) resulted in a significant increase in level of risk taking. Theoretical implications of these findings for the above taxonomy of risk will be discussed.

Ref: Vlek, Ch. & Hendrickx, L. (1988). Statistical risk versus personal control as conceptual bases for evaluating (traffic) safety. In: J. Rothengatter & R. de Bruin (Eds.): Road user behaviour: theory and practice. Assen (Neth.) and Wolfeboro (N.H.), Van Gorcum.

ANALYSIS OF SUBJECTIVE FACTORS IN RISK PERCEPTION

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Large-scale accidents and aggravation of ecological problems drew special attention of scientific community and wide public in the USSR to problems of risk analysis and safety. It is common knowledge that technological risk perception is largely determined by subjective factors. Their study is the topic of this paper.

Three experiments have been conducted. First, subjects had to rank different types of risk, with respect to the degree of danger, profitability, and justification. During the second experiment the subjects had, apart from ranking, to estimate the degree of manifestation of various attributes, in different types of risk, which, as is seen from a number of papers, determine the subjective perception of risk. The third experiment involved a questionnaire according to which the subjects had to estimate, on a 100-division scale, 75 types of risk encountered in our society, and indicate the degree of confidence in one's answer, as well as sources of information on the basis of which the estimate was produced.

The experiments made it possible to analyze the consistency in the respondents' answers, the relationships between risk assesments and mortality rate due to different technologies, dependence of education on technology risk estimates and compare data on technology ranking in the USSR with those conducted in the USA, Norway and Hungary.

ABSTRACT:

DECISION MAKING UNDER RISK:
DIFFERENCES BETWEEN PRIVATE AND PUBLIC ROLES

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The paper deals with an experiment that forces subject to choose between four different options to detect poisoned water in a community water supply system. The expected values for each option are identical, but the ratio of magnitude and probabilty varies from one option to the next as does the possibility for personal control. The subjects were asked to rate the risks and the attractivenes of each option in two different roles: as private citizens and as managers of a risk handling institution. The experiment was first conducted in 1979 in West-Germany with a student sample, it was repeated in 1988 with American College students and risk managers of a large electricity company in New England. The results show that the change of roles reversed preferences in both student samples, but not among the risk managers. They made hardly any difference between their judgements as private citizens or official risk managers.

RESPONSE MODE AND DECISION STRATEGIES

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Research in the field of multiattribute decision making can be categorized according to the type of research paradigm used (process tracing versus structural modelling) and the type of decision required (evaluation of each option versus choice of some options). In all cases the major issue is the cognitive process leading from information input to decision outcome, and more in particular, the question whether this process of information integration follows compensatory or noncompensatory integration rules. Ford et al. (1989) present an overview of the process tracing research in this area. One of their conclusions is that little attention has been paid to the influence of response mode (rating versus choice) on the decision process.

This paper summarizes the results of three experiments intended to investigate the influence of response mode on the cognitive process in multiattribute decision problems. Two approaches were used to analyse the decision process: process tracing by means of an information board and structural modelling by comparing linear, conjunctive, and disjunctive model predictions with subject responses. In addition, several task characteristics (number of options, weights of attributes) were manipulated.

Reference:
Ford, J.K., Schmitt, N., Schechtman, S.L., Hults, B.M., & Doherty, M.L. (1989). Process tracing methods: Contributions, problems, and neglected research questions. *Organizational Behavior and Human Decision Processes, 43*, 75-117.

Preference Judgments and Choice: Is the Prominence Effect due to Information Integration or Information Evaluation?

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Erik Lindberg, University of Umeå
Marcus Selart, University of Göteborg

In a recent paper Tversky, Sattah, and Slovic (1988) demonstrated an inconsistency between judgments of and choices between two-dimensional options. Judgments were elicitated by means of a matching procedure in which the decision maker adjusted one option to match another. It was found that the more prominent dimension loomed larger in choice than in matching. To account for these results Tversky et al assumed that choice is more lexicographic than matching. In other words, they assumed that different information integration rules are used in choice and matching. In the present study we tested (1) whether the prominence effect also occurs for preference judgments (i. e., quantitative judgments of how good or bad a single option is) as compared to choice. More importantly, we also tested (2) whether the prominence effect may be explained in terms of how subjects evaluate given information rather than in terms of information integration rules. That is, do choice subjects experience a larger discrepancy between the options on the more important attribute than is true for preference judgment subjects? Data collected from 80 subjects generally supported both hypotheses. It is concluded that the prominence effect is not primarily due to use of different information integration procedures as suggested by Tversky et al. Rather, the effect occurs because subjects evaluate (or frame) information about the options differently in choice than in judgment. In further data analyses we will investigate whether the results are in line with the dominance search model.

Newcomb's Paradox: Rational Choice under the Breakdown of Causality

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An Omniscient Being (OB) gives a Decision Maker (DM) a choice between taking one -- covered -- box, or two. The covered box contains either $ million, or $0. The additional box contains a certain $1000. The catch is that the content of the covered box was determined previously by OB according to its prediction about DM's future choice: OB put $million if and only if it predicted that DM would take only the covered box. OB is known to be a highly accurate predicter. What is DM's rational choice?

This problem, called Newcomb's Paradox, has been extensively discussed in the philosophical literature, including the refinement of decision theory into a separate causal versus non- causal component (e.g. Gibbard & Harper; Lewis). We had previously argued for a 1-box choice (Bar-Hillel & Margalit, 1972),though such a choice seems to violate dominance, and indicate a kind of "magical" -- rather than "rational"-- thinking. The present paper is a refinement of our 1972 argument, which takes into account the subsequent developments in normative decision theory (which will be briefly surveyed), and gives a normative prescription for choice under conditions of "pre- determined harmony" (real-life examples of which exist in modern quantum physics).

RISK COMMUNICATION: A PERSUASION APPROACH

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In the development of risk communication research the rich tradition of research on persuasion and attitude change in social psychology seems to be ignored. Recent developments in persuasion research focus on different types of information processing. It will be argued that these principles are highly relevant for research on risk communication as well as for risk communication practice.

A field experiment on risk communication (N=506) will be presented in which the Elaboration Likelihood Model (Petty & Cacioppo, 1986) was tested. The persuasive message comprised probabilistic information concerning consequences of large scale use of coal. Subjective probabilities (beliefs), attitudes, and behavioral intentions were the main dependent variables. Contrary to common sense notions, effects of source credibility were only found if individuals were little motivated to process issue-relevant information (elaboration likelihood, which was operationalized through 'involvement' and 'need for cognition'). More persistence of induced changes (measured one year later), as well as stronger beliefs-attitudes-intentions consistency was found for highly than for little motivated individuals.

R.E. Petty & J.T. Cacioppo. Communication and Persuasion: Central and Peripheral Routes to Attitude Change, New York: Springer-Verlag, 1986.

SELF-FULFILLING PROPHECY IN RISK: A WAY TO FIND WHAT ONE IS LOOKING FOR

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INTRODUCTION. In many works it has been demonstrated how people are sensitive to changes in task structure or in other external manipulations. Recent studies (Lopes & Schneider, 1987 and Leon & Lopes,1988) have shown how aspiration level and feedback successively modify attitudes toward risk in most of the ss. However, there was a group of ss who did not change. Here we propose that the behaviour of these ss could be explained by the self-fulfilling prophecy. METHOD. Subjects: 27 first year psychology students. Stimuli: 6 multi-outcome lotteries (showed in Lopes, 1987). Design: Independent variables were, 1, the six lotteries, 2, risk seeking and risk averse ss, 3, treatment - within ss (pre-feedback, feedback, post-feedback). The dependent variable was the number of times ss chose each of the lotteries in a complete pair comparison design. We focused on the riskiest lot. Procedure: 1) Pre-fb: a selection of two extreme subsets of ss was made through their patterns of lot. elections. 2) Fb: Ss actually played through a microcomputer, which displayed the lot. and showed the results. 3) Post-Fb: Subjects' preferences were measured when pairs of lot. were presented in a booklet. RESULTS: 1) Risk seekers obtained a proportion of good outcomes higher than risk averse ss ($z=2.23$, $p<.0113$). 2) There was no change in preferences between pre-Fb and post-Fb ($F1,25= .72$).3) Analyzing the risk perceived by the two groups through the variances of the obtained prizes, we tested that the var. for risk averse ss was higher than the other group ($F13,12=4.9087, p<.01$). DISCUSSION: Ss found in the Fb phase data to confirm their previous hypothesis about their preferences. We have tested that this statement is especially true if only a part of the data is considered and the rest ignored, as Hogarth (1980) proposed. Mathematically, when only good prizes are considered, risk seekers get better results.

THE EFFECTS OF INVOLVEMENT AND RELEVANCE ON RISK COMMUNICATION EFFECTIVENESS

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ABSTRACT

Our IRA theory of risk communication effectiveness identifies three key elements, Involvement, Relevance and Ability. In this study, we investigate the joint effects of involvement and relevance. Involvement is a motivational factor based on similarity judgments between the audience's interests, values, etc. and the hazard-information content of the message. Relevance is another motivational factor, but based instead on similarity judgments between the people in the audience and the people described in the message. Our primary hypotheses are these: a) Higher levels of involvement lead to more attention to the message and to more information processing. b) Higher levels of relevance lead to greater acceptance of responsibility and increased intention to act. In addition, we expect: 1) risk communication to be most effective when involvement and relevance are both high; 2) risk communication to be least effective when involvement and relevance are both low; 3) high involvement and low relevance to produce high information processing but low intention to act; and 4) low involvement and high relevance to produce both low information processing and low intention to act. This latter condition is of particular interest as it is often construed by outside observers to be "denial". These hypotheses are tested in a two-staged experimental procedure. First, subjects' levels of involvement with a large set of issues are measured, and the features that affect relevance judgments are determined. Second, subjects are given risk messages in the form of newspaper accounts of hazard events. The contents of these messages are designed (on the basis of the results of stage one) to produce four experimental conditions, high and low involvement crossed with high and low relevance. Measures of information processing effort, judgments of personal and community risk, judgments of the need for personal and governmental action and other dependent measures are compared across the four experimental conditions. Implications of these results for the theory and practice of risk communication are discussed.

MANAGEMENT DECISIONS INFERENCE: STRUCTURE IDENTIFICATION AND INTELLECTUAL CREATIVITY PROBLEM

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The research is under way to develop computer systems aiding to amplify intellectual creativity at decision making. Special logical calculus has been worked out to reflect decisions inference. A metamodel is described by a "goals-decisions" matrix (or gragh). Its elements are rank measures of sufficiency and incompatibility. A theorem has been proved that comparative decisions utility may be measured by means of special rank indexes - system priorities. Optimality conditions: decisions and goals compatibility, goals achievment at the pre-set time and at the lowest cost,- are inspired by elimination principle (1). To find a version compatible with all goals was the main obstacle to apply it in practice. To overcome it a theorem has been proved that made it possible to develop logical optimization procedures of a base decision by means of selection of its usefull and suppression of its harmfull features. The transfer to the design of decisions with predetermined properties gave an opportunity to avoid traditional difficulties of multicriterion choice theory. The decision design prosedure is divided into elementary logical operations in the form of answers to questions sequence "asked" by computer in natural language. It stimulates and intensifies users intellectual creativity at the expense of decision inference structural distinctness. The approach is applied to the solution of management problems using computer programs developed: logical optimization, relevance tree design, goals and decisions logical analysis, priorities calculation, decisions sets enumeration and choice, decisions planning (2).

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SPUDM 12, THE TWELFTH BIENNIAL CONFERENCE ON SUBJECTIVE PROBABILITY, UTILITY AND DECISION MAKING

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ABSTRACT OF PAPER FOR CONSIDERATION

DSS and Stimulation of Creativity

The paper is based on the results of a Ph.D. thesis on "Obtaining Quality Decisions through Decision Support Systems". Based on a literature study on creativity-enhancing procedures, 60 techniques for stimulating human creativity are considered and classified in 10 groups. The techniques are related to a classical decision situation: Choosing among many alternatives which are characterized by many criteria. Half of the techniques considered were found to be potentially beneficial for a (qualified) human decision maker using a stand-alone DSS as decision aid.

Some of the techniques are implemented in a DSS design for problem solving in a real-world setting (a consumer organization).

The paper considers why creativity is important in obtaining decision quality, and how well-known techniques of creativity stimulation may be implemented in DSS's. An enlargement of the concept of alternatives and criteria is brought into focus. Results from a case study of 13 users in a real life setting are discussed.

Information and the evaluation of computerized decision support

Tibert van Dijk
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University of Amsterdam

Nearly all computerized decision support systems that are based on a MAUT-type decomposition of the decision problem, rely heavily on user input for arriving at an advice for a particular decision. The support given is mainly in structuring the decision problem. The main inference support comes the shape of information combination algorithms, which either represent compensatory or non-compensatory models. Evaluation of computerized decision support can thus be performed at two levels : the level of the structuring of the problem and/or the level of the model that is taken as the justification for the information combination algorithm. The study that will be reported in the full paper adresses this last level.
The basic assumption behind many techniques for the construction of utility functions is that the ability to express strength of prefence through these functions will lead to more precise information about the individual's values. The corollary of this assumption is that more precise information will lead to better advices. Were this not the case, one could employ much simpler procedures than the often cumbersome and time consuming ones used by decision analysts. As the admissible information combination algorithms depend directly on the metric or non-metric nature of the input information, one could hypothesize that given *identical input into an identical structure* the information combination algorithm that uses more information will outperform algorithms that use less information.

Design of the study

The hypothesis mentioned above was tested in two different conditions : a real life one and an experimental one. Common to the two conditions was the general setup. We used the MIDAS decision support system as the computerized tool available for individuals. In this program the structure (i.e. the MAUT decomposition of the decision task) was the same throughout, but we changed the information combination algorithm in the following ways :

- the algorithm uses all the information that is present in the user input (i.e. the information is metric)
- the algorithm uses only the rankorder information that is present in the user input (i.e. the information is non-metric)
- the algorithm negates all information in the user input and gives a "random" advice

In the *real life situation* a large number of dutch high school students in their last year at high school used the MIDAS program for assisting them in their choice of a university course. Originally the program's advice was based on the use of all information. But as their input was logged, it turned out to be easy to use the same input for the other two algorithms. The satisfaction with the advice of MIDAS was measured by means of contrasting MIDAS's advice (using the three different algorithms) with the choice they actually made.
In the *experimental situation* 64 subjects had to decide between a number of holiday destinations in cooperation with the same MIDAS program. Unknowingly to them the algorithm used was one of the three mentioned above. Some subjects received a purely random advice, others an advice based on all the information present in their input. We asked all these 64 subjects whether they felt satisfied with the program's advice. Apart from the opportunity to test the hypothesis mentioned, this setup also makes it possible to detect biased responses to satisfaction measures, which are a quite common tool for evaluating computerized decision aids.

In the full paper results of this combined study will be given, with a discussion of their repercussions for the design and evaluation of computerized decision aids based on MAUT-like decomposition.

Gorelov I., Slonov N. (USSR)

COLLECTIV SUBJECT OF DECISION MAKING IN A PROBLEM-BUSINESS GAME

By means of special technology the Saratov group of Problem-Business Games (PBG) tries to turn a community of PBG participants into a collective subject of decision making (CSDM), collective-emotion, collective-intellect, collective-will. Under the guidans of a CSDM-methodologist a CSDM-player is formed in the course of search of a problem solution. CSDM-player passes through the same stages of searching and decision making as an individual. But the transition from stage to stage is not carried out according to the acts of insight but according to the intentional logic of an individual through a group-interest to a collective-interest.

On condition of equal partnership a CSDM-player makes some "play-move", a step to the problem solution. Due to the "return-move" of a CSDM-methodologist the players' motivation for the next logical step is created. Further advance through the problem field is consolidated with the help of methodological and psychological reflection. In the course of the game a CSDM-player develops himself from an outside-guided community of executors to a self-guided structure. It is formed first in competitive groups then in the groups consolidaling into a harmonious whole. CSDM functions exclusively due to contradictions (pluralism of opinions and intentions ensuring different components of inner moves). CSDM is a system of integration of personal and group interests through satisfaction of collective interests. Foemed on the game motivation a CSDM - player is further capable to carry out his own life interests.

The minimum critical time of a CSDM-player formation is 3-5 days, with participants being 30-50 organized in 3-4 groups.

"Foreign policy decisionmaking under varying situational constraints: An information processing perspective"

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ABSTRACT

Our basic interest in this paper concerns the cognitive foundations of decision making, especially during a political crisis situation. The ability to handle crises in an effective way is often considered the signpost of human ingenuity in politics. In fact, political leaders are often measured by the success of their choices under crisis condition.

In this analysis we are mainly concerned with a major crisis that was not described as a fiasco, to wit: the Cuban Missile Crisis. Besides Janis' group think concept, other theoretical perspectives have been used to analyze the decisionmaking process during the Cuban Missile Crisis including Thorson's artificial intelligence simulation approach and Allison's comparison of three models. While each of these approaches has been useful for explaining certain aspects of the decisionmaking process occurring during this famous case, we use a modified Bales interaction coding scheme and an information processing theoretical perspective. On the basis of this analysis we next discuss similarities in the cognitive operations evident in this case when compared to a more recent foreign policy decision - the effort to sell arms to Iran in exchange for hostages in Lebanon. In general, this study should allow us to assess the commonalities in the cognitive processes of foreign policy decision makers operating within the context of small groups.

Sincere vs. Sophisticated Voting Behavior in Noncooperative Voting Games with Complete Information

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We present, describe, and competitively test four models of voting behavior in 3-alternative voting games in which (i) communication among voters is disallowed, (ii) complete information of the preference orderings of all other voters is provided, and (iii) a single alternative must be elected. One model (S) postulates sincere voting, whereas the three others (models F, NF, and FRM) -- which allow for strategic (sophisticated) voting -- are predicated on alternative assumptions about the cognitive processes that underlie the voters' decisions. Three experiments with ten groups of five or six voters each are described, two using the plurality voting procedure and one using the approval voting procedure. The major findings are: (i) sophisticated voting is prevalent, (ii) Condorcet winners -- if they exist -- are very likely to be elected, and (iii) voters are much more likely to adopt initially dominated strategies under the approval than the plurality voting procedure. A competitive test of the four models over the three experiments tends to favor model FRM.

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Attribute weighting and use of non-compensatory models as a function of perceived attribute flexibility and control over it.

This study has examined what factors favor a compensatory or non-compensatory decision strategy. Previously, it has been shown that certain situational factors (e.g. task complexity, weight of attribute) can influence the choice of decision strategy. In this study it was proposed that perceived attribute flexibility and controllability could be such a factor. In two quasi-laboratory experiments following questions were investigated: (1) does a relation between the perceived attribute flexibility and controllability and the perceived attribute weight exist? (2) does a relation between the perceived attribute flexibility and controllability and the tendency to trade-off this attribute exist?

In Experiment 1 it was tested if the perceived attribute flexibility and controllability affects attribute weighting. The subjects were 126 students of the University of Warsaw. They considered relevant criteria of the selection for professional training of doctors, psychotherapists, drivers and pilots. Candidate's traits were the attributes. Trait flexibility and controllability was defined as the possibility to create, change, reinforce, or weaken the trait. In Experiment 1 the Subjects assigned intuitive weights to each trait selected from the pilot study. Next they were manipulated in order to change their opinion either on the importance of the traits or their flexibility and controllability. Finally, the attribute weighting was repeated. The data supported the hypothesis that the perceived flexibility and controllability of an attribute affects its weight.

The hypothesis tested in Experiment 2 was that the tendency to trade-off attributes and the use of compensatory strategy depend on the perceived relevant attribute flexibility and controllability. The Subjects were 186 students of the University of Warsaw. The Subjects obtained information about two possibilities described either on flexible and easy to control attributes or on inflexible and hard to control attributes. Attributes' weights were under control. The Subjects selected one out of these two possibilities providing their justifications. The data supported the hypothesis that there is a relation between perceived flexibility and controllability of an attribute and the tendency to trade-off this attribute as well as between the perceived flexibility and controllability of attributes and the use of compensatory strategy. Additionally, the data provided some information on the influence of some other task's characteristics (e.g. a number of dimensions with low or outstanding estimations) on the choice of decision strategy.

Abstract of a paper to be submitted to SPUDM-12 in Moscow 88

AN ANALYSIS OF MULTI-ATTRIBUTE UTILITY MODELS USING LONGITIDINAL FIELD DATA

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B o r c h e r d i n g , K. (Technical University of Darmstadt, Germany)

In a social-scientific field study, the issue of moving and housing decisions was used to analyze the following questions: What information is relevant for the evaluation of residences? How can the multi-criteria problem in successive decision situations be modelled? Are evaluations based on multi-attribute utility (MAU) models predictive for the actual choice? Which cognitive changes occur during the search and decision making process?

The study is based on a conceptual framework which connects perspectives from behavioral decision theory and environmental psychology. With respect to multi-attribute evaluations, a set of 12 housing attributes was defined. For each attribute, three preference-related variables were determined: subjective favorableness of defined attribute levels, utility scores, and acceptability ranges.

Empirical data have been gathered in a longitudinal approach: A group of 92 movers was surveyed during the search for a new residence; data were collected at 6 subsequent times by personal or mail or telephone interviews. Additionally, a control group of 72 'non-movers' was included. In order to obtain appropriate MAU data, a specific set of questionnaires and scaling procedures had to be developed.

Main topics of the statistical analyses have been: identification of crucial determinants of residence evaluation and selection, comparison of various weighted and unweighted MAU models and their relation to holistic judgments (using both an intra- and an inter-individual approach), changes in preferences over time and stability of MAU values.

Results available so far indicate that MAU models are moderate predictors of residential satisfaction and choice; that the 'conventional' model (additive/compensatory, with attribute weights) is slightly better than other ones; and that the reliability of preference judgments is restricted. Also, the difficulty of the judgmental tasks -- particularly MAU-related measurements -- for the respondents (under 'field conditions') became salient.

Finally, the usefulness and the practicability of MAU models for evaluating 'real-life' options as well as consequences for further research will be discussed.

SPUDM ABSTRACT

TITLE: Would You Know an Expert (System) If You Saw One?

AUTHOR: James Shanteau, Kansas State University, USA.

ABSTRACT: The purpose of this paper is to address two questions about the definition of expertise: First, what are the criteria by which expertise is defined? Second, what kinds of expertise are contained within an expert system? The paper will discuss issues related to each of these questions.

Although an obvious place to begin, the use of validity to determine who is, and who is not, an expert presents several difficulties: (1) External standards are often unavailable; that's why experts are used in the first place. (2) "Objective" criteria, when available, are defined from the subjective opinions of experts, not the other way around. (3) Standards evolve over time, so that what is correct may be changing. (4) Experts are usually close to correct; they are more concerned about large errors than small errors. (5) Final answers often are not available until later; yet expert opinions are needed now.

Various criteria, besides validity, have been proposed for determining expertise. Each of these, however, is flawed: (1) Between-subject reliability can determine if there is consensus across experts; however, experts may disagree at one level (diagnosis) and agree at another (prognosis). (2) The number of cues used can be evaluated using multiple regression techniques; however, using fewer cues may be superior, i.e., less is better. (3) Experience is often used as a surrogate measure of expertise; unfortunately, greater experience does not necessarily lead to greater ability (Meehl, 1954).

Several alternative procedures for defining expertise will be discussed: (1) Within-subject reliability is a necessary, but not sufficient, condition for expertise (Einhorn, 1974). (2) Discriminability is also a necessary, but not sufficient, condition (Weiss & Shanteau, 1989). (3) Psychological characteristics, such as self-confidence, can be used to identify experts (Shanteau & Levitt, 1989). (4) The strategies employed to make decisions may be used to distinguish experts (Shanteau, 1989).

Expert systems work best when there is a "ground truth." Unfortunately, this is lacking in most expert domains. Moreover, there is considerable user resistance in getting experts to cooperate in constructing expert systems or interact with a completed system (Ham, 1984). Expert systems cannot reproduce the communication skill nor inspire the confidence of true experts. As a consequence, expert systems frequently are based on and intended for use by novices, i.e., "novice systems."

Procedures of the Collective Decision Making of the Multicriterian Problems

A.S. Levchenkov, A.A. Prosin (USSR)

This paper deals with the problem of a collective decision making in order to achieve a common (global) objective with the help of a personal computer in a local network. The formalization of the decision making in order to draw the procedure of talks is given.

In a solution of some decision making problems an interactive operation to collective members takes place in order to develop a coordinated decision variant to the utmoust satisfying each decision maker (DM) of the group. The supra-DM decision making he discusses the procedure with collective members and controls it.

From the psychological point of view for the development and the decision of a conflict situation several stages may be marked out: the development of a conflict situation; the realization of the situation as a conflicting one at least by one of the collective members; the conflictive behaviour or interaction; the outcome or the development of a conflict.

Procedure of the collective decision making is implemented with the following algorithm.

Step 1. Definition of a set of controlled components of each decision maker (DM) with the help of an interactive procedure in the local network of personal computers. As a result the construction of collective basis models of an object and a set of controlled components (variables) take place.

Step 2. The development of individual and collective sets of criteria. Each collective member in an interactive procedure freely sets criteria and his own preferences for the choice of an individual decision.

Step 3. Generation by a personal computer on the basis of models of admissible set of multicriterial decision of a problem (optimum according to Pareto).

Step 4. Definition of the conflict situation (contradictory evaluations by some decision makers (DM) concerning the common collective decision). If there is no conflict, the problem is solved. And the end of the algorithm.

Step 5. Construction of scales and a negotiation set in an interactive process with the help of personal computers in a local network in order to display the degree of progress of a coordinated decision.

Step 6. Interactive negotiations in order to get the variant of a trade-off decision.

6.1 Recording of the negotiation process for the displaying the results of the decision problem to which the collective members want to return repeatedly both in case of receiving a compromise decision and in case of unsuccesful results of negotiations.

6.2 Evaluation for the negotiation records in a degree of concensus decision of achievements.

Step 7. Control by the supra-DM in a dialogue regime with a procedure of negotiations for receiving a supplementary informationand a prompt decision variant of concensus collective decision.

The algorithm is implemented by 3 decision makers (DM) and a supra-DM in a local network of personal computers of the type IBM PC in order to schedule a timetable with multicriterial estimations.

Social Utility and Decision Making in Interpersonal Contexts

George Loewenstein, Leigh Thompson, and Max Bazerman

We conducted three studies to examine individual preferences for outcomes to the self and a comparison other in a dispute context. Preferences were encoded in individual level social utility functions estimated using a policy capturing methodology. We explored how the social utility functions are affected by the nature of the dispute (personal, business) and the disputant relationship (positive, neutral, and negative). We contrast implications of the estimated social utility functions with predictions generated by individual utility theories. We found that, first, people care more about the difference between their own and the other party's outcome than the independent value of their own payoff. Second, the typical social utility function is positively sloped and convex for negative differences between own and other outcome (disadvantageous inequality) and negatively sloped and convex for positive differences (advantageous inequality). Third, although people generally prefer equality over inequality, they dislike disadvantageous inequality more than advantageous inequality. Finally, the negotiating environment and disputant relationship exert their main effect in the domain of advantageous inequity, whereas these factors have little effect on preferences for disadvantageous inequity.

FRAMING, JUDGMENT AND PREFERENCE

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Kahneman and Tversky's prospect theory has demonstrated that the way in which a decision problem is formulated, or 'framed', can have strong and predictable effects on the perceived attractiveness of the options it offers. These effects are noteworthy not only because they are sizable, but also because they violate important tenets of rationality, and because they influence not only behaviour but also how the consequences of behaviour are experienced.

This line of research has been criticized on several grounds, some critics have suggested that subjects have been misled by illusionary circumstances of little general significance beyond the laboratory. Some argued that the researchers themselves are mistaken about the correct inferential rules, and that some violations of statistical principles should be regarded as a form of satisficing; i.e.,cost-effective inferential shortcuts. Others regard prospect theory a succesful descriptor of decision behaviour because it predicts the direction of irrationality or bias when it occurs.

The present paper presents a series of experiments in which a total of 1500 subjects participated. These experiments addressed a number of issues within this field of study:

(a) it was attempted to provide additional demonstrations of framing effects.

(b) in order to test the generalizability of some of the findings of prospect theory, subjects were presented with a series of more 'everyday' problems in a variety of decision domains. Outcomes of the experiments will be compared with those obtained with the 'typical' problem used in this line of research.

(c) The effects of (1) perceived importance of the stakes and (2) the value of uncertainty on risk-aversion and risk-seeking is investigated in a variety of decision-domains.

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Effects of Framing on Purchase Decisions

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With the purpose of assessing framing effects, how travel distance to a store affects willingness to pay for a good was investigated in three experiments. In Experiments 1 and 2 subjects (60 undergraduates) either indicated how much they would pay for a good to make an offer in a store at a longer or shorter distance equivalent, or they indicated how much farther they would have to travel to make equivalent an offer to buy the good at a lower price. Framing effects were evident in that subjects indicated that a lower price was equivalent when the store was farther away than when it was closer. However, this effect was not observed when subjects indicated how much farther they would travel. The framing effect was in Experiment 1 found to be pronounced when subjects were requested to imagine they walked to the store rather than drove, and in Experiment 2 when the good was cheaper. In Experiment 3 the framing effect was replicated for another 36 undergraduates who were requested to choose between two offers. The results can be interpreted according to Kahneman and Tversky's prospect theory, that is in terms of whether an outcome is perceived as a gain or a loss. They are also congruent with a more recently suggested compatibility principle (Tversky, Sattah, & Slovic, 1988), even though an expected stronger framing effect in the choice task was not found.

A SUBJECT'S DECISION FORECASTING METHOD TAKING INTO ACCOUNT DELIBERATE AND UNDELIBERATE MOTIVES

M.A.Kotik, A.M.Emelyanov (USSR)

The existing decision making procedures taking into consideration personal features are not always adequate so long as they virtually include only deliberate logical component of his thinking. At the same time a decision making person sometimes deviates from common sense laws as long as he is guided not only with his inferences but with unconsious motives too.

We suggested a method providing elimination of the available procedures drawback resulting from the following assumptions. Decision maker's deliberate or undeliberate motives become apparent in his attitude to particular alternatives of the decision - in his emotional perceptions of significance-value and significance-anxiety for each alternative. That is the method is based on the estimation functions of the emotional reactions.

The significance-value and significance-anxiety levels are determined on the base of fuzzy evaluations (such as "strong-week","often-seldom") which are of use to predict the possible positive and negative after-effects. Experimental data revealed a connection between the decision maker's fuzzy evaluations and preference level for each alternative.

The suggested method is implemented interactively with the computer-aided system. The validity test showed that the coincidence between computer decisions and the really most preferable decisions of the decision making person amounts to 77 per cent.

PREDICTION AND POSTDICTION PREFERENCES IN GUESSING

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Abstract. - In three studies it is shown that most subjects, when asked to guess the outcome of an uncertain event (a die toss, the sex of a child, the winner of match) will prefer to do so before the event. This holds regardless of consequences of the guess, and of variations in waiting time from the guess is issued to the outcome is known. In a chance situation, a guess-first preference may be partly explained by a "magical control"-hypothesis, but the preference persists in situations where such influences are less thinkable (sex of child; die thrown by other person). When asked how prediction and postdiction guesses differ, most subjects agree that predictions are most exciting, and that postdiction failures cause more discomfort than prediction failures. Such differences are interpreted as due to the relative amount of perceived internal and external uncertainty in the task at hand. It is speculated that internal uncertainty is felt most acceptable when matched by a corresponding external uncertainty, and most aversive when contrasted to an externally established fact.

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Learned helplessness and the decision-making processes

Abstract

This study deals with the problem of information and evaluation processes in decision making, and how the psychological state of learned helplessness - a product of a control loss experience - affects these processes. We accepted Montgomery's concept of decision-making as a process of searching for and testing of hypotheses concerning which of the alternatives is superior or even dominant over the others. Present experiment attempted to study these processes under various settings, including conditions highly unfavorable to promising option emergence. The second treatment intended to produce an altered psychological state- that of learned helplessness- which could be expected to seriously affect both processes.

Main results obtained in our experiment showed that:

/1/ "Normal" subjects displayed a considerable focus on the option which was subsequently chosen, even under highly unfavorable conditions where the indication as to the evaluative saliency of any option was lacking.

/2/ As far as helplessness trained subjects is concerned, when cue to salient attractiveness of some alternative was present they examined thoroughly this particular alternative addressing little questions to the others. However, under conditions where no such a hint was given, they directed similar number of questions to all alternatives; thus they displayed a tendency to avoid mental effort.

/3/ Already in early predecisional period the promising option was sharply differentiated from the "background" in terms of its appraisal Moreover, this effect appeared highly robust, as exemplified by lack of any interactions with the experimental treatments of options' similarity and helplessness. This pattern suggests that the dominance structuring process might be fairly general phenomenon, noticeable in different circumstances, including those unfavorable to the selection of promising option.

COMPUTER-AIDED DECISION-MAKING BASED ON MULTI-CRITERIA DISCRETE OPTIMIZATION METHOD

V.G.Tanaevsky, D.V.Ofitserov

A new method for solving multi-criteria discrete optimization problems and its implementation as a complex of interactive procedures which are intended for computer aiding of decision-making process are discussed in the paper. A conceptual scheme of the method is presented. While discussing it, special attention is paid to the methods of obtaining reliable and consistent information from man. The adaptive decision maker's (DM) preference system model is described, on the basis of which a choice of rational solution should be performed.

The procedure of information receiving consists of correct simple operations. The questions are formulated in conventional and clear terms. Having received the DM's answers a control of completness and correctness of the information being entered is performed. The contents of the information is preserved on all the stages of its processing. The information coming from DM reflects his preferences on a set of criteria and on a set of criteria estimates of the alternatives. The use of this information in the adaptive model makes it possible to elicit the DM's preferences on a set of multi-criteria alternatives. During the dialogue the elements of DM's preference system are controlled to be consistent. To do this, formal description of the transitivity conditions of the preference relations on a set of the criteria is used.

The complex of interactive procedures developed satisfies the requirements of correctness and convenience. It provides the correspondence of the decision-making method to human practical abilities of information analysis and processing. Because the software is designed for users having no programming skill and who are not familiar with the decision making theory it may be promising for solution of many practical problems.

The numerical results of solving a particular combinatorial optimization problem on permutations using a multiple criterion are presented.

SUPPORTING GROUP DECISION MAKING: CHOICE SET INTERSECTIONS AND CRYPTOGRAPHIC PROTOCOLS

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Abstract:

It is well-known that different social choice procedures often result in different outcomes. When resorting to just one procedure the decision makers typically lose the opportunity to find out what the other plausible outcomes might have been, had the procedure being used been different. The paper reports results on the differences in the outcomes resulting from a number of choice procedures under various assumptions concerning the preference profiles of the groups. The paper thus complements an earlier one ("Discrepancies in the Outcomes Resulting from Different Voting Schemes", Theory and Decision 25, 1988, 193-208) by the same author.

Group decision can also be supported by devising negotiation and bargaining protocols for various purposes. Usually the parties in negotiations are interested in guaranteeing the secrecy of at least some aspects of their bargaining position. Cryptographic protocols for ascertaining that already exist and could be applied in some types of negotiations. The paper outlines some of the existing protocols and suggests uses for them.

Proposed paper to SPUDM conference, Moscow August 1989

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Group Decision Support Systems in a Complex Professional Environment:- The Case of International Bond Portfolio Switching.

The manager of a fund of government fixed-interest securities will normally seek to achieve a higher rate of return than a simple buy-and-hold investment strategy would attain. The manager may seek to improve the return by switching the portfolio from one country to another as yields and exchange rates move.

By definition, the price of a fixed-interest security will move directly against its yield:- when the yield goes up, the price goes down, and vice versa. However, yields depend in part on general interest rate movements in the country in which the bond has been issued, so that yields in different countries will move relative to one another. A fund manager may therefore seek to improve overall performance by selling a bond in a high yield country and buying one in a low yield country, on the assumption that the markets will revert to their customary relationship later. A capital gain will arise, which will augment the interest return.

For the fund manager, this involves bringing together a number of skilled professionals. Bond analysts, yield analysts, and exchange rate analysts must be involved. No single expert can be expected to deal with all the issues. As the bond market is valued at approximately four trillion dollars (US) at present, and as 1% of this total is traded daily, considerable care is needed.

The paper addresses the problem of specifying a group decision support system to provide the fund executive with an hourly updated description of present and expected yields and exchange rates, together with probabilistic decision rules. Constraints imposed by the investor must also be considered, particularly with respect to exposure to each of the currencies involved.

The fund manager is normally a company, with a well-established social structure. Each of the skilled professionals is more highly trained than the trader who actually operates the fund and has executive authority to buy and to sell. This means that the decision support system must act as a social buffer as well as a communications vehicle and decision aid.

THE EFFECTS OF DEADLINES ON INDIVIDUAL DECISION MAKING

A.J.Maule & P.Mackie

The paper reports one of the series of experiments investigating the effects of deadlines on decision making. Although Miller (1960) identified several ways in which behaviour may change in such situations, only two of these have been supported by research. Wright (1974) showed that deadlines lead to filtering in terms of an increased importance of negative information and Ben-zur & Breznitz (1981) reported that deadlines increase the tempo of responding. The primary aim of the present study was to replicate these findings and to see whether other changes outlined by Miller occurred with the imposition of deadlines.

The study was multi-method based on both a regression analysis of judgment and a process tracing approach analysing concurrent verbal protocols. Subjects were presented with information about cars, each described along six dimensions. They were required to judge the attractiveness of each car and choose one of seven courses of action to take. The task was computer controlled and was segmented into a number of distinct components - search, evaluation, judgment and decision. Using a within-s design, subjects were run under three deadline conditions. Neither the regression analysis of judgment nor the verbal protocols revealed any support for filtering in terms of an increased use of negative information under deadline conditions. However, as predicted, there was a general increase in the tempo of responding. Further data analysis is in progress and suggests that there other deadline effects, including some of those considered by Miller. The discussion will consider the implications of these findings in terms of changes in information processing within each component of the task and effects on subjective measures like experience of time pressure, confidence in the decision etc.

Decision Making in Dynamic Environments: The Use of System Dynamics to Explore Judgments across Time

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Multiple-cue probability learninig(MCPL) research has focused primarily on static environments in which the underlying characteristics of the system are taken to be fixed and unaffected by any elicited judgement. Maximum achievement on such tasks typically requires repeated, consistent application of a single, best rule for integrating available information about a cross-section of independent circumstances. The accuracy of each judgment can be assessed independently of all other judgments. In contrast, naturally occurring problems often unfold in dynamic environments. System characteristics change over time, exhibiting behaviors that are influenced directly and indirectly by elicited judgments. Maximum achievment would seem to require attention to the timing, order, and relation of judgments, since circumstances are connected continuously in time. The accuracy of each judgment cannot be assessed as if it were made in complete isolation.

The study of decision making in dynamic environments has taken several directions, including investigations of the effects of system feedback on judgmental performance(e.g., in response to additional information about fixed but relatively unknown systems, Schum, 1980; or in response to better known but changing systems, Sniezek, 1986) and investigations of the effects of elicited judgments on system perfomance(e.g., where behavior is determined in part by the judgment itself, Camerer, 1981; or where behavior responds to elicited judgment, MacKinnon & Wearing 1985; Kleinmuntz & Thomas, 1987). Brehmer and Allard (1987) have developed an alternative method of assessing cognitive skills revealed from sequences of related decisions in a dynamic environment, though the task is constructed as a gameboard in which playing pieces must be moved from square to square.

Sterman(1987,1988) has studied extensively the cognitive skill of players in another type of game STRATEGEM-2, based on a system dynamics model of the Kondratiev Cycle or economic long wave. The

dynamic environment involves the relation of production, demand, capital stock, depreciation, and unfilled orders of goods; judgments must be made over time to keep new orders for capital stock at a level that maintains equilibrium in the system. Although the model is elegantly simple with few levels, rates, lags, and feedback loops, available evidence suggests that players have considerable difficulty in making the right sequences of judgments; futhermore, eventual mastery of the task (i.e., minimizing errors) under one set of conditions does not appear to generalize to even slight variations in parameters. Such results have led to pessimism in the field of system dynamics about the extent to which individuals are capable of learning to control dynamic environments.

The present paper explores the STRATEGEM-2 game employed by Sterman(1987,1988) from a judgment analytic perspective, reconstructing the information provided to players as a judgment task containing multiple cues. Repeated runs of the game revealed that the cue set made available to players is poorly constructed; some cues are unrelated to successful task performance and some cues actually interfere with successful task performance, while the most diagnostic cues are not directly available and must be constructed mathematically. When an appropriately constructed cue set was made available in a useful form to players, task learning occurred quickly over only a limited number of judgment sequences; cognitive feedback containing cue validities further enhanced learning. Generalization of cognitive skill to conditions in which model parameters were varied also was found. These results provide some encouraging evidence that individuals are capable of learning to control dynamic environments. Whether such learning is possible in more complex dynamic environments (i.e., more levels, rates, lags, and feedback loops) requires considerably more investigation. The present study, however, does illustrate the significant role of information presentation in the study of dynamic decision making, since poorly constructed cue sets can reduce substantially the level of cognitive performance.

Null Hypotheses for Dynamic Decision Making

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Researchers in the important field of dynamic decision making have begun to call for research more soundly based in psychological theory (for instance, see the recent review of process tracing methods by Ford, Schmitt, Schechtman, Hults, and Doherty in Organizational Behavior and Human Decision Processes). As it stands, much of this work is exploratory in nature. The purpose of the present paper is to review and generalize several behavioral models which are (a) well grounded in psychological theory, (b) have some limited empirical support, and (c) can serve as models - or at least null hypotheses - for dynamic decision making research. The first class of models to be presented are based on the motivational processes which drive human choice processes. Exemplary of this class are Birch's Activation Time Scheduling model (formed out of Atkinson and Birch's Dynamics of Action motivation theory) and Holtgrave's new generalization of the model which allows for the assessment of environmental influences on the stream of choice behavior. Birch's model has found support in animal and human data. The second class of models to be presented are based on the premise that both the time spent in a type of behavior and the frequency of that behavior are related to the attractiveness of that behavior. In this way observable time and frequency aspects of the data are related to each other via attractiveness. Choice models (such as Luce's choice axiom) can be combined with dynamic models (such as semi-Markov processes) to aid in the time/frequency mapping. Support for certain of this class of models has been found by Holtgrave in animal data. Formal relationships between the two classes of models exist, and are presented herein. The field of dynamic decision making hereby has moved closer to a firm grounding in psychological theory.

Clinical diagnostic decision making in a multidisciplinary team

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The resarch has been conducted over the past four years in a institution for residential care for children with behavioral problems and learning disabilities. After an observation phase in the institution each case is discussed in a multidisciplinary group meeting. The aim of the meeting is to formulate a diagnosis and, consequently, to give a prescription for treatment. The persons participating in the diagnostic conference represent the following disciplines: child psychiatry, psychology, special education, social work, remedial teaching, speech therapy and play therapy.

The evaluation study. A category system for content analysis of the verbal protocols of the diagnostic group meetings (CSDG) was developed in order to evaluate the quality of the conferences. The CSDG was applied to the 14 diagnostic meetings of newly admitted children. Depending on the protocol the reliability of the CSDG ranged from .60 to .80 (Cohen's Kappa).

The instruction study. Approximately 3 months after the last diagnostic group meeting of the evaluation study, the members of the team participated in a so-called instruction training. The team had to analyse the record of an existing but new case in terms that corresponded to Bayes' theorem. The theorem was applied as a pedagogical tool to demonstrate that diagnosic reasoning could be formalized using intrinsic logic. One month after the training, the team rediscussed 5 cases of the evaluation study. The protocols were analyzed using the CSDG and were compared with the results of the evaluation study.

The implementation study. To explore the effect of organizational measures an alternative intake and observation procedure were implemented. The main features of the procedure consisted of the systematic streamlining of information and the active decision-directed participation of the representatives of the different disciplines. The new procedure was applied to 5 newly referred children. The verbal protocols of the meetings concerning these children were analyzed using the CSDG and the results were compared with those of both previous studies.

Results. The regular diagnostic group meetings (evaluation study) showed a high level of information exchange and a low level of diagnostic reasoning. Both frequency and sequence analyses showed that a relatively short exposure to a formal model (instruction study) enhanced the quality of the diagnostic reasoning in the conference while drastic organizational measures (implementation study) did not.

RISKING TO HAVE ANOTHER CHILD WITH A GENETIC DISEASE?
effects of varying information and decision method on decision quality

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In the field of medical decision making the physician is considered to be the responsible person deciding about diagnosis and treatment of a patient. However, in many situations the real stakeholder is the patient him/herself. He or she has to choose among several (medical) options with varying possible consequences. Is it possible to develop effective decision support for this kind of personal decisions? Most applications of decision support are found in organizational settings. Real decision support of personal decisions is rare. This may be related to a lack of systematic evaluation studies of the usefulness and effectiveness of 'supported' decision making contrasted with 'unsupported' decision making. The present paper extends previous research in that (1) the *patient* is the decision maker, and (2) a *personal* decision is evaluated systematically.

In an experimental study we examined the effects of two different decision support methods versus a no-support condition (variable: SUPPORT, 3 levels, between groups). A second variable of interest was the amount of information on the decision problem given to the decision maker (variable: INFORMATION, 2 levels, between groups). Ninety-four paid female subjects were asked to imagine being the mother of a four-year old son suffering from 'Cystic Fibrosis' (CF). This is an autosomal-recessive hereditary disease with a recurrence risk of 25%. It is a progressive degenerative disease with symptoms like respiration disturbances and gastro-intestinal deficits. Mean maximal age of CF-children is about 30 years. Subjects had to read an involving story about 'their' child's history. This story was based on several interviews with real parents of a CF-child, conducted a few months prior to the experiment. The final decision subjects faced was: "*Do you want to become pregnant again, having a 25% chance of having another child with CF?*". Under each primary option, several secondary decisions were involved.

In cooperation with the Institute for Genetic Counseling in Groningen two case stories were constructed. While both stories contained the description of the child's history and a brief overview of the possible options, they differed in whether an extensive background on the hereditary process behind the disease was provided (Extensive-level) or not (Brief-level). Concerning the variable SUPPORT we will focus here on only one of the decision support methods tested: a paper-and-pencil version of a decision tree and expected utility analysis. In the first part of the analysis the decision problem was represented by a decision tree. This was explained step by step on successive pages, building the tree branch by branch *for* them. This process eventually resulted in a 15-branched full decision tree, with probabilities at chance nodes, as provided by experts. In the second part the subjects were instructed to think about and write down aspects (attributes) of the several branches which played an important role in their decision. In the third part they were asked for utility ratings of the 15 different terminal consequences. Finally, the fourth part explained the decision rule (maximizing expected utility by 'averaging out and folding back' the decision tree). When the subjects were finished reading this final part, they were offered their advised 'best decision' (computed by the experimenter). In the *no-support* condition the subjects were asked to decide "in their preferred own way". We collected written protocols on those decisional thought processes, which were coded and analyzed later.

The dependent variables were: (a) perception of the decision problem in terms of subjective risk dimensions, (b) knowledge about the decision problem, (c) satisfaction with the decision method, (d) satisfaction with the (calculated) advised 'best decision', (e) time needed, (f) own preferred option before and after the decision procedure, and (g) certainty about own preference. The results of this study will be presented and discussed in view of three main questions: (1) is more information about a decision problem always beneficial? (2) how effective is the support of *personal* decisions? and (3) what are the crucial variables for evaluation of decision support methods?

Understanding Diagnosticity: Direction and Magnitude of Change.

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The Bayesian concept of diagnosticity was contrasted with subjects' intuitive evaluation of data for hypothesis testing, by Beyth-Marom and Fischhoff (1983). This studies found that when subjects were asked to test the validity of H, only half expressed an interest in P(H/D'). However, when subjects were presented with both components of the likelihood ratio, most of them revealed a qualitative understanding of their meaning vis-a-vis hypothesis testing. In those experiments subjects were given either non-diagnostic (e.g. P(D/H)=0.9 and P(D/H')=0.9) or very diagnostic (P(D/H)=0.9 and P(D/H')=0.1) data. It was not clear whether subjects revealed a latent understending of the meaning of diagnosticity or whether they figured out on the spot what it meant to have identical or divergent values of the likelihood ratio's components.

The prestent studies were designed to explore this question. Do subjects understand that (a) the **direction** of the prior's updating depends on the relative magnitude of the two components, and that (b) the ratio of both components determines the **magnitude** of that updating?

In the first experiment subjects were asked to assess a probability twice; once after getting base rate data and again after receiving the two likelihood ratio's components. Results indicated that subjects often determine the **direction** of the prior's updating by the **magnitude** of P(D/H) and seldom by the relative magnitude of both components.

In the second experiment subjects were given two pieces of data relevant to a given hypothesis, along with the likelihood ratio's components for each datum. Subjects were asked to judge which of the two pieces of data should change the prior more. Subjects' responses indicated that the **magnitude of the likelihood ratio's components** affected their estimate concerning the **magnitude of change** and not the size of their ratio. That is, a likelihood ratio of 0.9/0.7 was judged as more diagnostic than a likelihood ratio of 0.6/0.4 and the later was judged as more diagnostic than 0.3/0.1. The paper will discuss the implications of those misconceptions.

Abstract

An Integrative Operational Framework for Strategic Risk Analysis

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The risk handling literature is both extensive and diverse. But, for the most part, it is not integrative. While there are several lines of development in the literature that offer many important insights to the risk handling problem there is, as yet, little systematic approach that adequately considers all major aspects of risk handling in an organizational context. This paper presents an integrative model for strategic risk analysis which attempts to improve the risk handling process in organizations. Mainly adapted from Rowe's three-stage approach and drawn from the relevant findings of several disciplines, an extended four-phase strategic risk handling process will be presented. These four phases are: (1) Identify problem structure and critical risk factors; (2) Measure/classify project risk; (3) Assess firm risk and portfolio risk; and (4) Evaluate risk for project selection.

The framework emphasizes the importance of a more specific, explicit procedure to measure project riskiness prior to any risk/return trade-off decisions. It should be noted that in developing this integrated framework, attention is focused on the entire process of risk handling, i.e. the identification of project structure and "critical risk factors" is as important as quantifying risk or adjusting it. The framework also indicates some directions for achieving a synthesis of total project risk analysis approach with the CAPM approach. It is suggested that by using this conceptual/operational model managers can contemplate and confront the future uncertain environment more effectively.

AN ADVANTAGE MODEL OF RISKY CHOICE

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ABSTRACT

A descriptive model of choice between monetary lotteries -- called the Advantage Model of Choice -- is proposed. According to the model, people compare lotteries separately on the dimension of gains and on the dimension of losses. In making these comparisons, people employ both "absolute" and "comparative" strategies that are subsequently combined to yield a choice.

The model is evaluated on both qualitative and quantitative grounds, and compared to two popular alternative theories of risky choice: Prospect Theory and Utility Theory. As part of the qualitative evaluation, a number of well documented phenomena are reviewed, that characterize people's choices between lotteries. It is shown that only the Advantage Model is consistent with all the phenomena.

As part of the quantitative evaluation, three experimental tests of the model are reported, involving both "simple" and "mixed" lotteries. In the context of these lotteries, the model appears superior to both Prospect Theory and Utility Theory in predicting group preference, and generally more successful in predicting individual choice.

It is suggested that the Advantage Model captures one of the underlying processes that guide human choice behavior in risky situations. Examples of the model's relevance to nonmonetary domains are provided.

MODELLING KNOWLEDGE ABOUT MULTIPLE CRITERIA DECISION MAKING METHODS USING AN EXPERT SYSTEM SHELL

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This paper reports on an ongoing research effort intended to develop a prototype expert system for multiple criteria decision making (MCDM). The paper demonstrates how the information about various discrete alternative MCDM methods was organized into an MCDM knowledge base using a microcomputer based KNOWOL expert system shell.

The development of the MCDM knowledge base necessitated the specification of assumptions and information requirements of various MCDM methods. A taxonomy of preference information was also developed.

Initial experiments with the prototype system are discussed. The paper demonstrates the advantage of backward chaining versus forward chaining in reaching conclusions about the appropriateness of a particular method in a given decision situation.

The paper also describes conceptual, methodological, and technical difficulties in the implementation of a prototype knowledge-based advisory system. Possible approaches for overcoming these difficulties are suggested and future research and development efforts are discussed in detail.

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ABSTRACT: A Clarification of Prospect Theory:

Notes towards Extensions and Applications

Prospect Theory offers a well-established, mathematically and psychologically sound explanation of judgments about future uncertainty. However, the theory has not been as well utilized in important practical realms, especially leadership behavior, as its theoretical power would justify.

In order to widen the range of applications of Prospect Theory, this paper does the following. First, the primary statements of the theory are graphically redepicted so as to present the quantifiable relationships between risk and uncertainty from an alternative perspective. The initial figures have taken on a life of their own, being strictly reprinted exactly as first conceived. While they are accurate, certain axial ambiguities may hinder some concrete comparative analyses; the figures are more complex than they appear to be at first. To this end, clarifications are proposed (axial rescaling, different variable comparisons, three-dimensional graphics) which bring into focus additional testable hypotheses and applications.

Second, extensions of the theory are offered, covering: behavior near the ill-defined endpoints of null and certain probability; variation along dimensions of estimated probabilities (i.e., what is the range of elasticity away from the endpoints, e.g. between .2 and .8, for which the expected value of the prospect under risk equals the same certain prospect value?); and a graphical and statistical evaluation of individual differences (in addition to those related to reference levels) in the risk-vs.-certainty relationship.

Third, a recent utilization of Prospect Theory to explain the "risk-return paradox" is analyzed in light of the above extensions, illustrating the usefulness of the proposed clarifications. Fourth, concepts from James March's work on variable risk preferences are melded into Prospect Theory for application to managerial decision making. The paper concludes with 10 hypotheses ranging from the analytical to the empirical and from the individual to the group level of analysis, with a major thrust being to revitalize the study of leadership behavior, especially under conditions of extreme uncertainty.

CATEGORY SALIENCE IN FAULT TREES: THE INFLUENCE OF THE NUMBER OF CATEGORIES ON PROBABILITY ESTIMATIONS

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Fault trees can be a useful instrument for problem solvers to figure out why something goes wrong. A fault tree organizes possible sources of trouble into a branching structure. This systematic organization of the problem is believed to enable better and more reliable judgment. Fischhoff, Slovic and Lichtenstein (1978) showed that variations in this type of problem representation can have robust effects on judgment. Subjects presented with an incomplete problem representation failed to appreciate how much had been omitted and overestimated the exhaustiveness of the factors they saw. Using related tasks it was also demonstrated that estimates and predictions were affected by manipulations of the number of response categories. Further it was shown that providing more elaborate content information did not have a strong impact on judgment.

The present studies investigate the impact of characteristics of problem presentation on judgment. It is tested whether:

1) people use an anchor which approximates the number of events divided by the number of categories to be estimated,
2) probability estimates are mainly effected by the number of other categories to be estimated,
3. probability estimations are not or only marginally affected by content information, and
4) the total estimate of lower level factors is higher than the estimation of the corresponding over-all factor.

Implications of these findings for the use of fault trees and related instruments in decision making and judgment will be discussed.

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EXPERTISE: THEORY AND DATA

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Psychological studies of expert performance have produced contradictory findings: viz. experts are "good" and experts are "bad" decision makers. We propose a theory of expert judgement which accounts for the inconsistencies in the data. The domains of expertise previously studied are analysed in terms of knowledge sources available to experts, the quality of feedback and the type of judgements required. This analysis permits the identification of specific biases and heuristics which consequently allows the findings of individual experiments to be anticipated.

Having demonstrated the potential of our approach retrospectively we go on to test the theory prospectively with reference to expert life underwriters. Using knowledge engineering techniques we model the underwriting task within a single organisation and identify potential biases which we proceed to investigate experimentally.

To give a specific example: underwriters learn their trade by approximating their judgements to those of more senior staff; objective feedback about the accuracy of underwriting decisions is, however, severely limited. On the basis of this we predicted high consistency between successive generations of underwriters (including the perpetuation of biases), but low accuracy in relation to objective criteria. Our experiments supported these predictions. Underwriters showed consensus regarding the risk entailed by various lethal events, but displayed the same availability bias - stemming from media exposure to the events - as has been demonstrated in previous studies (eg. Lichtenstein et al 1978, Christensen-Szalanski et al 1983).

Finally, we discuss the implications of our research for decision support which we see as being able to permit the accurate prediction/identification of biases, and to permit debiasing by means of various targeted techniques.

Provision of Step-Level Public Goods: Effects of Social and Environmental Uncertainty

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The present paper concerns social dilemmas faced by members of small groups who are asked to make voluntary contributions toward the provision of step-level (binary) public goods. In particular, we consider the case where (a) preplay communication is prohibited; (b) the endowments of all group members are equal; (c) individual contributions are continuous, private and anonymous; and (d) the good is provided to all group members if and only if the sum of contributions exceeds a predetermined threshold. It is assumed that the provision threshold is not known; rather, it is a random variable with a commonly known distribution function.

First, we propose two alternative models: an expected utility model, and a Kantian model based on Kant's treatise on moral behavior. Each model predicts the optimal individual decision regarding how much to contribute. It also predicts the effects of social and environmental uncertainty on the level of contribution.

Second, we report the results of an experiment designed to test the effects of the two sources of uncertainty on individual and group contributions, and on individuals' beliefs regarding others' contributions. The results show that a moderate level of uncertainty regarding the threshold causes people to contribute more and to expect other group members to contribute more. The results also show that the Kantian model supercedes the expected utility model, suggesting that subjects tend to adhere to norms of equity.

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Dr.	Withauer,	FRG
George	Wright,	UK
Dan	Zakay,	ISRAEL
Zbigniew	Zaleski,	POLAND
Dr.	Zondak,	USA

AUSTRIA	1	ITALY	3		
BULGARIA	3	NETHERLAND	23		
CANADA	1	NORWAY	2		
CZECHOSLOVAKIA	1	POLAND	9		
DENMARK	1	SPAIN	2		
FINLAND	4	SWEDEN	4		
FRG	9	UK	15		
GREECE	1	USA	51		
HONG KONG	1	USSR	23		
HUNGARY	10	YUGOSLAVIA	1		
IRELAND	1	Country not			
ISRAEL	9	indicated	3	Total	176

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