SPUDM 14
fourteenth research conference
on subjective probability,
utility and decision making

1993 Aix-en-Provence
France
22-26 august

PAPERS

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SCHEDULE

	Monday	Tuesday	Wednesday	Thursday
09:00-09:30	Opening Speech	MAJOR PAPER J. St B.T. Evans	MAJOR PAPER M. Spies	MAJOR PAPER R. Thaler
09:30-10:00	MAJOR PAPER L. Lopes			
10:00-10:30		*Break*	*Break*	*Break*
10:30-11:00	*Break*	WORKSHOPS W 2 W 3 - W 4 W 5 - W 6	WORKSHOPS W 2 W 3 - W 4 W 5 - W 6	WORKSHOPS W 1 W 3 W 5 - W 6
11:00-11:30	ORAL PAPERS Sessions 1 - 2 - 3			
11:30-12:00				
12:00-12:30				
12:30-13:00	*Lunch*	*Lunch*	*Lunch*	*Lunch*
13:00-13:30				
13:30-14:00				
14:00-14:30				
14:30-15:00	ORAL PAPERS Sessions 4 - 5 - 6	POSTERS	ORAL PAPERS Sessions 12 - 13 14 - 15	ORAL PAPERS Sessions 16 - 17
15:00-15:30				
15:30-16:00	*Break*			*Break*
16:00-16:30	ORAL PAPERS Sessions 7 - 8 - 9	ORAL PAPERS Sessions 10 - 11		MAJOR PAPER Borcherding - Weber
16:30-17:00			*Break*	
17:00-17:30			MAJOR PAPER G. Gigerenzer	Final Speech
17:30-18:00				
18:00-18:30			BUSINESS MEETING	
18:30-19:00				
19:00-19:30				
20:00-20:30				
20:00-....				*Social Dinner*

Monday, 23

9.00-9.30 **Opening speech**

9.30-10.30 **Major Paper**
- Lola Lopes - On modelling risky choice : why reasons matter.

10.30-11.00 **Break**

11.00-12.30 **Oral Papers** (Parallel Sessions)

Session 1
- Katrin Fisher - Multinomial modeling in hindsight bias research.
- Raanan Lipshitz and Simon Givoli - Pitting hot against cold cognition. The effect of excalation of commitment on hindsight bias (and vice versa).
- Rüdiger Pohl - Disenchanting hindsight bias.

Session 2
- Berndt Brehmer and Peter Svenmark - Distributed decision making in dynamic environments: Time scales and architectures of decision making.
- Adèle Diederich - Decision field theory for multiattribute decision problems.
- James Shanteau and Ward Edwards - The psychology of expertise: a new paradigm.

Session 3
- Heiner Gertzen, F. Schmalhofer, O. Kuhn, J. Schmidt and K.M. Aschenbrenner - A decision-support system for the judgment of adverse events in clinical trials.
- Gwendoline Kiebert - Utility assessment in medical oncology.
- Frits Roest and J. Dik Habbema - Confidence intervals for individual utilities.

12.30-14.30 **Lunch**

14.30-15.30 **Oral Papers** (Parallel Sessions)

Session 4
- Peter Wakker - Testing rank-dependent utility and new prospect theory.
- George Wu - Editing and cumulative prospect theory: ordinal independence and outcome cancellation.

Session 5
- Jose Kerstholt - The effect of time pressure on decision making behaviour in a dynamic task environment.
- France Leclerc - Effects of salience and time pressure on the choice process and outcomes.

Session 6
- H.W. Brachinger - Risk measurement under partial probability information.
- Pieter Koele and Mirjam Westenberg - Measuring the compensativeness of multi-attribute decision strategies.

15.30-16.00 **Break**

16.00-17.30 **Oral Papers** (Parallel Sessions)

Session 7
- Reidar Kvadsheim - The intelligent imitator. Humans "maximize subjective expected value" but do so in a manner that differs radically from the traditional SEU conception.
- Maria Lewicka - Is hate wiser than love ? Positive-Negative Asymmetry in interpersonal decision making.
- A. John Maule - Framing elaborations and their effects on choice behaviour: a comparison across problem isomorphs and subjects with different levels of background knowledge.

Session 8

- Terry Boles and David Messick - When losing is better than winning: The impact of regret on the evaluation of decisions.
- Ilana Ritov - Anticipation of uncertainty resolution in choice.
- P. Roelofsma and G. Keren - Uncertainty and the reversal of time preference.

Session 9

- Christopher Ball and Leon Mann - Identifying the decision making skills of intellectually gifted adolescents.
- Rex Brown and Oleg Larichev - Russian and american decision analysis approaches tested on arctic issues.
- Laurie Hendrickx, Agnès Van Der Berg and Charles Vlek - Concern about tomorrow ? Effects of "time discounting" on the evaluation of environmental risks.

Tuesday, 24

9.00-10.00 **Major Paper**
- Jonathan St B T Evans - Reasoning as decision making.

10.00-10.30 **Break**

10.30-12.30 **Workshops** (Parallel Sessions)

-W 2 Jean-Marc Fabre and Allen Parducci - Context Effects on Judgments.
-W 3 Rebecca Frumkina - Verbal labels for evaluation and assessment
(R. Brown, O. Larichev, G. McClelland, A. Mikhejev, M. Shapira, T. Wallsten)
- W 4 Vittorio Girotto and Paolo Legrenzi - Reasoning and decision making.
- W 5 Nick Pidgeon and Mike Smithson - Qualitative approaches to uncertainty and decision.
- W 6 Peter Politser, Danielle Timmermans and Peter Wakker - Aggregation, rationality, and risk communication: Three current debates in medical decision making

12.30-14.30 **Lunch**

14.30-16.00 **Posters Session**

16.00-17.30 **Oral Papers** (Parallel Sessions)

Session 10

- Jeryl Mumpower, Jim Sheffield and Thomas Darling - "Fixed-Pie" and "Elastic-Pie" biases in negotiations.
- Zur Shapira and Itzhak Venezia - Asymmetric information and competitive behavior.
- Ramzi Suleiman, Amon Rapoport and David Budescu - The non-monotonicity effect in resource dilemmas under uncertainty.

Session 11

- Michael Lawrence and Peter Ayton - Decision making in the presence of asymmetric loss functions.
- Peter Politser - Testing the logical consistency of decision analyses.
- Marcus Selart and Tommy Gärling - Effects of uncertainty on relative attribute weights in preference ratings.

Wednesday, 25

9:00-10:00 **Major Paper**
- Marcus Spies - Uncertainty and decision making : Expert treatment of human expertise

10:00-10:30 **Break**

10:30-12:30 **Workshops** (Parallel Sessions)

-W 2 Jean-Marc Fabre and Allen Parducci - Context Effects on Judgments.
-W 3 Rebecca M. Frumkina - Verbal labels for evaluation and assessment
(R. Brown, O. Larichev, G. McClelland, A. Mikhejev, M. Shapira, T. Wallsten)
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12:30-14:30 **Lunch**

14:30-16:30 **Oral Papers** (Parallel Sessions)

Session 12
- Peter Ayton and Alastair McClelland - The bomb party probability illusion.
- Michel Gonzalez - Do predictions of an event result from probability judgments?

Session 13
- Karl Teigen and Wibecke Brun - Yes, but it is uncertain: Direction and communicative intention of verbal probabilistic terms.
- Danielle Timmermans - The role of experience and domain of expertise in using verbal versus numerical probability terms in medical decisions

Session 14
- Brian Gibbs - Inward vs. outward decision making: The self-manipulation of tastes.
- Hans Pfister - The influence of emotion-and utility-related evaluation and induced mood on choices in ambivalent decision situations.

Session 15
- Joke Harte - Structural modeling and verbal protocol analysis
- Peter Juslin, Anders Winman and Thomas Persson - Calibration of recognition judgments: Well calibrated judgments both for reconstructive and associative memory processes.

16:30-17:00 **Break**

17:00-18:00 **Major Paper**
Gerd Gigerenzer - Probabilistic mental models and bounded rationality.

18:00-19:30 **Business Meeting**

Thursday, 26

9:00-10:00 **Major Paper**
Richard Thaler - Mental accounting matters

10:00-10:30 **Break**

10:30-12:30 **Workshops** (Parallel Sessions)

-W 1 Lee Roy Beach and Terry Connolly - Image theory and non-normative decision theory
-W 3 Rebecca Frumkina - Verbal labels for evaluation and assessment
(R. Brown, O. Larichev, G. McClelland, A. Mikhejev, M. Shapira, T. Wallsten)
-W 5 Nick Pidgeon and Mike Smithson - Qualitative approaches to uncertainty and decision.
-W 6 Peter Politser, Danielle Timmermans and Peter Wakker - Aggregation, rationality, and risk communication: Three current debates in medical decision making

12:30-14:30 **Lunch**

14:30-16:00 **Oral Papers** (Parallel Sessions)

Session 16
- Eva Pascoe and Nick Pidgeon - Risk orientation in dynamic decision making.
- Els van Schie - Influencing risk-preference : Framing decisions versus emphasis on a specific outcome.
- Myriam Welkenhuysen, Gerry Evers-Kiebooms, Marleen Decrueyenaere, and Herman Van den Berghe - Unrealistic optimism and genetic risk.

Session 17
- Jane Beattie, Jonathan Baron, John Hershey and Mark Spranca - Factors influencing decision attitude: Regret, blame, autonomy and equity.
- Nicolao Bonini, Rino Rumiati and Paolo Legrenzi - When a loss becomes a cost and when remains a loss.
- Fenna Poletiek - The importance of subjective probability in modeling testing behavior.

16:00-16:30 **Break**

16:30-17:30 **Major Paper**
Katrin Borcherding and Martin Weber - Problems of weights in multiattribute decision making

17:30-17:45 **Final Speech**

20:30-... ***Social Dinner***

MAJOR PAPERS

MAJOR PAPERS

Katrin BORCHERDING and Martin WEBER
Problems of weights in multiattribute decision making.

Jonathan St B T EVANS
Reasoning as decision making.

Gerd GIGERENZER
Probabilistic mental models and bounded rationality.

Lola LOPES
On modelling risky choice: Why reasons matter.

Marcus SPIES
Uncertainty and decision making: Expert treatment of human expertise.

Richard THALER
Mental accounting matters.

PROBLEMS OF WEIGHTS IN MULTIATTRIBUTE DECISION MAKING

Katrin Borcherding and Martin Weber

In multiattribute decision making the model output is the overall evaluation of alternatives, its quality highly depends on the appropriateness of the attribute weights as the sensitive imputs. As a consequence the derivation of attribute weights is a central step in eliciting the decision maker's preferences. As in other measurement tasks, the set of weights and weight judgments can depend on a variety of different factors, e.g., hierarchical aspects of the value tree, the degree of diversification of values, weight elicitation procedures, effects of attribute ranges, response mode effects, and influences of status quo, framing and anchoring. In our survey we review studies which investigate these behavioral influences on weights. These results from descriptive research are of importance for the prescriptive use of decision analysis. Only if we know about behavioral influences we might be able to avoid or reduce them.

REASONING AS DECISION MAKING

Jonathan St B T Evans

Department of Psychology, University of Plymouth, PLYMOUTH PL1 5RR

What is the difference between a reasoning and a decision making task? Given the degree of separation and lack of cross-referencing between the psychological literatures on these topics, one might think they were very different indeed. However, let us look more closely. In a typical deductive reasoning task, subjects are asked to judge whether some conclusion follows from some premises, as in a syllogism. For example:

Some B are C

No A are B

Does it follow that:

Some C are not A?

The traditional assumption is that subjects attempt to reason logically from the premises in order to derive the conclusion. If they can, they declare the argument valid, otherwise invalid. Hence, the degree which subjects succeed in deriving the conclusions which are dictated by formal logic, is a measure of the accuracy of their reasoning.

In a decision making task, by contrast, subjects are asked to choose between alternative actions, the consequences of which are normally deferred and subject to risk. In this case it is classically presumed that people approach such a task by rational analysis of the consequences of each choice. They project forward a decision tree which elaborates the various consequences, their probability of occurrence and associated costs and benefits, classically described as utilities. The normative model in this case is provided not by logic but by decision theory derived from economic roots (Von Neuman & Morgenstern, 1947). A rational choice is one

which maximises subjective expected utility (SEU).

Now if subjects really approached reasoning tasks by logical analysis and made choices by decision-theoretic analysis, we might well be content to regard the separation of the literatures on these topics as justified. However, in neither case is the classical rationalistic analysis of human behaviour well supported by the evidence. In the case of deductive reasoning, for example, there is massive evidence of error and bias in the great majority of the hundreds of experiments now run in this area (see Evans, Newstead & Byrne, 1993, for a recent review). Subjects' inferences are affected not only by the logical structure of the problems, but by the content and context, the linguistic structures chosen and all manner of procedural variations. In the case of decision making, the theory of SEU has was found wanting as a descriptive model some years ago (e.g. Slovic, Fischhoff & Lichtenstein, 1977) although it still has application as normative model in decision analysis (Von Winterfeldt & Edwards, 1986). As with reasoning tasks, decision and judgement tasks are affected by a variety of psychological factors beyond the capacity of the normative theory to explain (for a review see Baron, 1988).

It will be argued here that reasoning and decision making are in fact closely connected. In the real world we normally reason in order to make decisions. However, decisions may be based either on an explicit process of reasoning or else on *intuitive judgement,* i.e. judgements that are made often rapidly and without conscious awareness of the processes which lead to them. Suppose for example that I ask someone in the UK a year ahead of a general election to estimate the probability that the Conservative Party will win it. People can do this in one of two ways. They can engage in a detailed process of reasoning in which various scenarios are explored concerning the likely development of the economy, foreign affairs that affect government popularity, internal strife among opposition parties and so on. The likelihood of these events can be considered, their effect on voting behaviour assessed and some overall answer to the question determined. Alternatively, people can be induced to answer such a question immediately, in which case they will give a non-random probability estimate reflecting their feeling of confidence in the issue. The latter method is "intuitive". This is not to say that the explicit reasoning method is free from selective processing and bias (see Kahneman &

Tversky's, 1982, discussion of the simulation heuristic).

What makes the connection between decision and reasoning research all the closer, is that many of the response to reasoning problems seem also to be judgemental and intuitive. In fact, when you look more closely at the nature of the reasoning tasks used by psychologists you find that it is actually a judgement or decision that is often required of the subject. For example, suppose we present subjects with the following statements:

(1) If a card has a letter P on one side then it has a number 4 on the other

(2) This card does not have a 4 on it

and ask the subject what, if anything follows. If the subject replies that this card does not have a P on it, then it seems clear enough that they have drawn an inference (Modus Tollens or MT). However, that is frequently *not* the manner in which deductive reasoning tasks are presented. More commonly, the subjects is asked whether a given conclusion follows. For example, in the above case they might be given the putative conclusion:

This card does not have a P on it

and asked whether or not it necessarily follows. Now this is actually a *judgement* and it is only our presumption that it may be based on an inference such as Modus Tollens. These judgements are actually biased by a logically irrelevant feature: subjects will accept many more arguments whose conclusions are negative rather than affirmative (see Evans et al, 1993, Chapter 2). The single most investigated problem in reasoning research is the Wason selection task (Wason, 1966) discussed later in this paper also involves decision making. Subjects are asked to decide which of four cards need to be turned over and it is far from clear, as we shall see later, that this decision rests upon any kind of explicit reasoning process.

In this paper, I will first discuss the issue of rationality in reasoning and judgement which I believe is central to the connection between the two fields and also to some of the illusory differences between them. Then I shall consider the nature of judgemental processes and biases which provide some key links between the two areas. Finally, I will then discuss some of the currently active research areas on the psychology of reasoning and examine the extent to which

their data can be understood in terms of judgemental and decision processes.

BIAS AND RATIONALITY IN REASONING AND DECISION MAKING

A clear connection between reasoning and decision research lies in the emphasis given in both fields to the concept of *bias*. Because most decision making involves risk, the capacity of people to make rational judgements about probability is a central issue. A series of highly influential papers by Kahneman and Tversky has proposed that people rely on a set of fairly simple heuristics in order to make such judgements, which lead in turn to a series of systematic errors or biases, such as neglect of sample size and base rate information or undue attention to relevant or vivid information (see Kahneman, Slovic & Tversky, 1982, Baron, 1988). Similarly, as already noted, there is much evidence of bias in deductive reasoning research. A recent attempt to summarise and discuss the main types of bias reported in both literatures is given by Evans (1992a). In both fields there are groups of authors who may be described as "bias researchers" and in a small number of cases the same authors have worked in both areas.

Rationality, as it turns out, is a highly emotive issue. It may not be the intention of bias researchers to impugn human rationality, but a number of rationalist authors have seen the work in this light and mounted vigorous defences. An attack on bias research in both areas was launched by the philosopher L Jonathan Cohen (1981) who claimed that irrationality could not be demonstrated by psychological experiments. He introduced three basic arguments which have pervaded the subsequent debate on rationality and are described by Evans (in press a) as the Normative System Problem, the Interpretation Problem and the External Validity Problem.

The Normative System Problem is that psychologists are wont to judge rationality by some normative system - such as standard logic - which may not be appropriate to the task and may not correspond to a system used by the subject. The Interpretation Problem is the argument that people reason logically from a personalised representation of the premises of the argument, i.e. they do not interpret the problem in the manner intended by the experimenter (see also Henle, 1962, Smedslund, 1970, 1990). The External Validity Problem encompasses arguments about

the artificial and unrepresentative nature of reasoning and judgment experiments and also the allegation that psychologists misuse their findings. For example, both Funder (1987) and Lopes (1991) suggest that inducing mistakes in experiments contributes to our understanding of the nature of inferential processes but does not provide a basis for the claims of irrationality in real world reasoning that some authors are prone to make. For a number of recent discussions of the rationality issue in reasoning as well as judgement research, the reader is referred to the volume edited by Manktelow & Over (in press).

Evans (in press a) has argued that the debate about rationality in human reasoning and decision making is confused by two different, but implicit definitions of rationality. These can be defined as follows:

rationality$_1$ (rationality of purpose) : reasoning or acting in a way which reliably helps one to achieve one's goals

rationality$_2$ (rationality of process) : reasoning or acting in a way which conforms to a supposedly appropriate normative system such as formal logic

One of the reasons that reasoning and decision research appears different is that the two fields have adopted these differing definitions of rationality. The traditional emphasis on logic in deductive reasoning research has lead to the adoption of rationality$_2$, which is exemplified in the current writings of both those who believe that competence is achieved by a mental logic comprised of general inference rules (e.g. O'Brien, in press) and those of the rival persuasion that it is based upon the manipulation of mental models. For example, the leading mental model theorist, Johnson-Laird has recently stated (1993, p. 2) that "at the heart of rationality lies the capacity of make valid deductions."

An idealised form of rationality$_1$ is the notion that people choose in such a way as to maximise expected utility, i.e. the traditional normative theory of decision research. However, I have argued in detail (Evans, in press a) that rationality$_1$ is more appropriate also in application to deductive reasoning research and that a false equation of rationality with logicality is the cause of a rather spurious rationality debate in this area. This argument rests in part upon a

demonstration that logic provides a poor criterion against which to assess the rationality of people's deductive inferences, and partly on the argument that much reasoning behaviour can be understood better on the assumption that people are trying to achieve certain goals. For example, the apparently irrational confirmation and belief biases can be reinterpreted in this light (see later section).

If people are rational$_1$ then their rationality is, of course, *bounded* or constrained by cognitive limitations. In fact, I concluded my earlier discussion with the observation that biases in reasoning reflect either (a) inappropriate appraisal by logic as the normative system or else (b) the influence of cognitive constraints such as selective attention to problem features or limited working memory capacity. I am happily not alone in taking a rationality$_1$ approach to reasoning. For example, Over & Manktelow (in press) state that "On evolutionary grounds, it is ... hard to see how this reasoning directed towards satisfying our basic needs and desires could tend to be anything other than fairly rational." Similarly, Gigerenzer & Hug (1992) state (p.129):

> "... what counts as human rationality: reasoning processes that embody content-independent formal rules, such as propositional logic, or reasoning processes that are well designed for solving important adaptive problems, such as social contracts or social regulations?"

Evans, Over & Manktelow (in press) have developed the distinction between these two forms of rationality further and also related it to the philosophical divide between theoretical and practical inference. The relevance for our present purpose, however, is that the rationality$_1$ approach provides a common perspective for the study of reasoning and decision making. In both cases subjects are seen to be attempting to achieve goals within cognitive constraints. The process by which this achieved, be it inferential or judgemental is then the major focus for psychological inquiry. The distinction between a reasoning and a decision task is now, quite rightly blurred.

INTUITIVE JUDGMENT, BIAS AND RELEVANCE

Once we start to view reasoning as a form of decision making, then the linking theme of intuitive judgement becomes salient. To what extent are our decisions and judgements the result of conscious thinking and to what extent unconsciously or intuitively determined? Are we aware of the causes of our decisions or do we lack insight and rationalise after the event? Do biases occur *because* we lack insight and therefore do not realise when we are making systematic errors?

These issues were addressed in detail by Evans (1989) in an attempt to provide a common theoretical framework within which to understand the biases reported in deductive and inductive reasoning tasks as well as in work on intuitive statistical judgement. It was argued that people do lack insight into key aspects of their cognitive processes, because the focus of their thinking is determined by preconscious or preattentive processes. Specifically, I argued for two stages. In first, preconscious heuristics determine the *relevance* of information. Relevance is a psychological, not logical concept, and is related to the notion of relevance proposed in the pragmatic theory of language comprehension of Sperber & Wilson (1986). What is relevant to the subject is what they think about, and is not necessarily what is *logically* relevant. With abstract reasoning problems I identified linguistic and perceptual cues as the main determinants of relevance. Once problems are set in realistic content, however, *pragmatic* cues - i.e. those associated with prior belief and expectation - dominate in determining attention.

The main thrust of argument by Evans (1989) was that biases occur because logically relevant information is selected out at the heuristic stage or irrelevant information selected in. The behaviour observed can be either based entirely upon the heuristic stage, i.e. be no more than an indication of what appears relevant to the subject, or may involve an inferential process at a subsequent analytic stage of reasoning. In the original account, I did not specify the nature of these analytic reasoning processes. However, I have since suggested (e.g. Evans, in press b) that mental model theory provides the most plausible account of analytic reasoning with novel problem materials, whilst subjects may well induce domain sensitive rules and schemas with

familiar material.

It is important to note the distinction between relevance and availability. For example, Pollard (1982) suggested that the availability heuristic proposed by Tversky & Kahneman (1973) to account for certain probability judgements could also account for responses on many reasoning tasks. Specifically, he suggested that people would choose options which were cued by prior associations. However, in my view availability may be necessary for relevance but it is not sufficient. A clear example is provided by research on the well known base-rate fallacy (Kahneman & Tversky, 1973). The basic effect is that people ignore base rate information when making posterior probability judgements, provided that some individuating evidence is presented - even if that evidence is non-diagnostic. The base rate information is salient in the presentation of these problems as is therefore clearly available. Subjects ignore it because it does not appear relevant. However, it may become relevant, for example, if a causal scenario is introduced which links the base rate with the event being judged and for other reasons (see Tversky & Kahneman, 1980; Bar-Hillel, 1980).

Whether relevance alone is sufficient to determine responding or whether analytic reasoning is also involved, depends upon the task and the motivation of the subject. The assumption of rationality$_1$ implies that the subject is motivated to fulfil the goal of the experiment in the context of the instructions given. However, as we shall see, there is more to it than this. Subjects may, for example, reason only to rationalise a decision which is in fact determined by relevance alone. This is illustrated by the following discussion of the abstract Wason selection task. Also habitual mechanisms of reasoning which normally assist subject may carry over into the experimental situation and interfere with their ability to perform the task according to the instructions. This illustrated by discussion of work on confirmation and belief biases. Finally, the decision making nature of reasoning task performance can be demonstrated by manipulations which specifically affect the preference structure of the choices, as is shown by some recent work using thematic content on the Wason selection task.

REASONING AS DECISION MAKING: SELECTED EXAMPLES

The abstract Wason selection task

The most intensively researched problem in the psychology of reasoning is the Wason selection task (Wason, 1966) a full detailed review of which is provided by Evans, Newstead & Byrne (in press, Chapter 4). Curiously enough, I have proposed (e.g. Evans, 1989) that this task might not actually induce any process of logical reasoning on the part of the subjects. In my view, the selection task is actually much more informative about the nature of judgemental and decision processes.

Most recent work on the selection task has investigated the effects of thematic contents and we will look at some of this later. For the moment, let us consider the abstract selection task, i.e. using arbitrary materials such as letters and numbers. Typically, the subject might be shown four cards which on their facing sides display the following values:

A D 3 7

The subject is told that these cards have been drawn from a deck in which each card has a capital letter on one side and a single digit number on the other. The claim is then made that the cards conform to the following rule:

If there is an A on one side of the card then there is a 3 on the other side of the card

The subject is told that the rule applies to the four cards and may be true of false. The problem is to choose which card or cards to turn over in order to decide whether the rule is true or false. Typically, subjects choose A and 3 or A alone. The correct answer is A and 7 since only a card with an A on one side which does not have a 3 on the other could falsify the rule.

The mystery is why subjects nearly always get this problem wrong when (a) it can be shown that they posses the relevant knowledge of conditional logic and (b) the task requires only a simple combinatorial analysis well within most people's working memory capacity to handle. It can easily be demonstrated that people understand that a conditional is false when the antecedent is true and the consequent is false (e.g. A7 in the above example). Also, they need only think about one card at a time and analyse just two logical possibilities about what could

be on the hidden side. For example, in examining the 7 card the subject need only consider the possibility of an A or a letter other than an A being on the back. They know A7 would falsify the rule, so why do they not the A and 7 cards?

The answer to this question has profound implications for the nature of human decision making. The evidence is that people make their choices intuitively, are biased by preconscious cues to relevance and reason consciously only to rationalise choices already made. I will briefly summarise the evidence for these claims.

It was demonstrated many years ago (Evans & Lynch, 1973) that subjects choices are influenced by a *matching bias*. That is to say they tend to match their choices to the cards named in the rule, regardless of their logical significance. The bias is demonstrated by introducing negative components into the rules. For example, if the above rule is reworded as

If there is an A on one side of the card then there is NOT a 3 on the other side of the card

then the great majority of subjects choose A and 3 which in this case is the logically correct answer. Thus it might appear that introducing a negative has made reasoning easier. The account of Evans (1989), however, is that subjects are merely choosing cards preconsciously cued as relevant without logical analysis. The source of relevance here is linguistic. Introducing a negative does not change the topic of the sentence. For example "I am working on my book today" and "I am not working on my book today" are both *about* the same topic - only the comment is different.

Actually, it appears that subjects do reason analytically on this task, but that this reasoning does not determine the decision made but serves rather to rationalise its outcome. There are two mains sources of evidence for this, one quite old and the other very recent. Wason & Evans (1975; see also Evans & Wason, 1976) demonstrated that the verbal reports given by subjects are rationalisations in the context of the experimental instructions. For example, a subject given the rule *If A then not 3* would typically choose the correct A and 3 and provide logically appropriate explanations of their choices, i.e. saying that a 3 on the back of the A would disprove the rule and vice versa. However, the same subject presented immediately afterwards

with the affirmative form of the rule, e..g If B then 8, would again typically choose the matching cards B and 8 with the explanation that and 8 on the back of the B would prove the rule true and vice versa. Thus it appears that subjects choices' are unconsciously determined by matching and that their verbal reasoning serves to justify these choices in the light of the instruction to prove the rule true or false.

Very recently (Evans, in preparation) I have provided a new source of evidence. Subjects are given the selection task on a computer screen and have to select images of cards using a mouse. The innovation is that subjects are instructed to point with the mouse at any card that they are *thinking* of selecting, but only to click on the card when they are sure. The prediction, derived from the Evans (1989) account of the abstract selection task is that subjects will only think about the cards that they end up selecting, because only these are "relevant" i.e. preconsciously cued to be the focus of attention. This hypothesis has been supported in several experiments which show that subjects inspect cards that will be chosen for much longer periods than those that will not. In fact, in most cases very little time indeed is spent considering cards that will not be chosen.

This finding has been demonstrated on a number of different abstract and thematic versions of the selection task which change the basic selection frequency of the cards. In almost all cases, however, the subjects who do select a particular card on a particular rule, inspect that card more than those who do not choose it. This strongly supports the claim that choices are unconsciously determined. It also explains which subjects do not choose the false consequent card (7 in the first example) despite their knowledge of the relevant aspect of conditional logic. They do not *think* about this card, so their knowledge cannot be applied. In one of these experiments, verbal protocols were also analysed and provided supportive evidence. Subjects refer only to the facing and hidden sides of the cards that they select, and make very few references to cards they do not select. Similar findings are reported in the protocol analyses of Beattie & Baron (1988).

In conclusion, then, work on the abstract selection task suggest that a well known "reasoning" problem is actually a decision task in which judgements are made intuitively and

biased by unconscious factors. Furthermore, it provides evidence against the rational model of decision making in which people are supposed to reason about the consequences of their decisions in advance of making them. My account of abstract selection task choices as non-consequential decision making supports the claims made recently by Shafir & Tversky (1992). However, I am also supplying a psychological account of the reasons for this. The implication is, of course, that many other decision we take may be made without prior reasoning and with little or no attention given to some of the options.

From the rationality$_1$ perspective given above decision making ought in general to be consequential, if people are fulfilling their goals. However, rationality$_1$ is bounded by cognitive constraints. What has been identified in the research discussed here is a major cognitive limitation, i.e. preconsciously determined relevance. However, when thematic content is used and preference structures are built into the selection task, decision making may become consequential as we shall see later in the paper.

Confirmation and belief biases

Two major and related biases reported in the literature are those of confirmation and belief bias. Confirmation bias is mostly demonstrated inductive reasoning tasks, and consists of an apparent tendency for subjects to seek evidence which supports their hypotheses and to avoid evidence which might refute them (see Evans, 1989, Chapter 3, for a review). Belief bias has mostly been investigated in syllogistic reasoning tasks, and consists of a tendency to evaluate the validity of an argument on the basis of a prior belief in the truth of the conclusion, rather than on the correct basis of whether or not it is determined by the premises (see Evans et al 1993, Chapter 8 for a review). Thus the difference is that confirmation bias relates to how evidence is sought and belief bias to how evidence is evaluated. Both phenomena, however, could be described as belief-maintaining biases.

To many authors, these biases provide strong evidence of irrationality in human reasoning. This is certainly justified from a rationality$_2$ perspective in which logicality is the key criterion.

In syllogistic reasoning, for example, the believability of conclusions can be shown strongly to influence both the evaluation and production of arguments despite clear instructions to subjects to base their answers on logical validity (see Evans, Barston & Pollard, 1983; Oakhill & Johnson-Laird, 1985; Oakhill, Garnham & Johnson-Laird, 1989; Newstead, Pollard, Evans and Allen, 1992). However, in contrast to the case of the abstract selection task, discussed above, there is also evidence that subjects choices are partially based on logical reasoning. In the three experiments reported by Evans et al (1983), for example, the percentage of conclusions judged valid by the subject on four classes of problem was as follows:

Valid-Believable	89%
Valid-Unbelievable	56%
Invalid-Believable	71%
Invalid-Unbelievable	10%

It can be seen that subjects do exhibit deductive competence in so far as they accept far more conclusions on syllogisms which are logically valid than on those which are invalid. Equally, however, they exhibit strong belief bias by accepting far more conclusions which are believable than unbelievable. The belief bias is particularly marked on invalid syllogisms leading to an interaction between the two factors (see Newstead et al, 1992, for a detailed discussion of the causes of this interaction).

Although belief bias is irrational$_2$, a case can be made that it is rational$_1$ (see Evans et al, in press). The principle theoretical accounts of the belief bias effect are the Selective Scrutiny Model of Evans et al (1983; given that name by Barston, 1986) and the mental model theory of Oakhill & Johnson-Laird (1985). Although differing in other respects, both accounts propose that people are inclined to accept believable conclusions without a full attempt to evaluate their validity. For example, subjects may accept a conclusion which *could* be true, given the premises, without any attempt to think of situations which provide counter-example cases in which the premises are true but the conclusion is not. The rational$_1$ argument is that we need to maintain a large and coherent set of belief in order to function at all. It is neither efficient nor

adaptive constantly to question the evidence for beliefs that we already hold. It is, however, important to examine and try to refute evidence that *contradicts* our beliefs. That is not to say, of course, that we should not be prepared to revise our beliefs from time to time.

A similar explanation can be made of confirmation bias phenomena, namely that these reflect a carry-over into the laboratory of reasoning methods which are adaptive in the real world. An explanation along these lines has been proposed by Klayman & Ha (1987) who suggest that many of the phenomena can be accounted for on the assumption that hypothesis testing involves the use of a *positive test heuristic* which is normally effective. It does not, however, work in the situations typically investigated in this literature such as the Wason (1960) 2-4-6 task. In this problem subjects are asked to generate number triples in order to discover the experimenter's rule. The initial example of a case conforming to the rule is 2 4 6. The actual rule, however, is a general one: *any ascending sequence*. What happens is that subjects adopt a specific hypothesis such as *ascending in equal intervals* and test this positively with cases such as

10 12 14

1 50 99

20 30 40

and so on, all of which conform to the experimenter's rule. Through such positive testing, the subject's hypothesis can never been disproved *on this particular task*. The hypothesis can be refuted with a negative test; for example if the subject says 1 2 8 then the experimenter will say that this conforms to the rule whereas it does not fit the subjects' hypothesis. Whether or not behaviour on this task should be called confirmation bias is moot, since there is no evidence that subjects are motivated to confirm their hypotheses - positive testing can lead to refutation in many other situations.

The other way in which a rational$_1$ account can be given of a bias is to argue for cognitive constraints. In fact, this is my own account of confirmation bias (Evans, 1989) and is similar to my explanation of matching bias on the selection task. I believe that subjects make positive tests

because they find it very hard to think negatively. There may be a general positivity bias which explains both positive testing and the focus on named features that produces the matching effect.

What the phenomena discussed in this section once again show is that performance on reasoning tasks may be better understood by looking at them as decision tasks. Belief bias, for example, reflects costs and benefits. The cognitive costs of questioning the evidence for beliefs already held outweighs the potential benefit and so people do not normally do this. On the other hand, the costs of accepting a conclusion incompatible with existing beliefs are potentially very high, in terms of the mental work required to produce a revised set of consistent beliefs and the reduced ability to understand and deal appropriately with various situations until this can be achieved. Ultimately, of course, if people's beliefs are fundamentally wrong then it is rational and necessary to revise them.

THE THEMATIC SELECTION TASK

In an earlier section, I discussed research on the abstract selection task and argued that decisions were determined by preconsciously cued relevance and that people's conscious reasoning served only to rationalise choices already made. The logically critical false consequent card was ignored because it was not psychologically relevant, even though the subjects have the necessary logical understanding of why it needs to be chosen.

From the early 1970's, however, there have been claims that reasoning on the selection task is facilitated if the problem is presented using thematic or familiar problem content. A number of versions have been produced in which most subjects choose the correct true-antecedent and false-consequent cards. A good example, is the Drinking Age Rule of Griggs & Cox (1982). Subjects are presented with the following scenario:

> On this task imagine that you are a police officer on duty. it is your job to ensure that people conform with certain rules. The cards in front of you have information about four people sitting at a table. On one side of a card is a person's

age and on the other side of the card is what a person is drinking. Here is a rule: "IF A PERSON IS DRINKING BEER, THEN THE PERSON MUST BE OVER 19 YEARS OF AGE". Select the card, or cards that you definitely need to turn over to determine whether or not people are violating the rule.

The subject is then shown four cards which display on their facing sides:

"DRINKING A BEER"

"DRINKING A COKE"

"16 YEARS OF AGE"

"22 YEARS OF AGE"

As Griggs & Cox (1982) and several replication studies have shown, most subjects correctly choose DRINKING A BEER and 16 YEARS OF AGE on this version.There have been a number of discussions as to why problems like this facilitate correct choices. It is not the case as was once thought that simply using thematic terms is sufficient. For example, if the the same rule and cards are presented in the Drinking Age Problem but without the preceding police officer scenario, then the facilitation disappears (Pollard & Evans, 1987). One explanation that has received a lot of support is that subjects retrieve and apply a pragmatic reasoning schema (Cheng & Holyoak, 1985). In this case subjects may apply a permission schema which classes the rule as of the form:

If an action is to be taken then a precondition must be fulfilled

Subjects instantiate the precondition as being over 19 years of age and the schema tells then that they must check the case where the precondition is *not* fulfilled. The scenario is necessary in order to cue the retrieval and application of the schema. A rival account which treats the problem more like a decision task is that of social contract theory (Cosmides, 1987). This proposes that for evolutionary reasons it is very important to check that people do not cheat on social contracts.

Manktelow & Over (1992) have pointed to an important distinction between the abstract selection task, discussed earlier, and the various thematic forms which facilitate performance.

The standard abstract version presents an indicative conditional - *if p is true then q is true* - and asks subjects to decide whether it is true or false. By contrast, problems such as the Drinking Age Rule are use deontic conditionals - *if you do p then you must do q* - and the subject's task is to decide whether such rules have been obeyed or not. Deontic reasoning, they argue, involves consideration of the utilities of actions and hence should lead to consequential decision making.

In support of this, Manktelow & Over (1992) produce evidence that subjects' choices may be shifted in given scenario according to the perspective or role assigned to the subject (for similar finding see also Politzer & Nguyen-Xuan, 1992; Gigerenzer & Hug, 1992). They used a rule given by a mother to a son, "If you tidy your room then you may go out to play." When subjects were asked to evaluate this from the viewpoint of the son to check whether the mother had followed their rule, they selected "tidy room" and "did not go out to play" (true-antecedent and false-consequent) but when asked to play the role of the mother checking if the son had followed the rule they chose "did not tidy room" and "went out to play" (false-antecedent and true-consequent). It is apparent from reading the above that each checks the method by which the other could cheat on the rule. From the mother's perspective the son is cheating if he goes out to play without tidying his room; from the son's perspective, the mother is cheating if he tidies his room but is not allowed out to play.

Research with deontic rules and social contracts thus shows that thematic materials do not simply serve to facilitate logically correct responses. In some cases they cue a non-logical combination (false-antecedent and true-consequent) but one which is consequential when viewed from a decision-making perspective. To put it another way the reasoning is rational$_1$ but not necessarily rational$_2$.

A question of theoretical interest, however, is whether choices in the thematic selection task are based on explicit reasoning to any greater extent than they are on the abstract selection task. Matching bias disappears when materials are thematic (e.g. Griggs & Cox, 1983) but it could be that pragmatic cues to relevance override linguistic ones in semantically-rich versions of the task. Recall that in the study of inspection times on selections tasks discussed earlier (Evans, in preparation) I investigated several thematic as well as abstract rules. These included social

contract rules which produce both the logically correct pattern and the inverted pattern of selections discussed above. In all these cases, the subjects spend very little time inspecting cards that they will not choose. For example, the false-antecedent card which is not chosen in most versions of the selection task is hardly looked at except on the kind of social contract rule which facilitates its selection. Thus is appears that pragmatic cues, including utilities, determine what is relevant and hence what is selected. This leads to consequential decision making, but not based upon an explicit process of reasoning.

CONCLUSIONS

In this paper, I have explored the idea that behaviour on a number of reasoning tasks may be understood better if viewed as decision making rather than in the traditional terms of logical reasoning. In the course of this, I have proposed that reasoning is consequential in principle (rationality$_1$) but highly constrained by cognitive limitations in practice. It is the nature of these cognitive constraints that needs to be examined if we are to understand the evidence for non-consequential decision making that is being reported in the literature (e.g. Shafir & Tversky, 1992; Baron, in press).

The most important theoretical issue, in my view, is the extent to which reasoning and decision making is based upon conscious, analytic reasoning or upon "intuitive" processes such as preconsciously cued relevance. In the case of the reasoning tasks discussed here, it has been suggested that syllogistic reasoning performance partially reflects explicit reasoning - accounting for the element of deductive competence shown - but that choices on the Wason selection task are entirely cued by "relevance" - even when they are logically correct and when, from a decision making point of view, they are consequential. In fact, if belief bias effects in syllogistic reasoning result from consequential decision making, as suggested in the earlier discussion, then the processes responsible must be seen as competing and interfering with the reasoning processes with which the subject attempts to solve the logical task given.

In conclusion then, and despite my proposal that people are rational$_1$, it can be seen that I

am not supporting the traditionally rationalist perspective, e.g. of classical economic theory, that people reason consciously about the consequences of their decisions and make their choices in that light. This may happen, but the evidence is that it frequently does not. Instead it appears that many decisions are made intuitively and are cued preconsciously by "relevance". It also appears that insight is poor and that explicit reasoning often serves only to rationalise decisions already made. Hence, the extent to which decision making is consequential may be largely a reflection of the fact that people have learned to respond to different situations in broadly adaptive ways.

The extent to which people's decision making is *not* consequential may also be seen as reflecting the reliance on intuition and relevance. Habitual methods of thinking, reinforced as successful in one context, may be carried over inappropriately to another. The tendency to think about only preconsciously selected aspects of the information given may thus greatly limit our ability to make appropriate decisions, especially when confronted with problems which are novel and unfamiliar in form. It is a disturbing thought that the best choice available to us in a given situation may be one that we never attend to at all.

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PROBABILISTIC MENTAL MODELS AND BOUNDED RATIONALITY

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The theory of probabilistic mental models (PMM theory) postulates a "satisficing" algorithm that produces good performance (e.g., percentage of correct answers in general knowledge questions) under conditions of limited knowledge, limited attention, and limited computational capacities. We have simulated how a PMM learns the structure of an environment and have derived several counterintuitive predictions, which we have tested. In particular, the PMM algorithm gencrates (i) a high level of performance with only very small knowledge, and (ii) the performance of the algorithm is -- across a broad range of situations -- related to amount of knowledge in an inversely U-shaped function ; that is, from a certain amount of knowledge on, more knowledge actually decreases performance. I will discuss PMM theory as a exemplary version of H. Simon's bounded rationality, and compare that approach to traditional explanations in terms of "heuristics and biases".

On Modeling Risky Choice: Why Reasons Matter

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Research on decision making comes in three flavors: descriptive, predictive, and prescriptive. If we consider also that decision research is often predicated on normative economic models, there is plenty of room for confusion about what it is that we are actually doing. The thesis to be defended in this paper is that accurate description is prerequisite to prediction and to prescription. We will focus at present on decision making under risk, but the argument extends easily to alternative areas such as research on linear models and on probability judgment.

In making description prerequisite to prediction and to prescription, I am explicitly rejecting positivist conventions for talking about the relation between theory and the world, conventions that were popularized in economics by Milton Friedman (1953) in his famous paper on positive economics. Friedman's main points have become part of conventional wisdom. Most famous is the dictum that one tests the adequacy of a theory by the accuracy of its predictions and not by the realism of its assumptions. Secondary points include the ideas that simplicity and fruitfulness should figure in breaking ties between theories that predict equally well, and that the relation between theory and reality boils down to "as if" rather than to "is." On Friedman's view, theories are no more than heuristic frameworks for organizing empirical data and for specifying the language in which phenomena are discussed. They are not intrinsically right or wrong but are only more or less accurate in predicting.

Michael Polanyi (1962) has argued a quite different case. For Polanyi, the most basic criterion for theory is truthfulness, which in turn resides in the contact of theory with reality. On his argument, wrong theories, no matter how elegant, are fruitful only in producing error. Polanyi's science does not reside in the cool application of scientific method but rather in the passionate pursuit of an unobstructed glimpse of the world. In Polanyi's words, "Scientists—that is, creative scientists—spend their lives in trying to guess right. They are sustained and guided therein by their heuristic passion" (p. 143).

Friedman and Polanyi differ sharply in the degree to which pure description is seen as contributing to right prediction. Friedman cares about right prediction because only right prediction can provide the foundation for economic policy. Provided that a theory predicts rightly, its descriptive accuracy is irrelevant. This is exactly the functional link that underlies behaviorism's focus on prediction and control. Polanyi's position is more in line with cognitivism in asking theories to do more than generate right predictions. In his view, science should seek truthful

theories that illuminate our understanding. Truthful theories generate right predictions because they embody right reasons.

In what follows, I will suggest how theories of human risk taking might have evolved differently if more attention had been given to accurate description at different points in history. In particular, I focus on the three basic phenomena that theories of risk taking aim to explain. The first is risk aversion which we can consider in its most behavioral formulation as a tendency for gambles to be less preferred than their expected values. The second is risk seeking which is the tendency for gambles to be preferred to sure things. The third is the Allais paradox which we can think of as a violation of the linearity assumptions of expected utility theory (EU).

Utility and Risk Attitude

Bernoullian Origins

As early as the mid-17th century, mathematicians converged on the idea that what we nowadays term "expected value" (EV) is a proper measure of a gamble's worth. In the 18th century, however, the idea was challenged by a hypothetical gamble known as the St. Petersburg paradox[1], a gamble that has infinite EV but that most people judge to be worth only a few dollars (see Lopes, 1981, for more on the St. Petersburg paradox). Many solutions were proposed for the paradox, one of which permanently set the mold for explaining why people undervalue gambles. This was the invention of Daniel Bernoulli (1738/1967) that we now call expected utility (EU) theory. Bernoulli pointed out that in computing expected value, the subjective value of money (utility) is implicitly assumed to be equal to its objective value. If we focus on subjective value, however, the St. Petersburg game looks much less attractive.

The explanatory device that Bernoulli used is known today under the name "diminishing marginal utility." Mathematically, we assume that utility (subjective value) is a concave (negatively accelerated) function of objective value. If we then replace objective dollars with utilities and compute the expectation of the utilities, it becomes apparent that the gamble is not worth much. The reason is that the concave utility function effectively compresses higher values, shifting the mean downward, and thereby reducing the game's average (i.e., probability weighted) value.

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[1] A fair coin is tossed repeatedly until it comes up tails, at which point the player is paid a sum equal to $\$2^n$, where n is the toss on which tails appears. For n = 1, the prize is \$2; for n = 2, \$4; for n = 3, \$8, and so forth. How much should a person pay for a single play of the game? According to the EV criterion, one should pay all one has because the EV of the game is infinite.

Bernoulli's utility construct provided *an* explanation for risk aversion, but he provided no supporting arguments to suggest that it was *the* explanation. In order to nail down the descriptive validity of his construct, he would have needed to move beyond the single datum that he was concerned with (i.e., the small value given to the St. Petersburg game) and figure out what sorts of subsidiary evidence might lend support to the role of diminishing marginal utility in producing risk aversion. In some sense, he would have needed to invent not only psychophysics (of which the utility construct is a precursor) but also cognitive psychology.

It is interesting to speculate how the history of research in risky choice might have evolved if Bernoulli and his contemporaries had been more concerned with descriptive accuracy. Several different questions might have been addressed. One clear tack would have been to verify that diminishing marginal utility has measurable impacts over the outcome ranges that occur in the St. Petersburg game and other large-prize lotteries. Examples of this tack can be found in direct measurements of utility reported by Allais (1986a). More telling, however, would have been attempts to link process measures such as protocols to judgments. The latter tack would have required Bernoulli to confront the issue of how diminishing marginal utility affects judgments.

Taken as mathematics, diminishing marginal utility reduces differences among large outcomes. The theoretical action, so to speak, is on the high end of the outcome continuum. This would lead one to predict that protocols concerning the St. Petersburg game would focus on comparisons among large outcomes. But when students in classroom settings are asked to decide (hypothetically, of course) how much they would pay to play the game just once and then to explain their choices, explanations almost invariably focus on small outcomes. One sort of explanation says, more or less, "I choose [a small number] because most of the possible outcomes are small." Another says, "I wouldn't pay more than [a small number] because I am unlikely to win more than that back." The explanations differ in whether or not they invoke a specific target or aspiration level but neither sort involves comparisons among large outcomes[2].

Inflected Utility and Linearity

Research on risk taking took a sharp turn against description following the publication of von Neumann and Morgenstern's (1944/1947) axiomatic restatement

[2] It is worth noting that, in other contexts, people are quite willing to use small subjective differences among large outcomes as explanations for risk aversion. For example, in the constant difference form of the Allais paradox, most people prefer $1 million for sure to .10 to win $5 million, .89 to win $1 million, and .01 to win zero. In defending their preference for the certain outcome, such people frequently point out that subjectively there is a much bigger difference between zero and $1 million than between $1 million and $5 million. This explanation would be consistent with Bernoulli's utility construct.

of the EU model. There is no need to get into specific axioms. The important point is that von Neumann and Morgenstern shifted the focus of theory away from description of underlying process and toward measurement and representation of preferences that were themselves taken to be primitive. Although von Neumann and Morgenstern defended their axioms as being psychologically plausible, their utility construct was to be seen as a device for *summarizing* preferences rather than for causing them. Similarly, the decision maker was considered to choose *as if* to maximize expected utility, though neither the mechanistic nor teleological aspects of maximization were taken to apply psychologically.

The von Neumann and Morgenstern theory not only eschewed description of process, it made it scientifically suspect. At the same time that the theory broadened the behavioral domain to include risk seeking-preferences as well as risk aversion, it trivialized description to mere insertion of kinks in a utility function, a move that now abjured psychological content (including psychophysics) as "nonsensical" (Savage 1954/1972, p. 96) and "meaningless" (Arrow 1951, p. 425). Although at one time there had been lively interest in the role of regret and ambiguity in risky choice (reviewed in Lee, 1971), these ideas did not make sense within an expected utility context. Consequently, they were banished from theoretical description for almost thirty years and have only recently been reclaimed descriptively as EU theory has begun to lose its luster. Similarly, the prominence of EU theory blurred and eventually erased the theoretical distinction between unique and repeated decisions even though it continued (and continues) to be central in actuarial contexts.

At the same time that EU theory was expunging the psychological content in the utility function and in the idea of EU maximization, its axiomatic focus opened the door to better understanding of the structural relations among preferences entailed by the EU principle. In this regard, Allais (1953/1979) contributed mightily by recasting EU theory into the proposition that preferences among lotteries should be linear in probability. His two paradoxical problems showed clearly that, contrary to linearity requirements, preferences were not constant over either additive (constant difference) or multiplicative (constant ratio) transformations of probabilities. Moreover, his focus on people's desire for certainty and on their need to trade off EU maximization with the prevention of ruin reasserted the primacy of psychological description in theory development.

Allais' critique had practical as well as theoretical significance since the failures of linearity that he exposed vitiated prescriptive applications of EU theory that used arbitrary reference gambles to measure utility (see Hershey, Kunreuther, & Schoemaker, 1982; McCord & De Neufville, 1985). But despite the theoretical relevance and intuitive cogency of Allais' counterarguments (even Savage succumbed to the paradoxes), his critique was virtually ignored for thirty years by most economists and most psychologists. (See Lopes 1988 for an analysis of how this

occurred.) By the late 1970s, however, economists and psychologists geared up to cope with Allais, a process that effectively redirected the energies of both groups to description.

Risk Theory in the Wake of Allais

Weighted Utility and Rank Dependency

Theory development after Allais can be divided into two phases. In the first phase, researchers tried to remedy the problems with EU theory by substituting subjective weights for probabilities much as Bernoulli had substituted utilities for objective values. Prospect theory (Kahneman & Tversky, 1979) was the most important development in this line, but it was soon recognized that the weighting tack Kahneman and Tversky had taken led to some undesirable mathematical consequences. Much more important from a descriptive point of view was their suggestion that the utility function is S-shaped about the status quo with risk aversion predicted for gains and risk seeking predicted for losses. Unlike the versions of inflected utility that had been proposed in the von Neumann and Morgenstern mold, Kahneman and Tversky's proposal reasserted the role of psychophysics in mediating risk attitude. Their version differed from that of Bernoulli, however, in that the mechanism operated on absolute magnitudes (producing mirror-image effects for gains and losses) and not on overall asset levels.

More recently, both psychologists (e.g., Birnbaum et al, 1992; Lopes 1984, 1990; Tversky & Kahneman, 1992) and economists (e.g., Allais, 1986b; Quiggen, 1982; Yaari, 1987) have moved toward a more radical reformulation of EU theory, one that gives up linearity while still retaining important mathematical properties of generalized averaging notions. The term that has evolved for referring to these theories is "rank dependent." While the term is not perfect (since rank *per se* is not really at issue) I will follow current convention and use it here as well.

The basic idea in rank dependent utility is quite simple. For simplicity, let us first examine a simple computational illustration. Consider a gamble of the form {.05,$1;.15,$25;.6,$50;.15,$75;.05,$99}. We would ordinarily compute the expected value as follows: (.05)($1) + (.15)($25) + (.60)($50) + (.15)($75) (.05)($99) = $50. It is in this form that one can immediately see the possibility for replacing dollar values by their utilities and for replacing probabilities by decision weights.

However, there is an alternative way to compute EV in which one writes the equation in decumulative form[3]: (1.00)($1) + (.95)($24) + (.80)($25) + (.20)($25) + (.05)($24) = $50. This can be interpreted as indicating that one gets at least $1 for sure, with probability .95 gets yet another $24, with probability .80 gets yet another $25,

[3] (1.00)($1) + (1.00-.05)($25-$1) + (1.00-.05-.15)($50-$25) + (1.00-.05-.15-.60)($75-$50) + (1.00-.05-.15-.60-.15)($99-$75) = $50.

with probability .20 gets yet another $25, and with probability .05 gets yet another $24. The final EV, $50, is unchanged by the decumulative computation but the apparent possibilities for psychological transformation shift. One can still replace differences in values by differences in utility, but transformation on probability would now involve decumulative probabilities rather than raw probabilities. For example, the original lottery has two outcomes each of which occur with probability .05. If raw probabilities were transformed (as in prospect theory), the same transformation would apply to both. In rank dependent theories, however, quite different things could happen to the .05 probability attached to the worst outcome and the .05 probability attached to the best outcome.

Three important possibilities for the decumulative transformation operation can be seen in Figure 1. On the abscissa of each graph are objective decumulative probabilities, D. A probability of 1.00 (to the right of the graph) is the decumulative probability attached to the worst outcome (i.e., you get at least the worst outcome for sure). To the left are decumulative probabilities for successively better and better outcomes, limiting at zero which is the probability of exceeding the best outcome. The ordinate shows psychologically transformed values, h(D), under three weighting scenarios.

The left panel displays what I call security-mindedness. The decumulative probability attached to the worst outcome (1.00) receives full weight. Successively better outcomes receive proportionally less and less of their objective weight (i.e., the weight they would receive in an EV computation). In terms of observable preferences, a person displaying this pattern of weighting would appear to be risk averse in the classic sense: sure things would be preferred to actuarially equivalent gambles. Mild risk aversion would be entailed by a curve bowing only a little from the diagonal. Extreme and even pathological forms of risk aversion (i.e., strict maximining) would be entailed by a curve running tight against the graph's vertical and horizontal boundaries.

The middle panel is the rank dependent analog to risk seeking in EU theory. The decumulative probability attached to the worst outcome receives a weight of 1.00, but weights attached to successively better and better outcomes receive proportionally more and more weight. I call this pattern potential-mindedness. It corresponds behaviorally to a preference for lotteries over actuarially equivalent sure things.

The right panel, labeled hybrid, has been proposed by Allais (1986) and by me (1990) to represent the weighting pattern for the typical decision maker. The weighting curve is basically security-minded for low outcomes (i.e., proportionally more attention is devoted to worse outcomes than to moderate outcomes) but there is some additional attention (over-weighting) for the very best outcomes in a distribution.

Protocols and Psychological Description

I have been arguing for some time based on protocols that psychological processes of this sort underlie the expression of risk attitude in choices among gambles (Lopes, 1987). Let me reiterate very briefly some of those arguments. For illustration, consider the two lotteries displayed in Figure 2. The 100 tally marks in each represent lottery tickets and the values to the left of each row represent possible outcomes. Each of the two lotteries has an expected value of $100. The labels printed below each lottery are for expository convenience only. Subjects saw unlabeled lotteries and referred to them by their position in the display (e.g., left lottery or right lottery).

When people with preferences that we would tend to label "risk averse" choose between these lotteries, they tend to prefer the short shot. A representative explanation runs as follows: "I choose the [short shot] because there is only one chance of me losing and the best odds indicate a good chance of winning $71 or more. The [long shot] has too many opportunities to lose—it is too risky." People with preferences that we would label risk seeking have quite a different slant on things. They tend to prefer the long shot, explaining themselves as follows: The chance for winning nothing is small with the [short shot] but since the dollar amount in the [long shot] is attractive I run the risk of losing and go for the [long shot]." Protocols such as these were my first clue that people were processing lotteries in decumulative form and that their risk attitudes were reflections of the relative attention that they paid to bad and good outcomes.

A recent doctoral thesis by Lindemann (1993) has substantiated the importance of security and potential in real-world decisions involving substantial risk. Lindemann studied the decisions of farm couples (husband and wife teams) to sell or hold grain. This is a continuing and complex decision for small farmers who must decide among forward pricing their grain (selling before the crop is harvested), selling at harvest to producers or in local spot markets, storing grain in hopes that prices will rise, or using options or futures markets to hedge against risk.

Lindemann found that most farmers could easily be classified as either security-minded or potential-minded. Security-minded farmers speak in terms of "protection," of "locking in prices," of "being sure of something," and of "avoiding loss." For example, as one woman commented on the decision of a farm couple who chose to postpone selling in hopes of higher prices: "They're gambling. Hopefully they don't gamble if they need the money or have to borrow for operating expenses. They could lose big." Farmers such as these tend to sell early, when the price covers costs plus a small profit.

Potential-minded farmers, on the other hand, typically wait to sell and often miss opportunities to sell at reasonable profit. These farmers frequently speak of

"hope," of "opportunities," and of "rising prices." They "shoot for prices" but do not see this as gambling. In one farmer's words: "Most farmers like to take even that remote chance to hit the highs." Another said "Farmers just naturally wait for a higher price even if there's a good price."

Lindemann also found that the women tended to be more security-minded than the men. She attributed the latter finding to the fact that women in farm couples tend to keep the books and so are more likely to be concerned with meeting costs plus a small profit. The men, on the other hand, regularly participate in "coffee shop" conversations with other farmers where social interaction and competition keeps everyone's focus on catching the season's high price.

Rank Dependence and Psychological Process

Although one tends to think of rank dependent models in algebraic terms and hence in terms of weighted averaging, the process can also be related to choice mechanisms. Strict security-mindedness corresponds as process to maximining in which the chooser compares risky options according to their worst outcomes. If they differ, the option with the better worst outcome is chosen. If they are the same, the attention switches to the second worst option and the comparison is repeated. In the same way, strict potential-mindedness corresponds to maximaxing in which choice is determined by a comparison of the best outcomes.

Strict security-mindedness and strict potential-mindedness (like maximining and maximaxing) can lead to very foolish choices when security or potential differences are small. Milder versions of the two, however, are not excessively affected by small differences in the critical regions of lotteries (i.e., small differences among worst outcomes for security-mindedness and among best outcomes for potential-mindedness). But both processes are relentlessly single-minded in the sense that the weighting operation focuses on either worst outcomes or best outcomes, but not both.

The hybrid function that Allais and I prefer (see again Figure 1) allows both worst outcomes and best outcomes to be considered. In terms of process, it has some relation to processing by what has been called a lexicographic semiorder (Tversky 1969). If two distributions are very different in their lower regions, the choice between them will probably reflect security-mindedness. On the other hand, if the two lotteries are similar in their lower regions, attention will shift to the best outcomes and the tie will be broken in favor of potential-mindedness. This kind of reasoning process applies both to the purchase of lottery tickets (in which the expenditure of $1 has little impact on one's overall fortunes, but the possibility of winning millions has major attractions) and for explaining both constant difference and constant ratio versions of the Allais paradox (see Lopes 1990 for a detailed explanation).

The idea of rank dependent weighting holds promise for linking traditional laboratory studies of risky choice involving experimental lotteries with studies of risk perception involving natural and technological hazards. One of the well-replicated findings of Slovic (1987) is that lay people's judgments of risks fall into a two dimensional space. One of the dimensions seems to correspond to "dread" or catastrophic potential and the other seems to correspond to lack of firm scientific knowledge (i.e., uncertainty) in the risk estimates.

These two dimensions have natural interpretations in a rank dependent model. In rank dependent terms, risk distributions that have potentially catastrophic outcomes (e.g., nuclear energy production) differ fundamentally at the low end from distributions with worse average outcomes but no catastrophic potential (e.g., production of energy from coal). Decision makers who combine outcomes and probabilities with the sort of security-minded weighting function shown in the left panel of Figure 1 would tend to prefer risks without catastrophic potential even if the probability of the catastrophic outcome were small and even if the average outcome of the more secure risk were worse.

Uncertainty or ambiguity in risk estimates also decreases the acceptability of risks in a rank dependent model. To see this, consider a technology that experts estimate will cause no annual fatalities with probability .99 and one or more fatalities with probability .01. To the extent that these estimates are firm (i.e., based on solid actuarial data), the numerical values will enter the weighting process as given. But if there is uncertainty in the estimates (as there often is with new and untried technologies) either the probabilities will be adjusted to allow for increased probabilities of bad outcomes (e.g., Einhorn & Hogarth, 1985) or the outcome levels will be adjusted to allow for worse outcome levels (i.e., more fatalities) or both. In either case, the option will become less acceptable in a rank dependent weighting scheme.

Beyond Rank Dependence

Rank dependent models of risky choice appear to do a good job of describing human judgments. While providing a natural place for capturing how people directly weight bad and good outcomes, they also allow for influences on judgment from psychophysical or utility effects of outcome magnitudes. However, rank dependence may not be sufficient to describe all risky choices even in fairly simple situations. I will briefly describe two such cases for illustration.

Risk Seeking for Losses

It has long been noted that people frequently take risks when they are confronted with possible losses (Bowman, 1982; Kunreuther & Wright, 1979;

Williams, 1966). Prospect theory (Kahneman & Tversky, 1979) provided a formal explanation for this phenomenon by proposing that the utility function is S-shaped, being concave (risk averse) for gains and convex (risk seeking) for losses. This idea has been retained in the new, rank dependent version of prospect theory (Tversky & Kahneman, 1992). However, close examination of the data from studies comparing choices for gains with choices for losses reveals frequent failures of reflection and framing predictions based on the S-shaped function (e.g., Cohen et al 1987; Fagley & Miller 1987; Fischhoff 1983; Hershey & Schoemaker 1990; Miller & Fagley 1991; Schneider 1992; Schneider & Lopes 1986). Although choices for gains are often risk averse, choices for losses are variable both between and within subjects. In addition, subjects express conflict much more frequently when choosing among losses than when choosing among gains (Lopes, 1987).

If people's greater willingness to take risks for losses were being caused by an S-shaped utility function, one would expect reasonable degrees of symmetry to hold for gains and losses. Although there might be small differences for particular comparisons reflecting the interaction of the weighting function with the utility function, by and large there should be similar patterns for gains and for losses, both in terms of preference and in terms of conflict. Absence of such symmetry suggests that some other mechanism may be causing the observed increased willingness of people to take risks for losses.

The variability in choices among losses and the experience of increased conflict may signal the operation of more than one psychological process in risky choice. This idea has been formalized as a two-factor model called SP/A theory (1987, 1990). SP refers to security-potential. This component uses rank dependent weighting to capture the way that a lottery's probabilities and outcomes are combined into an overall index of attractiveness. The three weighting forms shown previously in Figure 1 are from SP/A theory.

SP/A theory also proposes that people's choices are often aimed at maximizing the probability that they will achieve some aspiration level (the A in SP/A) at some acceptable level. For example, recall that in the St. Petersburg game many subjects would refuse to pay more than a small amount for the gamble because they believe that they would have too little chance of (at least) breaking even if they paid more. This would be an example of aspiration level thinking. Such processes are probability driven and are related conceptually to the sorts of "bold play" mechanisms that were initially described by Dubins and Savage (1965/1976) and now are considered part of the study of stochastic control.

Subjects who face choices among losses often describe their dilemmas in terms that suggest a conflict between their aspiration to lose little or nothing and their overall assessment that a lottery is potentially dangerous. To illustrate, Figure 3 compares the short shot lottery with a rectangular lottery having the same expected

value. Most risk averse subjects prefer the short shot for gains, expressing little or no conflict about the choice. For losses, however, preferences are more variable and conflict between aspiration and security is more prominent. For example, one subject who chose the (riskier) rectangular lottery said "Another difficult one. I chose the [rectangular] lottery because the odds are equal on each dollar amount, whereas the [short shot] shows the odds in favor of a loss of $70 or more, and very good odds of losing $130. The [rectangular] seems to be a safer risk despite the potential for a higher loss, i.e., $200 max."

The 2x2 table in Figure 3 schematizes the hypothesized difference between gain and loss choices. According to SP/A theory, risk averse subjects tend to be security-minded in rank dependent terms and tend to have modest aspiration levels for gains. If we suppose, for example, that some particular subject would be content to win $50 in a choice between the short shot and the rectangular lotteries, it follows that both the security-weighting mechanism and aspiration level considerations would favor the short shot. On the other hand, if we assume that the same subject facing a loss aspires to lose no more than $50, we see that the security mechanism and the aspiration mechanism now push in opposite directions. Security-mindedness prefers the short shot since it has a considerably lower maximum loss ($130 versus $200) but aspiration level prefers the rectangular since it gives the greater chance of losing less than $50 (25% versus 10%). The conflict between the two factors produces individual uncertainty and greater choice variability both between and within subjects.

Regret and Aspiration

At one time, before modern (axiomatic) EU theory had achieved theoretical hegemony in the area of risky choice, there was considerable interest in the idea that people's choices might be aimed at reducing or minimizing the possibility of regret once the outcome of a decision was known (see Lee, 1971, for a review). There were even attempts to incorporate regret into normative theory (Luce & Raiffa 1957), though these eventually were abandoned because they led to unacceptable consequences such as intransitivity and influence from irrelevant alternatives. Descriptive interest in regret has been rekindled recently, however, by theorists who have used the idea to explain and justify behavior that violates EU (Bell, 1982; Loomes & Sugden, 1982, 1987) and by laboratory research that confirms that regret plays an important role in choice and in our experience of outcomes (e.g., Johnson, 1986; Landman, 1988).

Even more telling, however, is the evidence of regret and other emotion-based thinking in the protocols of Lindemann's (1993) farm couples. In one task, for example, respondents were asked to comment on the experience of a farm couple

(the Grays) who had passed up an opportunity to sell in April at a small profit and then at harvest were fortunate to sell at an even higher profit. Although one might suppose that the Greys were elated, one security-minded respondent saw the Greys as foolhardy. As he said, "They had to be anxious....They should feel lucky they were rescued by a price increase." For security-minded respondents, avoiding regret appears to be normative and early sales (forward pricing) are described as "peace of mind during the growing season when the price is locked in."

For potential-minded respondents, regret works the other way. When another couple (the Browns) were described as selling in April at a small profit only to find prices at harvest even higher, potential-minded respondents expected them to be "disappointed that they did not sell when the price was at its highest." Respondents such as these think that "forward pricing is taking too big a gamble" and readily see the possibility for painful regret ("It hurt too much to harvest beans that they could have received 40 cents per bushel more for..."). As Lindemann (herself the co-owner of a family farm) remarked of this all-too-real situation, "What student of regret theory understands what it is like to measure regret by the bushel as it pours into a combine grain tank?" (p. 93).

Lindemann's protocols are filled with emotional language. They are also keenly attuned to aspirations set on the basis of a myriad of goals and needs (e.g., meeting costs, loans coming due, memories of past highs and lows, coffee-shop braggadocio, competition among neighbors and family members). Although some of these factors may be interpreted as affecting weights in a rank dependent scheme, conflicts among incompatible goals will require additional theoretical mechanisms (as in SP/A theory) as will both pre-decisional and post-outcome comparisons involving outcomes and aspirations (as in regret theory). Real-life risk taking is richly textured and many dimensioned, well beyond the limits of what most theoretical models can describe. Still, if we wish to predict human behavior in such settings and especially if we wish to help people make better decisions, we must grapple with the process as it exists, complexity and all.

Predicting and Prescribing for Real

As I noted in the introduction, there are three distinct lines of research in risky choice: descriptive, predictive, and prescriptive. These lines originate at a common point—the invention of modern EU theory—and they intertwine so tightly and so incessantly thereafter that even well-versed readers of the literature on risk taking may be hard pressed to know at any given point whether an author is describing what actually is, what is likely, or what ought to be.

Like the Hydra, which grew two new heads for each one lopped off, early laboratory results suggesting the descriptive inaccuracy of EU were met by more and

more hardened resistance to the idea that decision making might or should deviate from EU axioms. Evidence of this resistance is made apparent by holes in the literature signaling the suppression of entire topics of study during the first three decades after von Neumann and Morgenstern. I have already mentioned the moratorium on regret research. But this is just one of many suppressed topics. Allais' (1953/1979) penetrating critique of EU's linearity assumptions were met by a combination of smug superiority (i.e., if you really understood the axioms you would accept them) and stony silence. Ellsberg's (1961) commentary on ambiguity came to a similar fate. The familiar and previously undisputed distinction between unique and repeated gambles faded into obscurity. Only in the last 15 years have these topics resurfaced in descriptive research. And even so, the belief lingers, especially among psychologists, that deviations from EU theory represent misunderstandings and human limitations in information processing rather than alternative conceptions of rationality.

In recent years, economists and decision analysts have reluctantly come to accept the existence of preference reversals and other sorts of judgmental context effects and well-understand the serious impediments such phenomena place in the way of psychological measurement. Serious as these may be, however, the technical problems may be surmountable if attention is given to finding the "best" response mode for measuring or predicting values in particular contexts. In contrast, most of the failures of EU theory that have been discussed in this paper cannot be "fixed" even in principle because they represent fundamental differences between what people seem to care about and what adherence to EU provides.

Classical Dutch book and money pump defenses of EU axioms are on par with parental threats of the bogeyman. Sadly, perhaps, for children and for adults, what is out there in the world is much more immediate and threatening than what might be under the bed. The idea of counseling decision makers to eschew considering potential regret because it might hypothetically lead to intransitivity is silly and useless. If there is virtue in trying to help people avoid the potentially negative impacts of emotions and reasoning errors on decision making, such help will only be acceptable if it also aids the decision makers in achieving their own goals, including such positive emotional states as security, predictability, and even fun.

For illustration, let me return one last time to Lindemann's (1993) study of farm couples. It is an inescapable truth known to farmers and to bureaucrats alike that farming is a financially dangerous occupation. Nor is good advice hard to find. Farm agencies of all sorts routinely council farmers on such sound principles as setting price targets in advance and abiding by them even when it seems that prices might go higher, considering the hidden shrinkage and storage costs of choosing to hold grain, and turning a deaf ear to coffee-shop advice from friends and neighbors. Unfortunately, few farmers follow the advice even though they know from hard

experience that they should.

One particularly interesting example of a failed federal attempt to help farmers manage the risks of farming better was a program introduced by the U.S. Department of Agriculture in 1985 to encourage grain producers to use commodity futures and options markets to hedge against risk. The program was introduced with great fanfare and with the expectation that eventually it would involve thousands of producers. Three years later, however, the program quietly expired with only five grain producers having participated. This failure would have been entirely predictable had agency experts bothered to ask farmers about their perceptions of the relative risks and benefits of alternative risk reduction schemes. Had they done so, they would have found (as Lindemann did) that farmers and agency experts differ radically in terms of the perceived riskiness of holding grain versus using the futures market as a hedge. For the experts, hedging is judged to be the least risky of all alternatives and holding to be second most risky. For farmers, however, holding grain is second in safety only to selling while hedging ranks somewhere in the middle of the list.

Lindemann argues that prescriptions for curing the ills that plague small farmers ought to be based on realistic description of the producers' financial and social world. For example, she suggests that the cost-based caution that the women tend to show should be exploited when selling decisions are made. At present, even though women are more likely than men to have a proper idea of what costs are and what a profitable price would be, women participate very little in the final stage of making selling decisions. The reasons for this separation between costing and selling is mostly coincidental, reflecting the fact that cost computations are done at home by the women whereas selling decisions are made away from home by the men. Finding a way to involve the women at the point of sale is just one way to increase the influence of costs on decisions and decrease unwanted social influences.

Lindemann also suggests that decisions oriented solely to achieving security are unlikely to appeal to potential-minded farmers. She suggests that a strategy that acknowledges both kinds of goal and allows for their expression might work better than strategies aimed at stamping out all speculative and competitive urges. Her prescription is to separate these motives by dividing the available crop into two bundles: the security bundle and the opportunity bundle. The quantity allotted to the security bundle should be as large as necessary to cover the basic needs of the operation. Spouses would agree to sell this bundle when a certain price is reached or by a certain date. The opportunity bundle would be available for speculation by the potential-minded member of the team, with suitable conditions imposed to make sure that such speculation in no way endangers the income in the security bundle.

For most of the last fifty years, researchers in risk theory have supposed that accurate description is nice but unnecessary to prediction and prescription. This position is baffling given the important role that advances in description have played in improving prediction and prescription in the physical and biological sciences. In retrospect, there is a chicken-and-egg quality to the question of whether it was the normative allure of EU that hampered good descriptive studies of risk taking or the absence of good descriptive data that bolstered the empirically unsupported claims of the normative theory. Whichever it was, however, the chickens have flown the coop, one hopes never to return.

Much of the original normative appeal of EU theory lay in its potential usefulness for psychological measurement. But measurement doesn't require normative theory: descriptive theory will do just fine so long as it is accurate enough to allow researchers to devise measurement tools that reach beyond superficial responses to deeper values. Although it is humanly understandable that applied researchers will mourn the demise of techniques based on the assumption that EU describes both human behaviors and human intentions, let us hope that the time spent grieving will be brief. Time is precious and there is critical work to be done in rebuilding predictive and prescriptive tools for risk taking from today's new and more accurate descriptive base.

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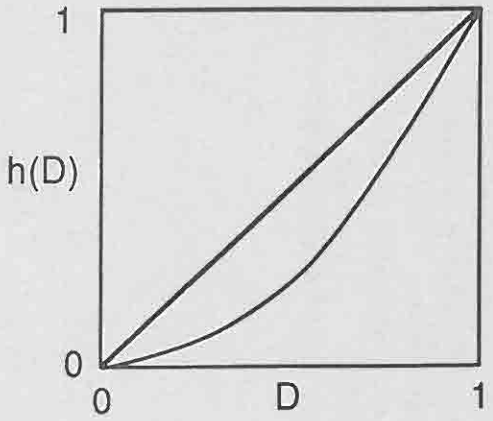
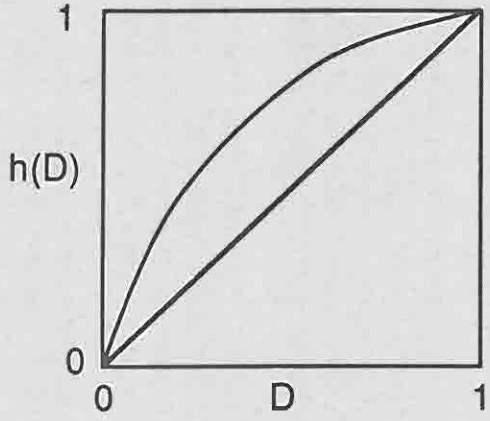


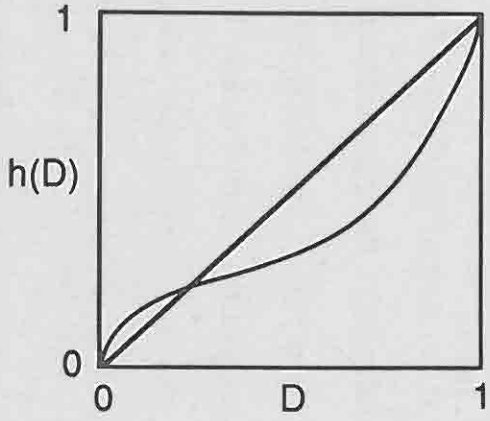
Security-Minded

D near 0 (better outcomes)
de-weighted relative to
D near 1 (worse outcomes)



Potential-Minded

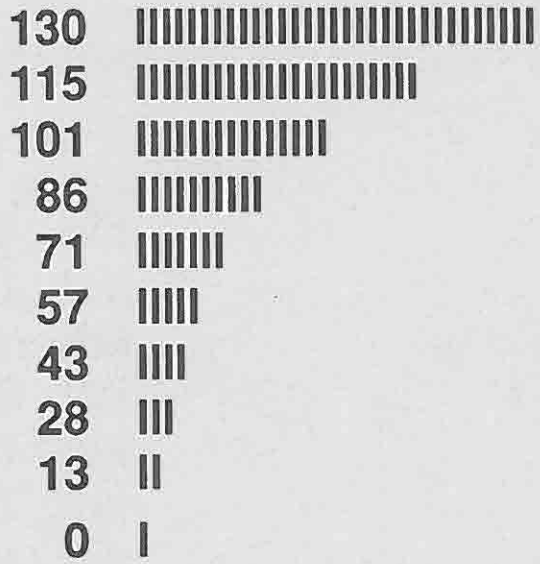
D near 0 (better outcomes)
over-weighted relative to
D near 1 (worse outcomes)



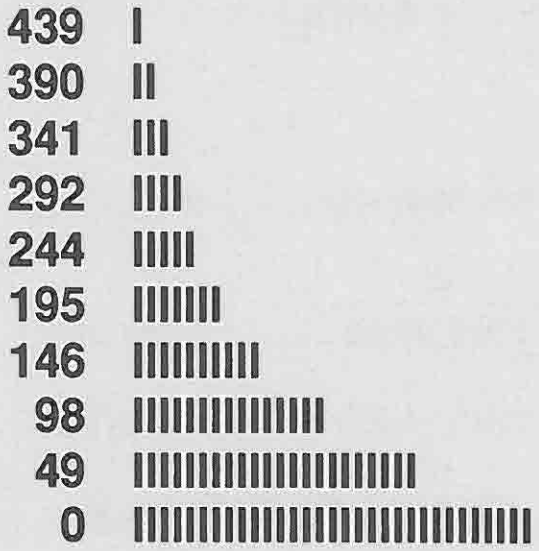
Hybrid

Basically security-minded
but potential is considered
when security differences
are small

Figure 1

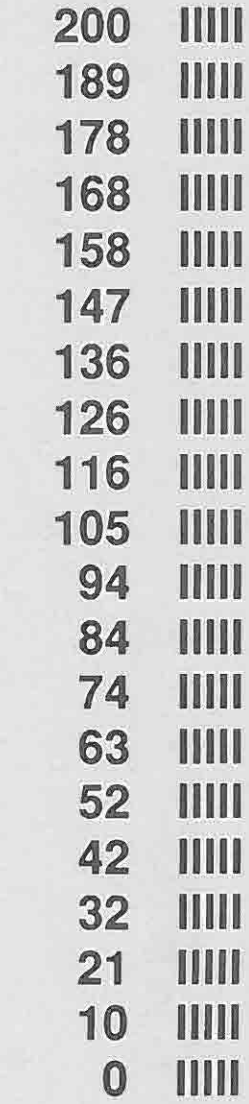


Short Shot

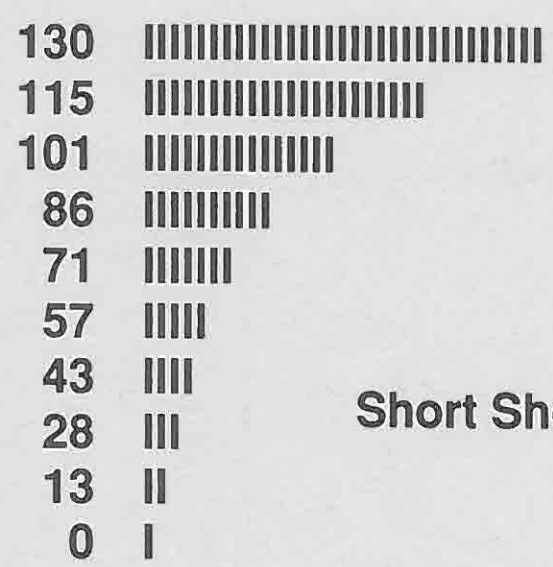


Long Shot

Figure 2



Rectangular



Short Shot

Risk Averse Pattern

	SECURITY	ASPIRATION
GAINS	Short Shot	Short Shot
LOSSES	Short Shot	Rectangular

Figure 3

Uncertainty and Decision Making – Expert Treatment of Human Expertise

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Abstract: Expert knowledge has greatly lost its image of an unbiased and reliable source of information to knowledge-engineers and cognitive psychologists. With respect to uncertainty in knowledge structures, some attempts have been made at reducing the distance between the requirements of formal models and empirical reality. — Beginning with the assumption that most expert knowledge can be characterized as incomplete conditional knowledge, in the first part of this paper, some decision-theoretic points are made that lead to considering more general models of representing uncertainty than classical probability. It is shown that belief functions provide sufficient generality for taking into account some of the systematic deviations of human judgment under uncertainty from classical probability theory. In the second part I develop some of the ways in which typically incomplete expert knowledge can be modeled using so-called conditional events. Probabilities on conditional events naturally take the form of belief functions. The scenario in this part is taken from diagnostic expert systems. Different models can be defined to account for varying specificity of the knowledge. They show markedly different behaviour w.r.t. incorporating new evidence.

Keywords: Dempster/Shafer theory, Combination of Evidence, Conditional Objects, Human Information Processing

1 Introduction

Human decision making and inferencing are commonly based on knowledge. Thus, if research is propagated in the realm of decision making under risk or uncertainty,

evaluation of knowledge has to be taken into account, and vice versa. One of the truisms in expert systems research was that human experts are able to evaluate knowledge and to make decisions in a more intellignet way than conventional computer software could. But this truism merely reflected implementation issues than modeling issues. A conventional computer program crunches numbers or even symbols, evaluates conditions, and so on, in a fixed sequence. It was assumed that human intelligent systems would process data in a more flexible way, testing only relevant conditions, economizing on the numbers of rules that have to be used, and so on. However, what this truism overlooked was man's ability to build formal models that are much better than individual intuition even of the most advanced experts. This is true for many domains, starting with optimization of resources or resource mixtures and ending with evaluating diagnostic probabilities. Our collective reason goes beyond the capabilities of individual reasoning. This is what makes the truism on the phantastic abilities of human experts sound a bit odd today.

As a consequence, expert systems have not been able to fulfil the expectations of neither the scientific nor the computer users' community. To a great extent, they even fell short of adequately modeling expert knowledge where this knowledge was undoubtedly individual and could not be formulated more precisely by using a formal model. Therefore, today, expert systems come along with much more moderate promises than they used to. They are increasingly designed such as to help carrying out administrative tasks that require browsing large amounts of data, like EC-customs regulations. The replacement of men or women by intelligent machines seems as remote a vision as it did 40 years ago; perhaps this is a more productive and realistic perspective for using computing technology.

All this leaves the opaqueness of human knowledge structures quite unresolved. The hope that computer expert systems would help us to ever better understand human experts or human cognitive systems has not been fulfilled. The ways along which computer science and cognitive psychology progress have crossed but today they seem rather diverge again than coming to a new crossing.

Since about seven years, the issue of uncertainty in expert knowledge has attracted an ever greater number of computer scientists all over the world (perhaps the most encompassing monography on the state of the art as of that time is Goodman & Nguyen, 1985). Both a yearly American and a bi-annuary European series of conferences is devoted to this theme. Expert systems using probabilistic calculus have become wide-spread since Pearl's book (1988) and a paper by Lauritzen & Spiegelhalter (1988). Basically, these systems are built on conditional dependence

and independence assumptions that are the probabilistic counterparts of rules in rule-based systems. Experts are asked to provide structural rather than numerical or judgmental information in these approaches. Like in traditional rule-based systems, they are asked to state possible dependencies between variables describing phenomena in the to-be-modeled domain. However, the marked difference w.r.t. older approaches is the strict locality of independence assumptions being maintained throughout the whole knowledge base. Only very few variables will be (marginally) independent, most independencies will be conditional. Conditional independence is much easier to verify, because it states independence only if *all other things are equal.* A simple interpretation of conditional independence, given by Pearl (1988), is that specifying a conditioning variable makes conditionally independent variables uninformative to each other. (There is a close relationship between these models and independence models in the analysis of contingeny tables, see Bishop, Fienberg, & Holland, 1975. There is also a relationship to discrete independence models used in database design theory, see Fagin, 1977; Beeri, Fagin, Howard, 1977; Ozsoyoglu & Yuan, 1987; Spies, 1991a.)

To sum it up, these approaches have, to some extent, alleviated the burden of judgmental tasks from experts. Their heuristics and biases in judgmental tasks *seem* to be of less relevance to judgments of influence of variables on other variables than to judgments that somehow imply valuations of whatever kind of degree of uncertainty— despite the fact that this is not proven at all by empirical psychological research, see the papers on covariance and control in Kahneman, Slovic, and Tversky (eds., 1982).

The meaning of independence assumptions for decision research is quite similar to that for probabilistic expert systems. In decision research, different kinds of independence are distiguished that help making value functions and utility functions easier to assess and to express. A link between probabilistic independence and additive independence in multiattribute utility functions has been established by Keeney & Raiffa (1976, p. 242). They prove that that an additive utility function exists if marginal probabilities on attributes are independent and if the multiattribute function is multilinear. In this case, certainty equivalents for probability mixtures of values of single attributes under fixed values of independent attributes can be combined into a joint certainty equivalent for a risky commodity bundle composed of realizations of all attributes in question. This result generalizes easily to conditional independence in both utility functions and probaiblites. This is a remarkable relationship; it shows that structures which help simplifying decision making also help simplifying the architecture of expert systems. To my knowledge, this relationship

has not been exploited yet.

2 Incomplete conditional knowledge

It would be an unrealistic approach to designing expert systems, if one assumed that all domains can be modeled by enough statistical data once an expert (team) has identified the necessary independence and dependence relationships among variables. Expert judgment, as odd a phenomenon as it may seem today, is still often a valuable and the only accessible source of evaluation. Moreover, the striking question of how humans arrive at their personal judgments of perceived uncertainty or risk is not solved by mere technical developments. In this paper I want to discuss the knowledge structures that may be used by humans in forming their judgments of probability or risk. I will start my considerations with the following principle:

Human evaluation of uncertainty is based on incomplete conditional knowledge.

By *conditional knowledge* I understand a rule-like structure of knowledge. It seems that human experts are only able to state conditional uncertainties rather than unconditional ones. For instance, if a surgeon assesses the odds of a disease given a symptom, he/she is usually unable to provide base rates of this disease. As a consequence, I do not see why humans should not exhibit was has been termed the overconfidence bias (see Liechtenstein, Fischhoff & Phillips, 1982). The analysis of this bias takes it for granted that humans are able to assess their own confidence in their probability judgment in a meaningful way without recurring to a baseline against which to compare themselves. I think it would be highly interesting to see how this bias looks if only conditional confidence ratings would be asked for.

By *incomplete* conditional knowledge I mean that often human knowledge relates only to some of the possible antecedents of a rule. For instance, the combination of two swollen cheeks indicates mumps, but is it hard to say whether one swollen cheek of a child on one day does indicate mumps or not. Generally, not all combinations of antecedents are considered in human knowedge, some may even be unreasonable. As a consequence, human conditional knowledge often cannot fulfil the requirements of a Bayesian model of uncertainty (this will be explained in more detail below). A second consequence is that if evidence concerning antecedents of rules (tagged with uncertainty valuations) comes in, often only partial matches exist that fail to lead

to a clear conclusion about the uncertainty valuation of any rule consequent.

The principle of incomplete conditional knowledge is meant normatively in this paper; I am not saying that a language that is based on incomplete conditional knowledge could describe any human judgment pattern without having to recur to the famous heuristics and biases investigated principally by Kahneman, Slovic, and Tversky (eds., 1982). However, it can be shown that incomplete conditional knowledge can explain at least some of the observed biases in human judgments. For the conservatism bias, I have shown this in a previous paper (Spies, 1991b; see also Edwards, 1982). I will not reiterate this argument here. I rather wish to concentrate on how incomplete conditional knowledge can be described and used to predict human performance.

Incomplete conditional knowledge, in my view, is one more of the possible languages for expressing uncertainty (see Shafer & Tversky, 1985; Dubois & Prade, 1988, 1989). It is, I hope, particularly suited to what we experience in practice when working with domain experts: the necessity to base judgments on some antecedents and the impossibility to assess uncertainty judgments under all combinations of relevant antecedents.

The remainder of the paper is built up as follows. First, I will show that a generalization of classical probabilities, the so-called belief functions, are one possibility to take into account failures of human judgment under uncertainty that cannot be attributed to biases but rather to a difference between normative and cognitive models. Second, I will give a very brief overview of some essentials of the theory of belief functions, often termed theory of evidence. Third, I will show that incomplete conditional knowledge can be decribed by so-called conditional events. Fourth, it is demonstrated that valuations of expert rules can be translated into belief functions on sets of conditional events. Fifth, integration of *a priori* knowledge and new evidence is described w.r.t. to its impact of model structures.

3 Evaluation of Risk beyond classical probability

The classical definition of decision making under risk presumes knowledge of the probability distribution of the states of nature on the part of the decision maker. Keeney & Raiffa (1976) show how lottery preferences translate into a scaling of

probabilities that obeys expected utility theory. In this section I wish to make the point that a very well known violation of expected utility theory by decision makers can be taken into account if we allow for partially known probabilities given by so-called belief functions. Thus, if we allow the classical distinction of decision making under risk vs. under uncertainty to be blurred, we get a normative model that is in better accordance with decision maker's behaviour.

The Allais paradox is one of the most famous examples of a human preference pattern that violates the axioms of expected utility theory (see Chankong & Haimes, 1983, p. 181). The paradox is constructed by contrasting two pairs of gambles. In the first pair, the two gambles are

Gamble 1.1 Win 1 million \$ with certainty.

Gamble 1.2
- Win 2 million \$ with $p = 0.09$,
- win 1 million \$ with $p = 0.9$,
- nothing with $p = 0.01$.

The two gambles in the second pair are

Gamble 2.1
- Win 2 million \$ with $p = 0.09$,
- nothing with $p = 0.91$.

Gamble 2.2
- Win 1 million \$ with $p = 0.1$,
- nothing with $p = 0.9$.

It is supposed to be reasonable (while not rational) to prefer gamble 1.1 over 1.2 and to prefer gamble 2.1 over 2.2. The reasoning behind this pattern of preferences, in the first pair, is that a certain prospect is better than a slightly uncertain one with higher expected value, and that, in the second pair, the higher probability of winning is traded off against the smaller gain being obtained. (Upon some reflection, this pattern of preferences is not as natural or reasonable as it seems.) An expected utility model for this pattern of preferences would require that

$$0.1u(\$10^6) > 0.09u(\$2 \cdot 10^6) + 0.01u(\$0) \tag{1}$$

and

$$0.09u(\$2 \cdot 10^6) + 0.01u(\$0) > 0.1u(\$10^6) \tag{2}$$

The first inequality follows from the first pair of gambles by subtracting $0.9u(\$10^6)$ from both sides of the relation between the corresponding expected utilities. The second inequality follows from subtracting $0.9u(\$0)$ from both sides of the corresponding relation between expected utilities. Obviously, there is a contradiction between the two inequalities describing the preferences in terms of expected utilities.

It has been noticed (see Jaffray, 1989; Kämpke, 1992) that this contradiction can disappear if we allow some distortion of the numerical probabilities. Usually, such a distortion is assumed to be a monotonous function from the unit interval onto the unit interval which is continuous from the left. Moreover, we assume that $\phi(0) = 0$ and $\phi(1) = 1$. From the decision-theoretic viewpoint, such a distortion corresponds to a subjective rescaling of, so to speak, the objective subjective probabilities. We can then rephrase the pattern of preferneces in the following inequalities. For the first pair of gambles, we have

$$u(1) > \phi(0.09)u(2) + \phi(0.9)u(1) + \phi(0.1)u(0) \tag{3}$$

which is equivalent to

$$(1 - \phi(0.9))u(1) > \phi(0.09)u(2) + u(1) + \phi(0.1)u(0) \tag{4}$$

From the second pair of gambles, we obtain

$$\phi(0.09)u(2) + \phi(0.91)u(0) > \phi(0.1)u(1) + \phi(0.9)u(0) \tag{5}$$

which is rearranged to

$$\phi(0.09)u(2) + (\phi(0.91) - \phi(0.9))u(0) > \phi(0.1)u(1) \tag{6}$$

The two equations thus obtained do no longer imply a contradiction. For instance, assuming, without loss of generality, that $u(0) = 0$ and $u(2) = 1$, since u is defined only up to a positive linear transformation, we obtain for the first pair of gambles the relation

$$(1 - \phi(0.9))u(1) > \phi(0.09), \tag{7}$$

and for the second pair

$$\phi(0.09) > \phi(0.1)u(1). \tag{8}$$

Taking these relations together, we require only that

$$(1 - \phi(0.9))u(1) > \phi(0.1)u(1) \tag{9}$$

If $u(1) > 0$ this is easily fulfilled by many choices of ϕ. A probability that is distorted in such a manner is usually called a *capacity* (see Kämpke, 1992, following Kohlas, 1990, and the basic work of Choquet, 1954). Formally, we can write $\phi \circ P$, where the operator $\circ$ denotes usual composition of functions. Using capacities, one substitutes the classical expected utility theory with a *bilinear model*, a model that is linear both in the utility function and in the capacity (or the subjective (subjective) probability function). Thus we postulate the expected utility of a gamble with probability vector $p = p_1, \ldots, p_n$ and outcome vector $c = c_1, \ldots, c_n$ to be

$$EU(G) = \sum_{i=1}^{n} \phi(p_i)u(c_i) \tag{10}$$

Models of this kind have been successfully used for explaining major human biases in decision making by Kahneman & Tversky in their *prospect theory* (Kahneman & Tversky, 1979) and by Coombs & Lehner (1984) in an analysis of compensatory changes on (subjective subjective) probabilities and gains / losses in decision making under risk.

Thus, the use of capacities literally enlarges the capacity of utility theory, i.e., enhances the possibility of modeling human preference patterns. From the probabilistic point of view it is, of course, desirable to restrict the class of capacities to some meaningful subset. Such a subset is formed by what is usually called *belief functions* (see Shafer, 1976, Kohlas, 1990). Belief functions require a form of additivity that gives the capacity constructed this way a special meaning, namely, that of a random set or set-valued random variable.

A random set is defined as a set-valued mapping from a probability space into some outcome space. Intuitively, expert knowledge very often takes the form of such an imprecise, set-valued prediction. As an example, take the list of candidate substances that may appear in a sample of soil where some known poisonous substances have leaked. Each of these substances has specific metabolits and will react with other substances present in the soil. If you know a probability distribution of the leaking substances, your knowledge about metabolits etc. will take the form of a random set. In fact, the notion of an imprecisely known probability distribution seems to cover a broad area of human expertise.

Let me collect some of the essential facts concerning belief functions.

4 Some Aspects of Evidence Theory: A very brief review

Evidence theory (see Dempster, 1967; Kämpke, 1992; Kohlas, 1990; Shafer, 1976, 1982; Shafer et al., 1988, Spies 1991b, 1993) is built up from the assumption that expert valuations of knowledge (in the normative as well as the descriptive sense) are less precise than a probability distribution. This is what decision analysts have expressed when they differentiated between decision making under risk (where a probability distribution is known) and decision making under uncertainty (where the distribution is unknown, or known only up to some set of parameters).

The essential ingredients of evidence theory are a (usually discrete) probability space $(\Omega, \mathcal{A}, P)$ and a set-valued measurable mapping $T : \Omega \rightarrow \Theta$ such that $T^{-1}(X) \in \mathcal{A}$. for all X in some σ-algebra on Θ. Θ is usually called the *frame of discernment*. The set-valuedness of T expresses the uncertainty that somehow is greater than a simple probability space allows to express. Note that this uncertainty is qualitative rather than quantitative: T induces some fuzziness into the events realized by choosing a given element of Ω, it is not some quantitative uncertainty (like the probabilities of probabilities sometimes encountered in statistical inference). A set-valued random variable (or, briefly, a random set) thus rather describes incomplete knowledge than data that are subject to random fluctuations (see also Spies, 1993).

A classical random variable is described by taking the sets of outcomes that are realized with some probability. Since a random set is more imprecise, we have only "'traces"' it leaves on Θ, the outcome space. One trace is given by the probability that $T(\omega)$ falls entirely into a given set $X \in \Theta$; this is termed lower probability or *degree of belief* (in the usual evidential interpretation of the probabilites involved here).

$$\mathrm{Bel}(X) = P(T(A) \subseteq X)$$

Sets X with $Bel(X) > 0$ are called *focal elements*.

The other trace is given by the "'hitting"' probability that $T(\omega)$ just intersects a given set X. This is termed the degree of plausibility or upper probability of the set in question.

$$\mathrm{Pl}(X) = P(T(A) \cap X \neq \emptyset)$$

Evidently, these two "'traces"' are related. If the image of a given ω lies enitrely outside a set X, it must lie entirely inside $\overline{X}$, this is expressed in the fundamental identity of evidence theory.

$$\mathrm{Bel}(X) = 1 - \mathrm{Pl}(\overline{X}) \tag{11}$$

It can be shown that a belief function is characterized by a generalized form of additivity. Recall that a probability measure is additive over disjoint events. Now, a belief function is always superadditive over disjoint events. This property (called supermodularity in Kämpke, 1992) does not generally hold for capacities and makes belief functions a subset among all possible capacities.

Finally, evidence theory tells us how to combine different sources of evidence (not to say, bodies of evidence), if they are independent. The easiest way to combine random sets is to take the so-called Möbius-inverse of a belief function, which is sometimes termed basic probability assignment:

$$m(X) = \sum_{Y \in X} (-1)^{|X-Y|} \mathrm{Bel}(Y) \tag{12}$$

This horrendous equation has a simple meaning. It says that you compute m-numbers just by looking at the smallest sets possessing degrees of belief greater than zero. These smallest sets may overlap. in contrast to a classical probability distribution. Adding up the m-numbers of subsets of $X \subseteq \Theta$ you get back the original belief function.

$$\mathrm{Bel}(X) = \sum_{Y \subseteq X} m(Y) \tag{13}$$

Assuming m-numbers are available, independent random sets are combined like independent random variables, but with the additional proviso that an empty intersection of focal elements is not allowed. Probability mass attached to the empty set is proportionally redistributed among all non-empty intersections of focal elements of the two belief functions. This operation is usually called orthogonal sum or Dempster's rule of combination. Given two sets of m-numbers, we obtain

$$m_1 \oplus m_2(X) = k \cdot \sum_{B_1 \cap B_2 = X} m_1(B_1) \cdot m_2(B_2),$$

where

$$k = \frac{1}{1 - \sum_{B_1 \cap B_2 = \emptyset} m_1(B_1) \cdot m_2(B_2)}.$$

This notation is particularly suited for computational purposes. If the m-numbers stem from two random sets T_1 and T_2 we can write the operation in a more abstract and logically clearer way:

$$\mathrm{Bel}_1 \oplus \mathrm{Bel}_2(X) = P(T_1 \cap T_2 \subseteq X | T_1 \cap T_2 \neq \emptyset) \tag{14}$$

It has been shown by Dempster (1967) that a convex set of probability distributions can be described by a random set (while not every random set can be described by a convex set of probability distributions). Thus, belief functions are not entirely the same thing as a convex set of probability distributions.

The development of independence structures in probabilistic expert systems has been extended to belief functions, as well (see Kong, 1986, Shafer et al., 1988). However, the difficulty of well defining empirically degrees of belief has prevented evidence theory to become a widely accepted tool. However, Fishburn (1985, 1986) has established a strong connection between probability intervals (which at least resemble belief functions) and his beuatiful interval orders. He also gives a purely judgment-based assessment procedure for belief functions. To my knowledge, this method has not been used yet.

Dempster's rule has been criticized because of its behaviour under conditioning (see Jaffray, 1990). Conditioning is not well described by a model of independent random sets (no wonder, the reader might say). Therefore, since a couple of years, researchers have begun to tackle the problem of conditioning in belief structures more fundamentally (again, see Jaffray, 1990; see Nguyen, Hestir, and Rogers, 1991). In what follows, I will show that the introduction of conditional events solves at least a good part of the problem, and that this solution sheds light on cognitive processes we are to assume in experts' incomplete conditional knowledge.

5 Conditional events and rules

It is a common problem in knowledge assessment that experts know the result of some process if some antecedent data are given, but that they cannot tell anything

about the outcomes of the process if the antecedent conditions are not met. This is not only an empirical fact; it is essential in the logic of scientific explanation that we only can tell about an *explanandum* if the antecedent conditions are fulfilled. Already in elementary propositional calculus we have the (formal) implication, which evaluates to true if the antecedent is false. Intuitively, that means, that a state of nature that is irrelevant to an *explanandum* cannot falsify an implication.

In contrast to this, in probabilistic reasoning systems (even in the most advanced ones, see Pearl, 1988; Spies, 1993) it is necessary to assess the probability of any *explanandum* on the condition that the antecedents do *not* occur. This is made necessary by Jeffrey's rule (sometimes coined law of total probability) which states that in order to obtain a marginal probability of an event given some antecedent variable, the marginal probabilities of all states of this variable, multiplied by the conditional probabilities of the *explanandum*, have to be summed up.

Let D_1 to D_n denote a set of mutually exclusive and exhaustive states of antecedent variable D, and let S be the *explanandum*, that is, some event in a probability space $(\Omega, \mathcal{A}, P)$. Then Jeffrey's rule states that

$$P(S) = \sum_{i=1}^{n} P(S|D_i) \cdot P(D_i) \; . \tag{15}$$

In case the antecedent variable is a proposition that can be true or false the application of Jeffrey's rule necessitates the evaluation of the conditional probability of the *explanandum* given the proposition is false. This may be, in many applications, a quantity that is either difficult to assess or even meaningless (consider epidemiological studies involved in estimating diagnostic probabilities in medicine: if a diagnosis is absent, how shall one assess the probability of a symptom).

It is this necessity to evaluate conditional statements which do sometimes not correspond to anything meaningful at all that makes probabilities hard to apply to expert knowledge in real world settings. And it is possible to overcome this necessity if one uses the formalism of conditional events and belief functions that I will describe in the rest of this paper.

Conditional events have been defined for the first time by Goodman & Nguyen (1988). Since then, there has been a considerable amount of work on this mathematical topic (see Goodman et al., eds., 1991). I will introduce them now starting with the concept of classical conditional probability.

6 Rules, Conditioning, and Probability

The probabilistic uncertainty attached to rules in expert knowledge is usually modeled by conditional probabilities. Alternative models, like the certainty factors, are known today to imply too many untestable independence assumptions (see Heckerman, 1986). Of course, if the rules we are given do not allow for probabilistic uncertainty at all, we have different models at our disposal, e.g., the theory of fuzzy logic (for an introduction, see Zadeh, 1985). The following considerations assume that we confine ourselves to probabilistic uncertainty.

It is well known that conditional probabilities are probabilities defined on a subspace of a probability space with universe Ω, $\sigma-$algebra $\mathcal{A}$ and probability measure P. The meaning of conditioning is that some subset $A \in \mathcal{A}$ has been found to contain the true realization of the random outcome $\omega \in \Omega$. Thus, the probability textbook definition of conditional probability given some event A with $0 < P(A)$ reads

$$P(B|A) = \frac{1}{P(A)} \int_B 1_A dP, \tag{16}$$

which, in the discrete case, simplifies to the well-known formula

$$P(B|A) = \frac{P(A \cap B)}{P(A)} \tag{17}$$

Sometimes I will call A the antecedent and B the consequent of the conditional $B|A$, thus establishing a terminological link to rule-based modeling.

Now, it is important to observe (see Goodman & Nguyen, 1988) that there is no element X of any σ-algebra $\mathcal{A}$ such that X is obtained as Boolean function of A, B, ..., and that in probability space $(\Omega, \mathcal{A}, P)$ $P(B|A) = P(X)$. for any $A, B \in \mathcal{A}$. Thus, *conditional probabilities are not probabilities of events in* $\mathcal{A}$. This is a surprising result. We have something that obeys the rules of probability distributions, but that refers to events not belonging to our initial event algebra $\mathcal{A}$.

What could the events be we are referring to when stating a conditional probability? Let us answer this question intuitively. If we know the true outcome to lie in a subset $A \in \mathcal{A}$, then we know that $\overline{A}$ and all of its subsets have conditional probabilities of zero (mathematicians say $\overline{A}$ is a $P-$null-set.). Similarly, if we take any event $B \in \mathcal{A}$ that has non-empty intersection with $\overline{A}$, its conditional probability will remain unchanged if we add or take away any of the null-sets in A. Thus,

denoting symmetric difference by $\triangle$, we have

$$P(B \triangle C|A) = P(B|A) \text{ if } C \subseteq \overline{A} \tag{18}$$

(It is recalled that, fo any sets U, V, the symmetric difference is defined as $(U \cap \overline{V}) \cup (\overline{U} \cap V)$. In terms of bitstrings, symmetric difference can be easily implemented by the XOR-function.)

Thus, we can see that the event a conditional probability refers to actually is a set of events, namely, the set of symmetric differences of the event whose conditional probability is being stated with all subsets of the complement of the antecedent of the conditional. Now let us define this set of events as a *conditional event* (in accordance with Goodman & Nguyen, 1998; Nguyen & Rogers, 1991; Dubois & Prade, 1991; Spies, 1991, 1993), denoted by $[B|A]$. We have:

$$[B|A] = \{X|X = B \triangle C, C \subseteq \overline{A}\} \tag{19}$$

Thus, a conditional event is precisely the set of events obtained by taking away or adding any subset of the null-sets under conditioning with antecedent A to a given event B.

What does this mean beyond mere formalism? First, this definition tells us that conditioning is actually a simplification. It establishes equivalence classes in our event algebra and chunks single events into them. This is analogous to what stating a rule in expert knowledge does. Second, it allows us to examine closely which events a rule (however small its probability may be) refers to. Let us see this in more detail.

If we take $C = \overline{A} \cap B$ we have $X = B \triangle C = B \cap A$: the intersection of events corresponding to antecedent and consequent. This intersection contains all elements ω of the universe that lie both in the antecedent and in the consequent event, or, so to speak, all ω that can serve as *verifying instances* of the rule "if ω is in A, then it is in B."

On the other hand, if we take $C' = \overline{A} \cap \overline{B}$ we obtain $X' = B \triangle C' = \overline{A} \cup B$, the formal implication of the consequent, given the antecedent. This event contains all elements ω of the universe that *cannot* serve as counter-examples or *falsifying instances* of the the rule "if ω is in A, then it is in B."

Now, it can be shown that each element of the set $[B|A]$ lies in between X and X' (see, for instance, Nguyen & Rogers, 1991). The converse is true, as well.

Thus, a conditional event corresponding to antecedent A and consequent B extends from the event of all elements verifying the formal implication of antecedent and consequent up to the event consisting of all elements that do not definitely falsify this implication. Therefore, a conditional event is an interval of events that *describe different variants of matching the rule "if ω is in A, then it is in B"*, ranging from purely verifying instances to all instances that are not in conflict with this rule. We can write this in a formula

$$[B|A] = \{X|B \cap A \subseteq X \subseteq \overline{A} \cup B\} \tag{20}$$

To sum it up, conditional events offer a language that seems eminently suited to describing partial matching, incomplete knowledge of rules, in other words, all the things that make real-experts' knowledge differ from model-experts' assumed knowledge.

7 Conditional Events in Models of Knowledge Structures

Let me now illustrate the meaning and use of conditional events in analyzing knowledge structures. These knowledge structures have been used by Thüring and Jungermann (1992) to develop the notions of ambiguity and validity in judgment under uncertainty. I think it is useful to take knowledge structures in order to show that it is the incompleteness of evidence rather than some dogma that compel us to advocate the use of belief functions (or conditional belief functions, as it will turn out) insteaed of classical probabilities.

The first structure demands no more than a standard classical probability model. It is characterized by two rules, given here under two conditional probabilities of a symptom (the fictitious Nagami fever), given a diagnosis (a virus):

1. $p(F|V) = \alpha$
2. $p(\overline{F}|\overline{V}) = \beta$

In this case α is simply the sensitivity of the symptom w.r.t. the diagnosis, while β is the specificity. These two numbers are frequently used in medical testing and they have a clear interpretation without any nedd to go into something beyond classical probability. Using sensitivity and specificity, we can compute the marginal probability of the fever F if the probability of the virus is given.

It is convenient to consider F and V as discrete variables with two states (yes or no, say). In Spies (1993) I refer to states of variables by using small letters while using capitals for the variables. In order to keep notation as simple as possible, in this paper, I will take capital letters both for variables and the event occuring if the variable has the state "'yes"'. It will be clear given the context which meaning applies.

The scenario changes somewhat if we consider a second knowledge structure. Here, a third variable enters the picture: it is the organism's disability to produce antibodies (D).

1. $p(F|V,D) = \alpha$
2. $p(\overline{F}\,|\,\overline{V}) = \beta$
3. $p(\overline{F}\,|\,\overline{D}) = \gamma$

Here the evidences are given for configurations such that a simple interpretation of the numbers in terms of medical testing is impossible. Since no antecedent occurs in both states in different rules, we are not ready to apply Bayes' theorem or Jeffrey's rule even if marginal probabilities of D and V are given. For instance, assume we are told the marginal probabilities of the states D and $\overline{D}$, we then know the specificity of the diagnosis "'unability to produce antibodies"' w.r.t. the diagnosis of the Nagami fever; but we lack the sensitivity information that is needed to compute a marginal probability of the symptomatic Nagami fever. This also makes it impossible, given the probability of the symptom, to use Bayes'theorem to compute the posterior probability of the diagnosis. So we're hung. What can be done?

One solution is to let the probabilities refer to the conditional events belonging to the conditional probabilities stated above. However, if we do so, these probabilities will refer to sets of events in our original space. Thus, we have to shift to the aforementioned belief functions in order to state probabilities properly. Table 1 shows the situation.

Rules:	1	2	3
a	$m([F\|D,V] = \alpha$	$m([F\|\overline{V}]) = \beta$	$m([F\|\overline{D}] = \gamma$
b	$m([\Theta\|D,V] = 1-\alpha$	$m([\Theta\|\overline{V}]) = 1-\beta$	$m([\Theta\|\overline{D}] = 1-\gamma$

Table 1: An unspecific interpretation of incomplete conditional knowledge.

Rules:	1	2	3
a	$m([F\|D,V] = \alpha$	$m([F\|\overline{V}]) = \beta$	$m([F\|\overline{D}] = \gamma$
b	$m([\overline{F}\|D,V] = 1-\alpha$	$m([\overline{F}\|\overline{V}]) = 1-\beta$	$m([\overline{F}\|\overline{D}] = 1-\gamma$

Table 2: A specific interpretation of incomplete conditional knowledge.

The second line (b) of table 1 deserves some comments.

We can put up several models of uncertain rules with conditional events. The first model assumes that some probability is attached to the rule, and with the remaining probability nothing is known about the behaviour of the system being described by the rule (Kohlas, 1990). This is known as the leaky capacitor model of uncertainty, I will call it here the unspecific model. The second model is the usual probabilistic model, where a certain probability is attached to a rule and the remaining probability is attached to the contrary rule, namely the rule that predicts the negation of the consequent, given the antecedent. I call this model the specific model. An interpretation of our Nagami-fever rules in terms of this model is given in table 2.

Finally, the third model combines the two previous ones. Here, some probability p is attached to the rule, some probability $q \leq 1-p$ is attached to the contrary rule, and the remaining probability $(1-(p+q))$ is attached to the whole universe or frame of discernment. I call this model the dichotomous belief model; it is treated in some detail (without reference to conditional events, however) in Baldwin (1986) and Spies (1989). It will not consider it here any further, because it can be viewed as a combination of the specific and the unspecific model. — It is by no means clear which of these models apply empirically when we either wish to model a particular domain or a particular human expert. Human knowledge structures show delicate nuances as to conditioning, see Wason & Johnson-Laird, 1972.

In a conventional model, the probabilities of each model would be attached to conditional expressions; as shown before, in many cases these quantifications cannot be used to derive anything about marginal probabilities. This changes if we attach

Event Rows	*Intersection*	*Probability*
aaa	F	$\alpha\beta\gamma$
aab	$V \cup \overline{D} \cup F$	$\alpha\beta(1-\gamma)$
aba	$\overline{V} \cup D \cup F$	$\alpha(1-\beta)\gamma$
abb	$\overline{V} \cup \overline{D} \cup F$	$\alpha(1-\beta)(1-\gamma)$
baa	$(D \cap V) \cup F$	$(1-\alpha)\beta\gamma$
bab	$V \cup F$	$(1-\alpha)\beta(1-\gamma)$
bba	$D \cup F$	$(1-\alpha)(1-\beta)\gamma$
bbb	Θ	$(1-\alpha)(1-\beta)(1-\gamma)$

Table 3: Result of combining *a priori* incomplete conditional knowledge in the unspecific model

the probabilities to the conditional events corresponding to the rules. We can then use the formalisms of combining belief functions such as to give *a priori* bounds on at least some marginal probabilities. We also can infer to which kind of evidence the model being examined is most sensitive.

To continue with the example let us combine the belief functions on conditional events in the unspecific and the specific model. Table 3 gives the result according to Dempster's rule for the unspecific model.

The computations involved in this combination are quite tedious, since intersecting intervals of events is required. This is most easily done by using results from the theory of Boolean rings, as demonstrated in Nguyen & Rogers, 1991, and Spies, 1991b (for an introduction, see Erné, 1987). Since my aim in this paper is to explain conditional events without recurring to the highly unintuitive notation in ring theory, I am not going to demonstrate the calculations in detail.

Let us examine the results for the *unspecific* model. We get one clear support of event F, and one clear support for the whole frame of discernment. The remaining probabilities are committed to events that, mostly, correspond to formal implications. For instance *aab* corresponds to $(\overline{D \supset V}) \supset F$. The cases *abb*, *bab* and *bba* correspond immediately to the formal implications given by the rules themselves. To give one more example, *bba* corresponds to $(\overline{V} \cup \overline{D}) \supset F$. Note that all these events contain only $\omega \in \Omega$ that *do not falsify* the rules in question.

The results of combining *a priori* evidences in the *specific* model are markedly different. Table 4 gives the results according to Dempster's rule.

Event Rows	*Intersection*	*Probability*
aaa	F	$\alpha\beta\gamma$
aab	$(V \cap (\overline{D} \cup \overline{F})) \cup (F \cap D)$	$\alpha\beta(1-\gamma)$
aba	$(D \cap (\overline{V} \cup \overline{F})) \cup (F \cap V)$	$\alpha(1-\beta)\gamma$
abb	$(\overline{F} \cap (\overline{D} \cup \overline{V})) \cup (D \cap V \cap F)$	$\alpha(1-\beta)(1-\gamma)$
baa	$(F \cap (\overline{D} \cup \overline{V})) \cup (D \cap V \cap \overline{F})$	$(1-\alpha)\beta\gamma$
bab	$(D \cap F \cap \overline{V}) \cup (V \cap \overline{F})$	$(1-\alpha)\beta(1-\gamma)$
bba	$(\overline{D} \cap F \cap V) \cup (D \cap \overline{F})$	$(1-\alpha)(1-\beta)\gamma$
bbb	$\overline{F}$	$(1-\alpha)(1-\beta)(1-\gamma)$

Table 4: Result of combining *a priori* incomplete conditional knowledge in the specific model

In the specific model, we find clear supports in favor and against event F (cases *aaa* and *bbb*); all remaining probabilities, however, are committed to mixtures of rules confirming F and disconfirming F. These mixtures, moreover, mostly correspond to *falsifying instances* w.r.t. the conditional in the respective rule. As an example, take case *baa*. The event $\overline{F} \cap D \cap V$ falsifies the rule predicting fever, given the virus infection and the disabilitiy of the infected body's immune system, which was expressed by the probability on conditional event $[F|D \cap V]$. The event $F \cap (\overline{D} \cup \overline{V})$ contains falsifying instances of at least one of the rules relating to the prediction of fever given no virus infection, or to the prediction of fever given in intact immune system of the patient. These rules were expressed by stating probabilities on conditional events $[F|\overline{D}]$ and $[F|\overline{V}]$, respectively.

In the specific model, there is a simple Bayesian interpretation of the resulting probability interval on event F, the occurence of the Nagami fever. The support in favor of the fever is $\alpha\beta\gamma$. This is simply the probability that all three rules are true (or fire). On the other hand, the support of its non-occurence is $p = (1-\alpha)(1-\beta)(1-\gamma)$. Therefore, the plausibility of the fever occuring is $1-p$ which is nothing but the probability that any of the three rules fires. Thus, the degress of belief and plausibility reflect the probabilities of an AND- vs. and OR-connection of the rules, or, as Shafer (1986) has put it, of the concurrent vs. successive testimony implied by the rules.

In the unspecific model, if either rule can be fulfilled, the support goes to the entire frame of discernment (Θ).

We have thus derived, for both models, *a priori* intervals of probability of the

predicted event. This was impossibel without conditional events. The result is simple and plausible. Moreover, we are now in a position to predict the effect of incoming evidence on either model. These predictions can be used in practice to decide which model to choose or to desribe a human expert.

Let me briefly cooment on the normative content of the combination of incomplete conditional knowledge I have demonstrated here. In an accompanying paper (Spies, 1993, in press) it is shown that this combination reduces to Jeffey's and Bayes' rule in case of complete conditional knowledge and given marginal probabilites ogf the antecedents.

8 The effect of evidence on incomplete conditional knowledge structures

To sum up the resulting situation after evaluating the *a priori* information in both models, let me introduce the notion of consistency of a belief function, as introduced by Dubois & Prade (1987). Intuitively, a belief function is consistent, if its focal elements largely overlap, else it becomes more and more inconsistent. (A numerical definition of dissonance is used in Dubois' and Prade's paper to quantify this intuitive notion.)

Now, let us imagine what happens in these two models if evidence comes in (until recently, people liked to speak of *bodies of evidence*). By evidence, I mean some new probability statement or belief function that can be combined with the *a priori* beliefs or our models to give new, *á posteriori* beliefs. I will discuss the impact of evidence separately for evidence providing non-falsifying information w.r.t. the rules being used in the conditional events and for evidence providing falsifying information. These evidences can be understood in terms of a hypothesis-testing paradigm of subjective knowledge processing, see Klayman & Ha, 1987.

In the unspecific model, the effect of verifying (or, more generally, non-falsifying) instances is to make the model more specific, i.e., to break down the support for the frame of discernment into support for smaller events that correspond to rule-verifying instances. The consistency of the model, however, will remain large. In

the specific model, on the other hand, the effect of verifying instances is to make the model ever less consistent, because these instances will produce empty intersections with the events found by combining the *a priori* conditional knowledge. Now, according to Dempster's rule, probability mass attached to the empty set is summed up and proportionally distributed among all non-empty intersections of events. As a consequence, more and more probability mass will flow "'downward"', to the atomic events. As a further consequence, the model will become more specific, since ever sharper contradicting events will be focused on. Thus, both models are made more specific by non-falsifying evidence; the unspecific model is made less consistent.

If evidence in the form of falsifying instances comes in, the effect on the two models will be different. In the unspecific model, we now generate empty intersections between the events after combining *a priori* information and the evidence. Therefore, this model will lose consistency: belief will spread over non-intersecting events increasingly. In the specific model, the effect of falsifying instances will not be harmful to overall consistency, since the events in this model mainly consist of disjunctions of falsifying elements. Again, both models will become more specific.

Thus, we can make the following predictions for experts using either model. If we assume that consistency makes the processing of a model easier, we can predict that non-falsifying information will be easier to integrate in the unspecific model and that falsifying information will be easier to integrate for people relying on the specific model. Since the specific model contains focal elements that correspond to violations of rules, some general processing difficulty could be assumed for this model w.r.t. human cognition. This would be in accordance with earlier findings (Spies, 1989).

These considerations show that conditional event evaluations of probabilities in incomplete conditional knowledge reveal a deeper structure in the rules. It becomes clear what kind of evidence will have what kind of impact on the model. It seems interesting to tests these impacts empirically for human subjects and to implement them in evidence-combining devices like sensor-fusion software. Moreover, they allow for generating *a priori* probability intervals, which was impossible using classical conditional probabilities.

9 Conclusion

This paper establishes a motivation to use belief functions as generalizations of classical probabilities in decision making, since they allow for a better account of human preference patterns that cannot legitimately be seen as being biased. After a brief review of concepts in belief functions the special question of conditioning is treated. It is shown that in expert knowledge situations of incomplete conditional structures prevail. In these situations, conditional probabilities can suitably be understood as referring to conditional events. Conditional events are nothing but equivalence classes of events with equal probabilities under conditioning. This idea is applied to a knowledge structure from medical diagnosis. It is shown that intervals of probability can be deduced prior to any incoming evidence under incomplete conditional knowledge. Moreover, different models can be set up for the same set of rules which differ w.r.t. to the way they are modified by non-falsifying and falsifying evidential data. From these models it is possible to derive predictions of human cognitive processes which can be empirically tested.

10 Acknowledgement

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MENTAL ACCOUNTING MATTERS

Richard Thaler

(not available on June)

WORKSHOPS

WORKSHOPS

Lee Roy BEACH and Terry CONNOLLY
Image theory and non-normative decision theory.

Jean-Marc FABRE and Allen PARDUCCI
Context effects on judgments.

Rebecca FRUMKINA
Verbal labels for evaluation and assessment.

Vittorio GIROTTO and Paolo LEGRENZI
Reasoning and decision making.

Nick PIDGEON and Mike SMITHSON
Qualitative approaches to uncertainty and decision.

Peter POLITSER, Danielle TIMMERMANS and Peter WAKKER
Aggregation, rationality, and risk communication: Three current debates in medical decision making.

IMAGE THEORY AND NON-NORMATIVE DECISION THEORY

Lee Roy Beach and Terry Connolly
University of Arizona

This workshop will begin with a discussion of Image Theory and the research that it has motivated. The focus will be on an explanation of the basic theoretical concepts and a presentation of empirical findings related to them. This will be followed by a group discussion of the theory's strengths and weaknesses, and possible avenues for its improvement as well as exploration of directions for future research. Then the scope of the discussion will be expanded to consider non-normative, descriptive decision theories in general, the relationship between non-normative and traditional decision theories, and the implications of non-normative theories for J/DM research and decision aiding.

CONTEXT EFFECTS ON JUDGMENTS

Jean-Marc Fabre
Université de Provence

Allen Parducci
University of California

Much interest has recently been expressed in the conceptual and technical developments of theories about the effects of contexts on psychological judgments. Examples of such developments are the analysis of the levels of treatment involved in contextual effects, the concept of consistency and simulations of contextual effects. Another current topic is the effectiveness of implicit contexts applied to judgments of a single stimulus. Due to such effectiveness, psychological theories may account for complex social judgments and decisions. The workshop will examine recent developments of the range-frequency theory in both the psychological and psychosociological domains, and the role of contextual cues in everyday situations.

Structure

Session 1 (Three hours)

Theoretical and methodological developments of contextual theories.

Session 2 (Three hours)

Applications of contextual approaches to judgments under uncertainty in complex and social situations.

VERBAL LABELS FOR EVALUATION AND ASSESSMENT

Rebecca M. Frumkina

The goal of the workshop is to discuss problems concerning the usage of verbal labels for the evaluation and assessment of the alternatives for decision and choice. Individual opinions and preferences are regularly expressed (both by experts and laymen) via verbal labels aiming at evaluation of possible outcomes as desirable, timely, proper, risky, sound, useful, probable, hardly probable etc.

Topics to be discussed at the workshop include: Types of verbal scales (e.g. unipolar vs bipolar ; symmetrical-nonsymmetrical) ; The effect of context-dependent labels ; The specific biases provoked by social, political and emotional contexts ; Effects in probability/frequency evaluation ; Anchoring procedures ; Experimental approaches to the study of meaning of verbal labels and verification of the validity of the scales.

REASONING AND DECISION MAKING

Vittorio Girotto and Paolo Legrenzi
Università di Trieste and CREA, Paris

The general aim of the symposium is to discuss some recent development in the relatively separate domains of reasoning and decision making. Original results and theoretical analysis will be discussed under the assumption that decision making implies reasoning, and therefore that mechanisms underlying reasoning processes are also at the basis of decisions, both in laboratory setting and daily life. Mental model theory, originally developed in the deductive reasoning domain, seems to be a particulary good candidate to bridge the gap between the two areas. This theory will be assessed in several of the present contributions. The areas covered include: Medical decisions, probability and causal judgments, conditional reasoning and performances on the Wason selection task.

QUALITATIVE APPROACHES TO UNCERTAINTY AND DECISION

Nick Pidgeon
Birkbeck College, London

Mike Smithson
James Cook University, North Queensland

Interest has recently been expressed in "qualitative" approaches to both modelling uncertainties and normative choice ; examples of the former include theories of ambiguity and ignorance, and of the latter so-called "approximate" reasoning. These developments within decision research have parallelled a more general trend within the human sciences to admit a range of qualitative methodologies. The workshop will examine the emerging qualitative approaches to decision research, their role in the future development of the discipline, and the role of SPUDM researchers in this.

Session 1
Issues in qualitative representation of uncertainly (including ignorance, ambiguity and vagueness).

Session 2
Qualitative approaches to approximate reasoning (evidential bases for reasoning with different uncertainties and/or how to reason with qualitative uncertainty states).

Session 3
Combining qualitative and quantitative uncertainty and utility in decision models.

AGGREGATION, RATIONALITY, AND RISK COMMUNICATION: THREE CURRENT DEBATES IN MEDICAL DECISION MAKING

Peter Politser
M.I.T. Cambridge, USA

Danielle Timmermans and Peter Wakker
University of Leiden, The Netherlands

Decision analysis prescribes a systematic way of decision making under uncertainty based on probability theory and utility theory. However, when applying decision analysis to practical clinical problems, we encounter some dilemmas. In this workshop we will address three dilemmas. These are also relevant to other domains in which normative decision models are used for individual applied decisions. On each day, following 2 or 3 speakers, an expert panel will discuss the papers, the issues, and the research needs.

Day 1: Aggregate optimality versus individual discretion.

Medical decision analyses often use aggregated empirical data to provide guidelines for managing groups of patients. These guidelines are derived from aggregated empirical data, which enable probability and utility estimates for such groups. But such estimates' use has raised many questions. When should we consider patients comparable, divisible into subgroups, and most efficiently managed with aggregate guidelines? When should we consider them unique, indivisible, and requiring freedom of choice? And should the decision to aggregate depend on other factors, such as equity? Do we fail to adequately consider the equity of resource allocation when we aggregate different individuals' preferences? Do we need methods to assess preferences for the distribution of resources? Speakers: Peter Politser (MIT): How the desired balance between individual and aggregate views may depend on the dilemma; Rakesh Sarin (UCLA): Individual, group, and Social Equity.

Day 2: Rationality issues in intuitive vs. prescriptive approaches.

People do not always make decisions according to EU theory. They may overweigh small probabilities and do not always revise probabilities adequately after receiving new information. In treatment problems, they may judge unfavorable outcomes attributed to doctors' actions as more serious than those caused by inaction. In diagnostic problems they may do the opposite. For instance, the possible regret physicians would feel when "missing" a tumor would be much greater than the regret after operating upon a healthy patient. In decision analysis outcomes are evaluated independently of the actions that produce them. In human reasoning, however, the responsibility for outcome does seem important. How should we deal with decision makers' deviations from the EU model? Is it sensible to include factors such as responsibility and anticipated regret in a normative model? Speakers: Peter Wakker (Un. of Leiden, NL): Modeling decisions; what should be normative and what should be descriptive? Graham Loomes (UK): The role of anticipated regret in medical decisions. John Fox: (Imperial Cancer Research Fund Lab, UK; ~~not certain~~).

Day 3: Perception and Communication of Medical Risks.

Legal doctrine often allows medical interventions once the patient is informed of their risks and approves. The assumption is that the necessary information is adequately communicated and understood by the patient, and that he/she can handle this information in a rational way. When risks are communicated in verbal terms, people's interpretation may differ and may also depend on context. Qualitative factors such as familiarity, controllability and voluntariness, and whether risk is caused by action or inaction are important determinants for the acceptability of risks. What is the best presentation mode to communicate risks to patients? What are the factors that influence the acceptability of medical risks? Speakers: Daniel Timmermans (Un. of Leiden, NL): Do patients and physicians differ in the risk appraisal of medical treatments? Ido Erev (Technion Haifa, Israel): Advantages and disadvantages of using verbal probabilities. Charles Vlek (Un. Groningen, NL): Perceived control and expected utility in personal decisions.

ORAL PAPERS

ORAL PAPERS

Peter AYTON and Alastair MCCLELLAND
The bomb party probability illusion.

Christopher BALL and Leon MANN
Identifying the decision making skills of intellectually gifted adolescents.

Jane BEATTIE, Jonathan BARON, John HERSHEY and Mark SPRANCA
Factors influencing decision attitude: Regret, blame, autonomy and equity.

Terry BOLES and David MESSICK
When losing is better than winning: The impact of regret on the evaluation of decisions.

Nicolao BONINI, Rino RUMIATI and Paolo LEGRENZI
When a loss becomes a cost and when remains a loss.

H.W. BRACHINGER
Risk measurement under partial probability information.

Berndt BREHMER and Peter SVENMARCK
Distributed decision making in dynamic environments: time scales and architectures of decision making.

Rex BROWN, Oleg LARICHEV
Russian and american decision analysis approaches tested on Arctic issues.

Adèle DIEDERICH
Decision field theory for multi-attribute decision problems.

Katrin FISCHER
Multinomial modeling in hindsight bias research.

Heiner GERTZEN, F. SCHMALHOFER, O. KHUN, J. SCHMIDT and K.M. ASCHENBRENNER
A decision-support system for the judgment of adverse events in clinical trials.

Brian GIBBS
Inward vs. outward decision making: The self-manipulation of tastes.

Michel GONZALEZ
Do predictions of an event result from probability judgments?

Joke HARTE
Structural modeling and verbal protocol analysis.

Laurie HENDRICKX, Agnès VAN DER BERG and Charles VLEK
Concern about tomorrow ? Effects of "time discounting" on the evaluation of environmental risks.

Peter JUSLIN, Anders WINMAN and Thomas PERSSON
Calibration of recognition judgments: Well calibrated judgments both for reconstructive and associative memory processes.

José KERSTHOLT
The effect of time pressure on decision making behaviour in a dynamic task environment.

Gwendoline KIEBERT
Utility assessment in medical oncology.

Pieter KOELE and Mirjam WESTENBERG
Measuring the compensativeness of multi-attribute decision strategies.

Reidar KVADSHEIM
The intelligent imitator. Humans "maximize subjective expected value" but do so in a manner that differs radically from the traditional SEU conception.

Michael LAWRENCE and Peter AYTON
Decision making in the presence of asymmetric loss functions.

France LECLERC
Effects of salience and time pressure on the choice process and outcomes.

Maria LEWICKA
Is hate wiser than love ? Positive-Negative Asymmetry in interpersonal decision making.

Raanan LIPSHITZ and Simon GIVOLI
Pitting hot against cold cognition. The effect of excalation of commitment on hindsight bias (and vice versa).

A. John MAULE
Framing elaborations and their effects on choice behaviour: a comparison across problem isomorphs and subjects with different levels of background knowledge.

Jeryl MUMPOWER, Jim SHEFFIELD and Thomas DARLING
"Fixed-Pie" and "Elastic-Pie" biases in negotiations.

Eva PASCOE and Nick PIDGEON
Risk orientation in dynamic decision making.

Hans PFISTER
The influence of emotion-and utility-related evaluation and induced mood on choices in ambivalent decision situations.

Rüdiger POHL
Disenchanting hindsight bias

Fenna POLETIEK
The importance of subjective probability in modeling testing behavior.

Peter POLITSER
Testing the logical consistency of decision analyses.

Ilana RITOV
Anticipation of uncertainty resolution in choice.

P. ROELOFSMA and Gideon KEREN
Uncertainty and the reversal of time preference.

Frits ROEST and J. Dik HABBEMA
Confidence intervals for individual utilities.

Marcus SELART and Tommy GÄRLING
Effects of uncertainty on relative attribute weights in preference ratings.

James SHANTEAU and Ward EDWARDS
The psychology of expertise: A new paradigm.

Zur SHAPIRA and Itzhak VENEZIA
Asymmetric information and competitive behavior.

Ramzi SULEIMAN, Amon RAPOPORT and David BUDESCU
The non-monotonicity effect in resource dilemmas under uncertainty.

Karl TEIGEN and Wibecke BRUN
Yes, but it is uncertain: Direction and communicative intention of verbal probabilistic terms.

Danielle TIMMERMANS
The role of experience and domain of expertise in using verbal versus numerical probability terms in medical decisions

Els van SCHIE
Influencing risk-preference: Framing decisions versus emphasis on a specific outcome.

Peter WAKKER
Testing rank-dependent utility and new prospect theory.

Myriam WELKENHUYSEN, Gerry EVERS-KIEBOOMS, Marleen DECRUYENAERE and Herman VAN DEN BERGHE
Unrealistic optimism and genetic risk.

George WU
Editing and cumulative prospect theory: Ordinal independence and outcome cancellation.

THE BOMB PARTY PROBABILITY ILLUSION

Dr Peter Ayton
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Imagine that you are invited to a party where all six guests are obliged to pick a cracker from a barrel. Your host tells you that five of the crackers each contain cheques for extremely large sums of money but the remaining cracker contains a bomb that will kill the person that pulls it. This is the predicament that the characters in Graham Greene' s (1980) novel 'Doctor Fischer of Geneva or The Bomb Party' find themselves in. While they are standing around discussing who will go to the barrel first one of the characters runs to the barrel and pulls a cracker. A large cheque pops out. This causes the remaining guests to protest strenuously; they feel that they have been cheated because, as now there are only five crackers left, the chance of being blown up is increased to one fifth - whereas before it was one sixth. When another guest pulls his cracker and also gets a cheque the odds on being destroyed by the next cracker have increased to one quarter causing further consternation among those yet to take their turn.

An analysis of the bomb party reveals that, normatively, there is no change in the likelihood of being destroyed as a function of the a priori order that one may select for drawing a cracker. The chances of being destroyed are equal whether one elects to draw the first, last or any other cracker. Nonetheless, our experiments confirm that the illusion of an advantage in going first is held by many subjects; only a minority correctly affirm that all positions are equally likely to draw the bomb.

When asked to communicate their preference for a position in the queue, however, first position was not the single most popular position; as many subjects preferred to go last as preferred to go first in the sequence. Those that went first commonly cited the better chance of survival as a defence. However those that went last did so not because they thought they were more likely to survive, but because they would know their fate when they pulled their cracker.

We explored these perceptions experimentally and attempt to account for the findings in terms of existing descriptive theories of risk perception and choice under uncertainty. In particular we considered whether the patterns of probability judgements and choices observed can be explained as over-generalisations of a strategy that is appropriate for rational action in different, though somewhat similar, circumstances.

IDENTIFYING THE DECISION MAKING SKILLS OF INTELLECTUALLY GIFTED ADOLESCENTS

Christopher Ball and Leon Mann
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This paper extends previous work on the development of decision making competence in early adolescence (Mann, Harmoni & Power, 1989) by investigating the decision making capabilities of intellectually gifted children and adolescents. In our research, Sternberg's triarchic theory of intelligence as applied to intellectual giftedness (Sternberg, 1986) is used as a framework for the analysis. Samples of 61 intellectually gifted and 122 non-gifted adolescents in the age range 12-15 years were administered the following tasks:

(1) A test of metacognitive knowledge of decision making (Ormond, Luszcz, Mann & Beswick, 1991) to measure knowledge about decision making strategy. This captures aspects of Sternberg's concept of "executive" or control processes.

(2) A series of decision tasks presented in the form of an information matrix (Ball & Mann, 1991; Payne, 1990) to test the use of efficient search strategies in acquiring information about choice alternatives. This corresponds to aspects of Sternberg's performance and knowledge acquisition components and also the concept of elementary information processes in decision strategies (Huber, 1980; Johnson, 1979; Payne, Bettman, Coupey & Jonshson, 1991).

(3) A test of probability "tuning" (Ball, Mann, Brocchi, 1991) to measure the ability to adjust responses in relation to changes in the probability of outcomes. This, again, captures aspects of Sternberg's performance components.

In addition, the Flinders Decision Making Questionnaire (Mann, 1982) was administered to provide a measure of self-esteem as a decision maker and self-reported decision coping patterns.

Consistent with previous evidence about the cognitive abilities of gifted children (Coleman & Shore, 1981), we found that intellectually gifted adolescents had better cognitive knowledge about strategic aspects of decision making, executed efficient search strategies (e.g. lexicographic) more often and faster, were better at "tuning" information correctly and reported a more competent decision style than non-gifted adolescents.

Our findings illustrate the importance of higher order "executive" processes in planning, monitoring and performing complex decision tasks and raises the question of similarities between gifted individuals and expert decision makers.

Factors Influencing Decision Attitude: Regret, Blame, Autonomy and Equity

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We introduce the concept of "decision attitude" and argue that it is analogous to the concept of risk attitude in risky decision making. One's decision attitude refers to the propensity that one has to seek, or avoid, making a decision (holding outcome constant). A decision seeking attitude is shown when a person prefers to obtain an option by active choice rather than to be given it without choice. In decision aversion a person would rather obtain the same option by fiat than through their own choice. A decision neutral attitude is shown by no preference concerning how the item is obtained. In certain cases there are normative justifications for a non-decision-neutral attitude. For example, the presence of transaction costs predicts that, all things equal, people should be decision averse. Conversely, a person might be decision seeking if she will have the opportunity to learn something useful about her preferences by making the decision. However, we hypothesized that subjects might show decision seeking or decision aversion in a variety of circumstances in which these factors did not hold.

We performed a series of experiments to demonstrate the existence of these three decision attitudes and to explore their psychological determinants. Subjects were asked to rate the attractiveness of hypothetical scenarios which manipulated a number of factors hypothesized to affect decision attitude. Experimental manipulations and subjects' justifications pointed to anticipated regret, fear of blame for poor outcomes, and desire for equitable distributions as sources of decision aversion. A main source of decision seeking (for self) and decision aversion (when deciding for others) appeared to be the desire for the self-determination of the affected parties. We consider the implications of our results for personal choice and public policy decisions.

When Losing is Better Than Winning: The Impact of Regret on the Evaluation of Decisions.

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The quality of a decision should be evaluated on the basis of information that was available to the decision maker at the time the decision was made. Two people making the same decision may not be equally lucky about their outcomes, however, and Baron & Hershey (1988) demonstrated that the lucky person whose outcome was positive was judged to have made a better decision than the person whose outcome was poorer. In this demonstration of an outcome bias, the outcomes were compared to each other. It is possible that the judged goodness of an outcome may be inversely related to its positivity if the better and worse outcomes are compared to different referent outcomes rather than to each other.

In this experiment, subjects read about a person who chose a gamble (from two possible) and either won or lost. The person knew the outcome that would have been received if the alternative gamble had been chosen. The winner would have won more with the alternative and the loser would have lost more. Thus the regret resulting from the comparison of the obtained outcome to the alternative should render the winner less satisfied and the loser more satisfied than if the alternative outcomes were unknown. By manipulating variables intended to make regret maximally salient, we created a condition in which the loser of the gamble was judged as more satisfied and as having made a better decision than the winner.

WHEN A LOSS BECOMES A COST AND WHEN REMAINS A LOSS

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Tversky and Kahneman (1981) found that people more often refuse to go to the theatre when they lose a ticket than when they lose a bill of the same monetary value. Singer, Singer and Ritchie (1986) found that people more often refuse to go to the theatre when they lose a bill which was especially put aside to buy a ticket (a "special bill") than when they lose a bill of the same monetary value without having put it aside for that purpose. They all interpreted these results by the means of the so called "transaction hypothesis". To lose a bill is psychologically different than to lose a ticket (or to lose a "special bill") because only in the latter case an exchange took place (in reality or fictiously) such as to give up money vs. to get the right to see the play. The presence/absence of a transaction "per se " would induce people to construct different mental accountings of the equivalent monetary loss and to make different choices. Henderson and Peterson (1992) interpreted these results by the means of a perspective based on categorization processes. Once a cognitive script related to the act of going to the theatre is triggered, people would "treat" the loss of the ticket in a different way than that of the bill. Whereas the script "would also include the notion of buying a ticket, it would be less likely to include the notion of losing money" (p. 98). In a few experiments it was tested a prediction made by both the "transaction" and the "cognitive script" interpretations. Subjects were presented with causal information specifying the way they lost the ticket/bill (or the "special bill"). For example, in one condition it was stressed the own responsability of the subject ("your fault") or of that of a friend of his/her ("fault of some one else"). The same causal information was presented in both the versions of the theatre problem. These experimental conditions do not modify the (supposed) crucial difference in terms of presence/absence of a transaction (real or imagined) or compatibility/not with the cognitive script. Results show that the effects demonstrated by Tversky and Kahneman and Singer, Singer and Ritchie disappear when subjects are provided with causal information suggesting their own fault for the loss.

RISK MEASUREMENT UNDER PARTIAL PROBABILITY INFORMATION

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In many practical decision problems, actual probability information about the states of nature lies somewhere between the classical situations of risk and uncertainty. The question arises of how to measure risk under such conditions of partial probability information.

In the literature on risk measurement, usually, a difference is made between the measurement of pure risk and that of speculative risk. In the case of pure risk only potential losses of an action are affected : risk increases with probability and amount of loss. In the case of speculative risk, also potential gains have an impact on perception: risk increases with probability and amount of loss, but it is reduced by increasing gains and gain probability. According to that, in this paper, theories of pure and speculative risk under conditions of partial probability information are developed.

First, a well-known means of modelling partial probability information is introduced which serves to build up a general framework for risk under partial probability information. Then, following the measurement theoretical approach, a binary risk relation $\geq$ is established as a quasi-order. This relation is assumed to fulfil an axiom of risklessness, two dominance axioms and a scale invariance axiom. It is to be numerically represented by an appropriate risk measure. Such a risk measure should, e.g., possess a certain multiplicativy property introduced by Luce (1980). On the basis of these requirements, in a representation theorem, it is shown how to measure risk under conditions of partial probability information. A corresponding uniqueness theorem shows that this measurement measures risk on a log-interval scale.

Based on that theory of pure risk, furthermore, a representation theorem is developed which shows how to measure speculative risk under the conditions of partial probability information. An essential three-parametric class of generalized risk measures is derived. Each of these parameters characterizes the decision-maker's risk attitudes.

DISTRIBUTED DECISION MAKING IN DYNAMIC ENVIRONMENTS: TIME SCALES AND ARCHITECTURES OF DECISION MAKING

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Distributed decision problems require a team of decision makers to cooperate to attain a common goal. Each decision maker controls part of the resources needed, but has only a limited "window" on the task. Consequently, the decision makers have to communicate to achieve a the shared "situation awareness" that is needed to guide their decision making.

When the distributed tasks are dynamic, i.e., when they require a series of interdependent decisions, when the state of the task changes, both autonomously and as a consequence of the decision maker's actions and when the decisions have to be made in real time, it becomes important to monitor all the relevant time scales in the problem. There are at least two relevant time scales in a dynamic task with distributed decision making: one fast scale that has to do with the actions required by the individual decision makers, and a slower one that has to do with the coordination of the team of decision makers as a whole. The coordination is necessary, for it is only by a coordinated effort that the team can carry out its task; the resources available to each individual decision maker are not sufficient.

This paper presents a general paradigm for the study of distributed decision making in dynamic environments called D^{3}FIRE. It is based on the earlier fire fighting paradigm for the study of dynamic decision making developed by Brehmer and Allard, but it differs from that paradigm in that each subject can control only one of the fire fighting units and has only the local information available to an individual unit, i.e., they see only part of the fire on their computer screens. They communicate by means of electronic mail, or face to face, and it possible to vary the architecture of the distributed decision system (by varying who can communicate with whom), as well as the characteristics of the problem (the properties of the fire) and information provided to the subjects (by varying the size of each subject's window).

In experiments with the paradigm, all decisions as well as all messages sent are recorded and analysed.

Theoretical analysis suggests that coordination requires communication of intentions, rather than actions, and that the architecture should be adapted to the time scales in the problem, i.e., in a problem, such as the fire fighting problem, a hierarchical architecture, where all communication must pass through one decision maker, should be more effective than a democratic architecture where each decision maker can choose the person with whom he or she will communicate. This is because the former architecture makes it more likely that the information needed for the coordination of the different units will be collected in at least one place in the system. An experiment with D^{3}FIRE is presented which supports both these hypotheses.

RUSSIAN AND AMERICAN DECISION ANALYSIS APPROACHES TESTED ON ARCTIC ISSUES

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The authors report on the first year of a four year project to compare Russian and American approaches to decision aiding, which differ mainly in the degree to which they quantify judgment.

The test bed is the Arctic. Society's need to preserve the physical integrity of the Arctic and to manage its natural resources soundly and defensibly calls for systematic integration of conflicting economic, social and environmental considerations. NSF's Division of Polar Programs is funding this project through George Mason University and Arctic specialists Elena Andreyeva and Nick Flanders are contributing case material.

Both approaches are being tested on difficult or controversial live decisions to be made by each country. For example, a major Russian case study addresses a choice of gas pipeline route on the Yamal Peninsula, working with the head of the State gas concern. A U.S. case addresses the dumping and dispersal of nuclear materials into Arctic drainages and waters. Cooperating officials at three federal agencies are weighing whether the US should commit resources or political capital to combat it. The acid test is whether we can add something useful to how choices are made (or justified). Do we help the "client" make effective use of available knowledge? How burdensome is the exercise? How well does our approach fit psychological realities? How to take account of institutional differences in how decision are made in the two countries?

Decision Field Theory for Multiattribute Decision Problems

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Decision Field Theory (DFT) is a model recently developed by Busemeyer & Townsend (1992, 1993) which takes into account both the dynamic and stochastic nature of decision making. The goal of the model is to understand the motivational and cognitive mechanisms that guide the deliberation process involved in decisions under uncertainty. It provides an explanation for why preferences waver over time and provides a mechanism for determining how long deliberation lasts. Moreover the model provides a unified theoretical treatment of a wide range of measures of preference including approach-avoidance movements, choice probability, choice response time, selling prices, buying prices, indifference judments, and strength of preferenc ratings.

Specifically, suppose a person is asked to choose between two alternatives, A and B. The preference state for these alternatives can be presented by a unidimensional variable, denoted P. Positive values represent a tendency towards alternative A, say, negative values represent a tendency towards alternative B. Immediately after the alternatives are presented, an initial preference state, $P(0)$, is aroused, and this preference begins to change and evolve during deliberation time, producing a new state of preference at each moment in time, denoted $P(t)$. Eventually, the magnitude of this preference state exceeds a threshold, denoted θ, and an alternative is chosen, depending on whether $P(t) \geq \theta$ or $P(t) \leq \theta$. The deliberation time, denoted T, equals the interval between presenting the alternatives (e.g. onset of a display) and the actual choice of an alternative (e.g. pressing a response button). Preferences changes from moment to moment as the decision maker anticipates the various possible consequences that may occur if each alternative were to be chosen. It is usually the case that we do not observe the actual sequence of thoughts that occur during deliberation (an exception may be when "think aloud" protocols are recorded). In the absence of this information, we may still be able to manipulate the probabilities of each type of change in preference state (i.e., the transition probabilities) in terms of certain experimental factors.

Here we present an extension of the model to multiattribute decision problems based on an information processing model developed by Diederich (1991, 1992).

MULTINOMIAL MODELING IN HINDSIGHT BIAS RESEARCH

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This paper presents a discussion and application of a methodology, called multinomial modeling, that can be used to study those cognitive processes underlying the so called hindsight bias phenomenon. Multinomial modeling is a statistical based technique involving the estimation of hypothetical parameters that represent the probabilities of different cognitive processes. Applied to the hindsight bias paradigm these models represent possible cognitive processes causing a hindsight bias when people are asked to remember an earlier given estimation after receiving new information. This class of models, which was initially used in cognitive psychology by Riefer & Batchelder (1988), allows the analysis of data that is independent of a specific index for the calculation of the hindsight bias. Following this approach it seems to be possible to overcome those problems in hindsight bias research related to the use of different indices. Up to now these different indices have produced results which are hardly comparable and difficult to interpret.

Two substantive examples of multinomial models in hindsight bias research are presented. Each example involves the development of a multinomial model and its application to a specific experiment. The experiments were carried out to identify possible determinants of the hindsight bias when using numerical almanach questions. Two of these determinants are subject's judgment strategy when generating the first estimation and the correctness of this first estimation.

Our experiments show a significant influence of the judgment strategy on the amount of hindsight bias. Almanach questions requiring inference strategies cause a higher hindsight bias than those questions requiring simple guessing processes. Furthermore, we find a greater hindsight bias when the correctness of the subject's first estimation is already very high.

It can be shown that multinomial models facilitate the interpretation of the experiments and the study of those factors and processes causing hindsight effects.

A Decison-support System for the Judgment of Adverse Events in Clinical Trials

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Government regulations require that the effectiveness and the safety of a new drug must be investigated and established in clinical trials before it can be released for general use. In order to guarantee the safety of the drug, adverse events (AEs) which occur in these trials (such as the death of a patient or alarming lab results) should be carefully evaluated based upon all the knowledge and the experiences available at that time. Thereby it must be decided whether the adverse event is related to the experimental drug or due to other causes, such as other drugs or the patient´s general clinical condition. In order to reduce the time period between the discovery of the pharmaceutical substance and its release as a drug, a qualitatively good decision about the causes of the adverse events should be achieved within a relatively short time period. The variability of the quality and quantity of the available input data and the currently available knowledge (adverse event report, patient record, knowledge about diseases and other drugs) requires an adaptive strategy selection for obtaining the desired decision (Payne et al., 1991). On the other hand, the quality of a decision will increase with a more standardized decision strategy being followed and the amount of knowledge being taken into consideration.

We present the architecture of a decision support system where large amounts of heterogeneous information can be retrieved (from various data bases) and integrated for making decisions in clinical trials. Such decisions include a comprehensive judgement of the observed AEs. Knowledge-based judgements are thus seen as component processes for making complex real life decisions. Advanced information technology and state of the art knowledge acquisition methods (Schmalhofer, Kühn & Schmidt, 1991) are used for implementing this architecture. It is expected that the described system will supply significant intelligent support for making complex decisions in clinical trials: the effectiveness of the information presentation and knowledge utilization will be improved, thereby reducing the decision maker´s effort for achieving a certain decision quality (Gertzen, 1992). Since the decision strategies are explicitly represented in the system, highly objective and reliable decisions will be achieved. Automatically working decision modules will reduce the decision maker´s routine workload. These expectations will be evaluated with a prototypical system. In a study, the exerted effort and the quality of decisions obtained with the assistance of the described system will be compared to the decisions obtained in the currently available environment.

SPUDM 14, 1993

INWARD VS. OUTWARD DECISION MAKING: THE SELF-MANIPULATION OF TASTES

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In contrast to the standard decision theoretic view of utilities as "givens," it is proposed that tastes are self-manipulable: Decision makers can enhance satisfaction not only through outward action, by manipulating the environment, but also through inward action, by manipulating their tastes. An informal model of inward action, outlining the conditions under which taste self-manipulation is expected to occur, suggests several types of experiment. *Impending-exposure* experiments demonstrate that the experienced utility of an aversive stimulus increases if subjects expect to be exposed to it repeatedly. *Opportunity-cost* experiments demonstrate that the experienced utility of an aversive stimulus increases if subjects expect to have to forego money to avoid future exposures to it. Taste self-manipulation is evidenced both as an effect on hedonic ratings, and, in a self-timed endurance test, as an increase in the time subjects are willing to remain in contact with the aversive stimulus; and this latter effect obtains even after the experimental treatment has been withdrawn. The results are interpreted and implications for decision making are discussed——in particular that decision making should be viewed as a bimodal process involving not only getting what one likes, but also liking what one gets.

Do predictions of an event result from probability judgments?

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CREPCO - Université de Provence et CNRS

Take a question about an uncertain event E. Let us call prediction the bet that E will or will not occur, and probability judgment the grading of E, by means of a percentage for example. The results of an experiment asking for predictions or probability judgments to a series of problems (providing various pieces of information about an uncertain event) suggest that the two kinds of responses depend on different information processing. The following conclusions are derived from the data :

1. Predicting that an event will occur is not judging that its probability is higher than 50%. It was observed that the frequency of predicting an event was often very different from the frequency of judging its probability as higher than 50%.

2. Predicting that an event will occur is not judging that its probability exceeds a fixed level. This conclusion is based upon an analysis of the responses given to various problems concerning the same event, and differing by the given information. The pattern of frequencies of probability judgments higher than p (whatever p between 0 and 1) is not consistent with the patterns of predictions of E.

3. Prediction and probability judgments at times use different information. This conclusion is based upon two facts:

   a. probability judgments can be responsive to a given information and predictions unresponsive to the same information: when information was added, probability judgments were at times modified while prediction frequencies remained unmodified.

   b. Predictions can be responsive to a given information and probability judgments unresponsive to the same information: adding information about an event at times modified the prediction frequencies but did not modify the distribution of probability judgments.

These lacks of correspondence between predictions and probability judgments are considered in the light of a model assuming that available information is solved by various indicators which are then converted into the appropriate response mode. Assuming that a given indicator can be converted differently into the two response modes (categorical prediction vs. assessing a percentage) explain the observed effects.

Structural Modeling and Verbal Protocol Analysis

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Research on cognitive processes underlying judgment and choice in multiattribute decision situations can be divided into two distinct paradigms: structural modeling and process tracing. In structural modeling the relation between the attribute values and the judgments is modeled by means of a statistical technique, which provides an equation representing the decision maker's strategy. Process tracing techniques focus on which information in which order is used by the decision maker to arrive at a decision. From these data inferences are made about the strategy used.

However, both research paradigms do not always provide similar results. An explanation for this lack of convergence might be that one of the approaches is not able to give a good representation of the cognitive processes underlying a decision. Another possible explanation is that the two approaches focus on different phases of the decision making process. To be able to investigate the (dis)similarities between process tracing and structural modeling results, techniques of both approaches have to be applied on the same decision problem.

In this presentation two such multimethod experiments will be presented. In both experiments structural modeling and process tracing data were gathered at the same time. The process tracing data were verbal protocols, obtained by having the subjects think aloud during the judgment task. In the first experiment the validity of the verbal protocols was tested and appeared to be satisfactory. In the second experiment the response scale for the judgments was varied. The results from both approaches will be discussed, and related to each other.

Concern about tomorrow? Effects of 'time discounting' on the evaluation of environmental risks

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Environmental risks are often characterized by the fact that possible negative consequences do not occur immediately, but are delayed in time. The temporal remoteness of negative effects may strongly affect people's risk judgments and decisions. Riskiness and acceptability judgments may be susceptible to 'time discounting', meaning that people will judge present activities or situations as being less risky (and, thus, more acceptable) if the possible negative consequences are expected to occur at a later moment in time. It is argued that two different cognitive mechanisms may underly 'time discounting' of risks: we expect that more remote negative consequences will be judged as both less serious ("value discounting") and less probable to occur ("probability discounting"). The latter form of discounting, however, is expected to occur if, and only if, the situation at hand is (perceived as) 'controllable', i.e., if outcomes (co-)depend on future decisions or behaviour. As a consequence, temporal effects on risk judgment and decision making are expected to be stronger if the (perceived) amount of future control is higher.

The above hypotheses were tested in a laboratory experiment. Subjects rated the relative riskiness of 16 different cases of soil pollution, systematically differing with regard to three independent variables: (a) the probability of a negative outcome, (b) the temporal delay of this outcome, and (c) the amount of future control. Subjects also rated the seriousness of the unwanted consequence (i.c., "*destruction of a unique nature reserve*"), if this event would take place at different moments in time. The experimental results supported our main hypotheses. Risk judgments were lower when the negative consequence was expected to occur later in time, and this effect was due to both value discounting and - in the 'controllable' subconditions - probability discounting. Implications of our findings, e.g. for environmental policy, will be discussed.

Calibration of recognition judgments: Well calibrated judgments both for reconstructive and associative memory processes

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A common distinction in memory research is that between *retrieval* and *reconstructive memory processes*. In a recent study, Wagenaar (1988) argued that while retrieval should be characterized by good *calibration*, reconstructive and inferential processes should be associated with poor calibration and *overconfidence*. He also presented results from experiments on recognition and recollection suggesting that: (a) Subjects are poorly calibrated when relying on reconstructive processes and well calibrated when relying on retrieval, and (b) show very poor calibration (no discrimination) for "new" items and good calibration for "old" items in a recognition task. More recent *ecological models* (Gigerenzer, Hoffrage, & Kleinbölting, 1991; Juslin, in press a, in press b), would predict that, if calibration is evaluated in terms of a reference class that is representative of the subject's natural environment, i.e., where the probabilistic inferences are allowed to have their everyday validity, calibration should be good also for reconstructive and inferential processes. This hypothesis was tested in an experiment that compared three conditions, where the first two coditions were designed to resemble the conditions of Experiment 1 in Wagenaar's study (i.e., lists of nonsense syllables and words, respectively). The third condition was designed to require more reconstructive processes (words from a coherent text). Great care was taken to generate an unbiased reference class by selecting the distractors (new items) randomly from a pool of everyday texts. The results indicated: (a) Almost identical, and quite good, calibration for all three conditions at a recognition test after 30 minutes. In particular, calibration was just as good even if the task involved reconstructive and inferential processes. When tested again after about 1 and 1/2 month, subject were severly overconfident for the nonsense syllables while still quite well calibrated for the words from a coherent text. (b) The pattern observed by Wagenaar, poor calibration for new items and good calibration for old items, was observed only for the nonsense syllable and the word list conditions. For the (more real-life-like) text condition, subjects were well calibrated both for new and old items. It is suggested that, *in the subject's natural environment*, reconstructive memory is highly efficient and adaptive and that the subject's confidence judgments are well calibrated to this reference class.

THE EFFECT OF TIME PRESSURE ON DECISION MAKING BEHAVIOUR IN A DYNAMIC TASK ENVIRONMENT

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Dynamic aspects of the task environment will affect decision making behaviour in several ways. First, as a dynamic situation continuously changes, a decision maker must take the time dimension into consideration. Second, if the decision maker receives information on the state of the system, feedback is provided on the consequences of executed actions. Third, in most studies on time pressure, deadlines were used. In dynamic situations however, time pressure can be induced by an ongoing decline in system performance.

In order to investigate decision making behaviour in dynamic situations, with respect to these neglected aspects, an experimental paradigm was developed. The task required subjects to monitor on a computer screen the continuously changing fitness level of an athlete, to diagnose, on the basis of probabilistic information, the exact system state in case the fitness level declined, and to select the action that would restore the athlete's fitness level. The overall fitness level is depicted by means of a graph. Specific, detailed information, which is needed to make a correct diagnosis and, relatedly, to select the right action, can be requested. Time pressure is manipulated by the speed at which the fitness level deteriorates by itself.

An experiment will be discussed in which the effects of various levels of time pressure were registered on time allocations (to various phases of the decision making process), behavioural responses and diagnosis. The results showed that more athlete's collapsed under high levels of time pressure, that subjects requested the same amount of information but made better diagnoses (given the information requested) under a moderate level of time pressure, and that they speeded-up information processing under increasing levels of time-pressure. Furthermore, the strategies (the way the problem was approached) remained constant across different levels of time pressure.

UTILITY ASSESSMENT IN MEDICAL ONCOLOGY

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One of the medical fields where trade-offs between quality and length of life are made continiously is oncology. As the effects of cancer treatment on survival or recurrence are often uncertain, decisions about treatment involve careful weighing its 'costs' and 'benefits'. Weighing treatment specific costs and benefits implicitly suggest the existence of quantitative values for quality of life on a scale encompassing perfect health at one end, death at the other end, and various health states in between. Decision analysis uses the concept of 'utility' to make different and in principle incomparable health states or treatment outcomes comparable by assigning them numerical values with the aid of a reference scale. The obtained valuations can be used as a utility parameter to compute for instance QALY's, which is an acronym for 'quality adjusted life years'.

Condiserable methodological as well as practical problems still need to be overcome before utility measurement techniques can be used in an acceptable and reliable way for real patients confronted with real diseases and real choice alternatives. Two methods that have been used most frequently to measure the utilities of different health states are the Standard Gamble [SG] and the Time Trade-Off [TT0]. A criticism of the SG-method has been that the axioms of utility-theory from which this method originates, do not take account of the specific 'utility of risk'. Criticism of the TTO-method refers to the underlying assumptions of the QUALY-model from which this method originates, i.e., the constant proportional trade-off and the independence of time and quality.

We have applied both methods in a population of patients with testicular cancer [N=30] to measure their utilities of two different health states related to testicular cancer and for two periods of time [2 versus 10 years]. A monetary gamble was included in the SG-method to investigate if this would lead to a different risk-attitude of the subject.

Gambling for money in the SG-method resulted for all patients in a risk-attitude significantly different from the one including health states [gamble concerning health states resulting in an attitude of much more risk-aversiveness]. Results of the TTO-method revealed a different utility function for both health states in different periods of time. Both findings indicate a violation of the assumption of the QUALY-model.

Measuring the Compensativeness of Multi-Attribute Decision Strategies

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In multi-attribute decision problems the subject has to evaluate a number of options with given values on a number of attributes, in order to arrive at some conclusion about the attractiveness or utility of these options. The information processing procedure leading to a conclusion is called a *decision strategy*, and one of the main topics in multi-attribute decision research has been the nature of these decision strategies.

Decision strategies are usually classified as either *compensatory* or *non-compensatory*. Strategies are considered to be compensatory when low values on some attributes can be (partly) compensated for by high values on other attributes, as is the case with *Linear* and *Additive Difference* strategies. If low values cannot be compensated for, as for instance in the *Elimination by Aspects* strategy and the *Conjunctive* strategy, the strategy is said to be non-compensatory.

In *process tracing* studies using the *information board* technique, descriptions of decision strategies are usually based on three indices of the information search process, *Variability of Search*, *Search Pattern* (Payne, 1976), and *Depth of Search*. Variability of Search, defined as the standard deviation of the proportion of cards turned over per option, is considered to give an indication of the compensativeness of a decision strategy, compensativeness being smaller as Variability increases.

In this presentation we propose an alternative way for establishing the compensativeness of decision strategies in information board studies. We will argue that compensativeness depends on both Variability of Search *and* Depth of Search (the proportion of cards turned over), and that a valid measure for compensativeness has to be a *multiplicative* function of these two indices. As a continuous measure it reflects the fact that empirical decision strategies are not rigid applications of formal strategies, but possess properties of such formal strategies *to a certain extent*. Apart from the derivation of the measure we shall present empirical data on its reliability and validity.

THE INTELLIGENT IMITATOR

Humans "maximize subjective expected value" but do so in a manner that differs radically from the traditional SEU conception.

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The paper presents the main features and initial achievements of a novel Exemplar-based Choice Theory of human behavior, ECT. A detailed exposition of the theory as developed so far has recently been published: *The intelligent imitator: Towards an exemplar theory of behavioral choice.* Volume 95 in the series *Advances in Psychology*, North-Holland, Amsterdam, 1992.

Metaphorically, the basic claim of ECT is that human beings are "intelligent imitators". That is, they try to do as others would have done in the same situation. Their "intelligence" consists in the "rational" way they select and use information about people's behavior (their own included) in order to find out what the prototypical other actor would have done. Among other things, they take account of the fact that other people may be acting under different circumstances and, therefore, should not be copied indiscriminately. Also, the actor may receive conflicting messages from different sources, so that the various pieces of information must be integrated into an "intelligent" guess. In particular, items of information about the value of the action alternatives facing the actor are combined into a weighted arithmetic mean that may be conceived of as an "estimate" of the value. The intelligent imitator is proposed to choose the action alternative with the largest "estimated" value. Although this idea looks similar to the traditional notion of "maximization of subjective expected utility", the difference is fundamental and has far-reaching implications.

The major characteristics of the theory include:

- Basic ideas and terms have been adopted from decision theory, in particular expectancy-value theories. ECT contrasts with these theories in that it - instead of assuming that the choice situation is given - aims at explaining action alternatives, outcome expectancies and values in terms of their determinants in the social environment and in the current situation and past history of the actor.
- The novel theory is an "exemplar" theory of choice in the sense that the choice of the actor is proposed to rest on stored memory representations of observed past action events.
- Like traditional theories of instrumental or operant learning, ECT stresses the role of response consequences in behavior modification. However, there are also many differences, the major one being the mechanism of motivation. For example, the motivational mechanism of the theory makes it predict effects of past behaviors even in situations when feedback to the actor about the consequences of his or her action has been blocked.
- Information about the actions of others are processed by the observer according to the same principles as information about his own actions and influences him similarly. Hence, ECT is also a theory of "social learning" or "modeling".

In sum, the new theory offers numerous challenges to existing approaches and opens new horizons for further investigation.

DECISION MAKING IN THE PRESENCE OF ASYMMETRIC LOSS FUNCTIONS.

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There is considerable experimental evidence that people are quite good at forecasting underlying trends in time series which suggests that human judgement can filter out randomness and extrapolate underlying patterns (Lawrence, Edmundson and O'Connor 1985; Bunn and Wright 1991). However, judgmental estimates of confidence limits around forecasts are typically reported to be poor; they are insensitive to the randomness in a series, affected by the trend in the series and not significantly improved by outcome feedback (O'Connor and Lawrence, 1990; Lawrence and O'Connor, 1991) . We speculate that this is because forecasting is frequently performed but estimating confidence intervals is rare. Thus, as a task, judging confidence intervals may have low 'ecological validity'.

This position is supported by surveys of business decision making which reveal very low use of forecast prediction intervals - despite the ready availability of computer based decision support tools which can process uncertainty information. Forecast uncertainty information is critical under conditions of an asymmetric loss function. Such loss functions are frequently encountered in business, e.g. estimating cash flows for loan granting (asymmetric because returns below a certain point may lead to bankruptcy) and sales forecasting (a manager may judge it to be far safer to be a bit over rather than a bit under).

Why then don't people use forecast uncertainty information? One reason may be that they use an alternative that is mentally simpler to process than a prediction interval. One such alternative is a loss adjusted forecast (LAF), which is the forecast judged to minimise the forecaster's perception of the loss function. While no survey information attests to the practical value of LAFs, informal comments made by forecasters support the notion that forecasts are often adjusted by reference to the perceived outcome risks of losses.

We experimentally explored the ability of individuals to produce LAFs by asking people to forecast time series with asymmetric loss functions. Subjects examine a time series that represents a series of journey times to college. They predict the next journey time and also say how much time they will allow for the journey, given that being early entails different consequences to being late. It will cost one point (or five) for every minute that they are early and five points (or one) for every minute that they are late. Normatively, to estimate the LAF, the decision maker needs to estimate the forecast, the forecast uncertainty and combine these with the loss function. Other subjects gave forecasts and confidence intervals. The decomposition rationale underlying decision analysis suggests that LAFs will be more difficult (worse) than decisions computed using subjects' elicited forecast uncertainty. We compare the quality of these decisions with those derived from subjects' estimated confidence intervals (forecast uncertainty) around their forecast.

Effects of Salience and Time Pressure on the Choice Process and Outcomes

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Many decisions are made under conditions of moderate to severe time constraints. Given the potential importance of time pressure to decision-making, it is surprising how few empirical studies have directly examined the influence of time pressure on choices. One of the main findings in this limited literature is that under time pressure people spend more time looking at and give greater weight to the "most important" information. For instance, Zakay (1985) reported that in post-experimental interviews, subjects indicated that under time pressure they relied mainly on the information that they felt to be the most important. This phenomenon of processing only a subset of the information is referred to as "filtration".

Most of this work, however, seems to suggest that people either know what is the "most important" information or have general rules of thumb that help them select it. For instance, when presented with information on both the negative and the positive aspects of attributes, subjects tended to place greater weight on the negative aspects of alternatives when under time pressure (Wright 1974, Wright and Weitz 1977, Ben Zur and Bretznik 1981, Svenson et al. 1987). Also Payne, Bettman and Johnson (1988) in a task in which subjects had to choose among a set of risky options, reported that under time pressure subjects spent more time looking at the outcome with the largest probability of occurring.

An interesting question then becomes whether one can manipulate externally what is the "most important" information. For instance, would an attribute made salient in a manner totally irrelevant to the choice be processed more, and ultimately be weighted more under time pressure, or would a lack of time make consumers even more focused and prevent them from paying greater attention to the irrelevant salience of a manipulated attribute. This is obviously an important issue, since equating salience and importance of information could induce radical changes in the choice outcomes.

In this study, subjects had to choose among alternative brands of cameras. Salience of a target attribute and time pressure were manipulated. Salience of a target attribute affected attribute importance ratings but did not interact with time pressure. Time pressure, however, induced a preference reversal. Process-tracing measures are used to discuss these findings.

IS HATE WISER THAN LOVE ? POSITIVE-NEGATIVE ASYMMETRY IN INTERPERSONAL DECISION MAKING

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The phenomenon of positive-negative asymmetry (PNA) refers to the tendency to process positive and negative information and react to positive and negative stimuli in a way that is not fully symmetrical. For instance the available evidence suggests that the "positive" and the "negative" may have an unequal epistemological status: Positive evaluations are more a product of subjective wants and wishes while negative evaluations tend to reflect real "objective" properties of evaluated targets. This has implications for the final evaluations as well as for how the evaluation process is taking place.

In a series of four studies we investigated differences between decisions to SELECT one alternative (a person) out of five, or to REJECT one alternative. It was hypothesized that negative decisions (rejections) 1) are preceded by an information search which is analytical rather than holistic (an attribute-wise rather than alternative-wise search strategy); 2) are less prone to "dominance structuring" and hence preceded by a less biased information search; and, consequently 3) are less a product of constructionist tendencies in the subject and more a reflection of real properties of the alternatives, than are positive decisions (selections).

The first study showed that Ss tended to apply mixed (attribute-wise followed by alternative-wise) search strategies for accept decisions, while they prefered the attribute-wise search strategies when making reject decisions. They also displayed less dominance structuring in "reject" than in "accept" situations.

These findings were partially replicated in the second study, which also showed that the information search was significantly less biased towards the finally chosen alternative when the task was to reject rather to accept a person.

The third study manipulated the search strategy (mixed versus attribute-wise versus alternative-wise), and type of decision (accept versus reject) and investigated decision time and amount of dominance structuring as an effect of these two factors. In other words we tried to find out what happens when the imposed strategy of information search (alternative-wise versus attribute-wise) goes against the natural preferences of subjects (when the former are required for "reject" and the latter for "accept" decisions).

In the fourth (unfinished) study SELECTION (or acceptance) versus REJECTION instructions were given with alternatives of "objectively" unequal attractiveness. It was hypothesized that "reject" decisions will reflect this "objective" order better than "accept" decisions.

PITTING HOT AGAINST COLD COGNITION
The effect of Escalation of Commitment on Hindsight Bias (and vice versa)

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Escalation of Commitment (EOC) is the reinvestment of resources in a failing course of action (Brockner, 1992; Staw & Ross, 1987). Hindsight bias (HB) is the tendency to attenuate postdiction (retrospective estimated likelihood of events) to accord with their occurrence or non-occurrence (Fischhoff, 1975; Hawkins & Hastie, 1990). Both EOC and HB are retrospective behaviors. (i.e., behaviors that are informed by outcome information):

EOC : DECISION #1 => OUTCOME => FEEDBACK => DECISION # 2

HB: PREDICTION =>OUTCOME => FEEDBACK => POSTDICTION

Despite their similarity EOC and HB have been so far studied separately. Furthermore, while both phenomena have been explained in terms of "hot" as well as "cold" cognition (Janis & Mann, 1977), research on EOC indicates that it is principally caused by hot cognition (self-justification, Brockner, 1992), while research on HB indicates that it is principally produced by cold cognition ("creeping determinism", Hawkins & Hastie, 1990).

To explore this contradiction we tested two hypotheses by studying EOC and HB simultaneously. Based on hot cognition models we hypothesized that EOC decreases HB while HB increases EOC. Based on cold cognition models hypothesized that EOC increases HB while HB decreases EOC. Combining standard EOC and HB research designs, we asked subjects to invest in one of two options, informed them on the outcome of their decision, and asked them to posdict the likelihood of this outcome and allocate additional resources among the same options. Half of the subjects were feed-back positive outcomes and half were fed-back negative outcomes; half made the second investment prior to postdicting the outcome of the first decision and half worked in the reverse order.

The results of the study can be summarized as follows:

(a) The study replicated previous results concerning the effects of outcome information on EOC and HB. Outcome knowledge attenuated the postdiction of outcomes and negative outcomes induced subjects to reinvest in their first decision more than negative outcomes.

(b) EOC increased HB. Subjects who estimated the likelihood of negative outcomes after making a second investment decision produced higher retrospective estimates of failure than subjects who worked in the reverse order.

(c) HB reduced EOC. The significant difference in reinvestment following negative outcomes disappeared when subjects first estimated the likelihood of their outcomes in retrospect.

Although our results support cold cognition models of retrospective behavior, they also demonstrate experimentally that HB is affected by motivational factors. We conclude that while EOC aggravates the difficulty of valid learning that is produced by HB, HB enhances the effectiveness of combating EOC by means of critical inquiry.

FRAMING ELABORATIONS AND THEIR EFFECTS ON CHOICE BEHAVIOUR: A COMPARISON ACROSS PROBLEM ISOMORPHS AND SUBJECTS WITH DIFFERENT LEVELS OF BACKGROUND KNOWLEDGE

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Maule (1989) reported a study using verbal protocols to identify the decision frames adopted by subjects undertaking the Asian Disease problem originally used by Kahneman & Tversky (1981). He showed that subjects could elaborate their decision frames in one of three ways: recognition of the potential losses in the version of the problem described in terms of lives saved, recognition of the potential gains in the lives lost version, or by considering issues outside the formal problem description, like moral issues. Further, the findings indicated that Prospect Theory could only account for the choice behaviour of subjects who did not elaborate their frames in this way. This suggested important limitations to the predictive ability of Prospect Theory. The present paper presents two further studies exploring this effect. In Study One, groups of social work and psychology students were presented with one of two sets of decision problems. One set was drawn from the classic framing problems used by Kahneman & Tversky, the other involved isomorphs of these problems using social work scenarios (eg. the Asian disease problem had an isomorph involving the same figures but based on child abuse). It was predicted that for the social work problems, social work students would elaborate their frames to a greater extent than psychology students due to their superior knowledge and commitment. This greater degree of elaboration should make social work students less likely than psychology students to show the reversals of preference predicted by Prospect Theory. This difference should not occur with the original versions of the problems. Analysis of choice behaviour indicated that for all the problems and their isomorphs, the usual reversals of preference occurred in both subject groups, and there was little evidence for differences between either problem isomorphs or subject groups. There was, however, some tendency for all subject to be generally more risk averse in the social work problems. This failure to find a reduction in preference reversals in social work subjects was unexpected and further explored in the second study. In Study Two, two groups of social work students were asked to generate concurrent verbal protocols whilst solving the two sets of problem isomorphs. The analysis undertaken so far generally supports Maule (1989) linking frame elaborations to violations of the predictions of Prospect Theory. Analysis is currently under way to explore further the nature of these elaborations and results of this analysis do far suggests that there may be other ways to classify frames and relate these to explanations of choice behaviour.

"FIXED-PIE" AND "ELASTIC-PIE" BIASES IN NEGOTIATIONS

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Interpersonal learning (IPL) in negotiation was studied in the context of a simple two-issue, two-party role-playing task. Participants negotiated once, with different partners, on two versions of the same substantive task. One version was distributive (i.e., fixed-sum), whereas the other version possessed integrative potential (i.e., positive, variable-sum; see Walton & McKersie, 1965).

After reaching a settlement, negotiators were asked to estimate the payoff achieved by the other negotiator. Negotiators' estimates of the other party's payoffs demonstrated only modest levels of predictive accuracy IPL ($r = .43$). Contrary to the typical assumption that good understanding of the other negotiators' objectives and desires facilitates performance, the degree of accuracy of IPL was not significantly associated with negotiators' payoffs -- good IPL did not seem to help negotiators reach high payoffs.

Most negotiators appeared to estimate the other negotiators' payoffs largely on the basis of the value of their own payoff. A minority of negotiators displayed evidence of the widely-hypothesized "fixed-pie" bias (Bazerman & Neale, 1991), which assumes that the negotiation situation is a distributive, zero-sum game. In both distributive and integrative versions of the task, however, the vast majority of negotiators displayed evidence of what might be called an "elastic-pie" bias. They tended to estimate that the other negotiator's payoff was identical to their own, implying a perceived positive-sum negotiation, or their estimate was best modeled as a weighted average of their own payoff plus the other negotiator's true payoff, representing a compromise between accurate IPL and the elastic-pie assumption.

RISK ORIENTATION IN DYNAMIC DECISION MAKING

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Although there is a high level of theoretical interest in the relationship between individual differences in risk taking and decision processes in static decision making tasks, there has been little investigation of this relationship in dynamic contexts. This paper reports the results of an investigation exploring the validity of Lopes' (1987) Two-Factor model of risk in the context of dynamic decision making. Within the Two-Factor model the present study is focused primarily on the influence of the dispositional factor (ie risk orientation) on the behaviour of individuals during a dynamic, real-time decision making task.

The task used in the experiment was presented as a computer-based simulation of an alcohol production process. Subjects were first classified into Risk Seeking and Risk Averse groups on the basis of choices made in static gambles, and subsequently trained to operate the alcohol production system. The basic task required subjects to maximize the goal of alcohol production over a series of trials, while maintaining an overall level of safety for the process.

As predicted, the results of the experiment indicated, that there was a relationship between individual risk orientation (as defined from the choices made in the static gambles) and both preference for, and actual observed strategies used to control the production process. Specifically subjects who were classified as Risk Seeking in the gamble task consistently selected more risky strategies in the dynamic context. The Risk Seeking subjects also achieved higher performance levels, but their preferred strategies under conditions of normal operation of the process caused significantly more safety problems. However, there was some evidence to suggest that Risk Seeking subjects would cope better with abnormal 'emergency' conditions. Results from a range of measures of the subjects' risk-taking behaviour in the dynamic task are presented, and the practical and theoretical implications of the findings are discussed.

THE INFLUENCE OF EMOTION- AND UTILITY-RELATED EVALUATIONS AND INDUCED MOOD ON CHOICES IN AMBIVALENT DECISION SITUATIONS

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The influence of emotions on decision making is assumed to be twofold: First, the current mood of the decision maker might modify the processing of relevant information (Lewinsohn & Mano, 1993). Second, specific emotions might be anticipated or elicited when considering the decision alternatives and modify preferences based on utilities (Pfister & Böhm, 1992). It is assumed that emotions are only partially integrated in utilities and that choices are based on a combination of utility- and emotion-related evaluations. Under special circumstances, utilities and emotional evaluations will dissociate, especially in ambivalent decision situations. These are defined as situations with contradictory preferences derived from either utilities or emotions. Consistent situations, on the other hand, imply congruent utility/emotion-evaluations. It is assumed that the relative salience of emotional and utility evaluations is moderated by the current mood of the decision maker. If he/she is in a positive (negative) mood, corresponding emotions will have more impact on choices compared to a neutral mood state. Additionally, mood is assumed to affect kind and depth of information processing.

In an experimental study, three groups of Subjects (N=71) with positive / or negative / or neutral mood induction made binary choices concerning six ambivalent and six consistent decision problems. Subjects first rated utilities and probabilities for self-generated consequences as well as intensities of associated emotions. Analyses of the frequencies of correct predictions for choices by utilities or emotions indicate that overall prediction is worse for ambivalent decision situations. No difference is found between emotional and utility evaluations or between mood groups. Surprisingly, a correspondence analysis shows a slight tendency for emotion/utility-dissociation in consistent situations. With respect to information processing, positive mood Subjects generated more and more probable consequences. In ambivalent situations, less and more negative consequences were produced. Overall, more negative than positive emotions are found.

It is concluded that induced mood state and ambivalence of decision situation primarily determine characteristics of information processing, with positive mood and consistent situations leading to a more elaborate production of relevant consequences. With respect to choice prediction, however, utility- and emotion-based evaluations yield no difference.

Disenchanting hindsight bias

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Hindsight bias refers to the phenomenon that persons who gave estimates as answers to difficult almanach questions and who later received the solutions tend to "remember" better estimates of their own. While this effect appears ramarkably robust, its causes are not well understood at all. Previous research has justly been criticized for not disentangling different knowledge-retrieval states that a subject might be in at test time. The problem of separating subjects' hindsight judgments can be approached either empirically or – perhaps even more convenient – theoretically. This paper explores both ways. The theoretical approach consists of a *multinomial model* that allows to estimate proportions of different retrieval states. Applying the model to several sets of empirical data gave rise to some new considerations in explaining hindsight bias. The empirical approach, on the other hand, contains several *experimental manipulations*, that were devised to restrict the number of possible retrieval states, as well as *introspective data*, that were gathered in order to separate different states within subjects. The findings show that (apart from ever present regression effects) *response bias* and *blending* seem to be the two most influential processes in hindsight judgments.

TESTING THE LOGICAL CONSISTENCY OF DECISION ANALYSES,

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Lacking a clear validity standard, decision analysts often evaluate analyses subjectively. To help them do so more objectively, this paper developed a "logical" consistency check. Unlike most consistency checks, the new one need not assume the axioms' or the model's validity. It checks consistency with partial orders of alternatives or choice strategies based on logical knowledge---e.g., knowledge that some medical treatment is better than none or that expert physicians' choices outdo a random rule's. The new method derives inequalities implied by the above knowledge and by hypotheses e.g., the hypothesis that analyses outperform physicians (or vice versa). The method also derives tests of its ordered metric scale (OMS) assumptions.

One study evaluated the method with 75 subjects (44% doctors) making intuitive choices in 40 decision analyzed medical dilemmas. A second study did so with 100 subjects (57% doctors) making intuitive choices in only one dilemma but rating utilities in four response modes: category scales (CS), time tradeoffs (TTO), probablility equivalents (PE) and lottery equivalents (LE).

The results confirmed 3 hypotheses. First, the OMS assumption was satisfied (in 75% of experiment 1's data, 80% of experiment 2's). Second, after eliminating tests violating the OMS assumption, analyses outdid intuition (in 68% of experiment 1's data, 83% of experiment 2's). Third, study 2 found analyses using CS utilities worse than those using TTO's, PE's or LE's, also worse than intuition. This finding questions U.S. health policy-making methods, which usually use the CS to measure health programs' benefits and to guide resource allocation. The other findings confirm the new method's potential to assesss analytic performance. They should motivate studies to determine how widely the method applies, whether it can help answer other questions about how and when to do analyses, and ultimately whether it can contribute to a newly emerging science---a science of decision aids for selecting and designing decision aids.

The importance of subjective probability in modeling testing behavior

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So far, investigators of testing behavior have typically focused on falsification. For several reasons, falsifying hypotheses as a testing strategy is considered superior to gathering confirming evidence for them. Falsifying testing behavior is prescribed by theories on scientific methodology (Popper, 1963) and it goes against prejudices. Wason (1960) was the first scientist to experimentally study testing behavior with his famous *rule discovery task.* However, his original definition of falsifying testing has been very much criticised (Klayman & Ha, 1987). Subjects were thought to carry out a falsifying testing strategy when in fact they carried out 'negative' tests. Negative testing means testing with predictions that are not explained by the hypothesis. However, as Klayman & Ha (1987) argue, falsifying testing should be a strategy that maximizes the probability of obtaining evidence that leads to falsification of the hypothesis. In this presentation, an alternative model for studying testing behavior is presented. First, it will be argued that this model is theoretical consistent with the Bayesian view on testing, as well as with the Popperian view and the information theoretical view. A principle common to these theories is that testing with predictions that have a high probability under the assumption of the hypothesis, and also a low unconditional probability, can lead to strong support (or probability) a posteriori. Choosing these kinds of predictions characterises a falsifying strategy. Indeed, although the test can provide the tester with a strong support a posteriori, a priori it holds a high risk of getting a falsifying result (the unconditionalised probability of the prediction coming true being low). Operationalising this model in a testing task first requires an assessment of subject's subjective (unconditional) probability of several predictions of their hypothesis. Subsequently, the preference for high- or low-probability must be measured.

In the presentation, the subjective probability model for testing behavior will be elaborated on. Subsequently, an experiment will be presented based on Wason's rule discovery task, in which the subjective probability model for testing is tested. Subjects give their probabilities and their relative preference of several predictions generated by the same hypothesis. The results will be discussed in relation to recent analogous results on testing behavior (Slowiaczek et al., 1992). Subjects do seem to prefer high-probability predictions.

Anticipation of Uncertainty Resolution in Choice

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In choice between uncertain options, one may expect uncertainty to be eventually resolved for all options, or just for the chosen option. It is proposed that expectations concerning partial or complete uncertainty resolution may elicit different choice processes. In particular, we hypothesize that people are more likely to rely on a process of comparing outcomes per possible states of the world if they expect to learn what would have happened with each option. In those cases, the outcome of the alternative option serves as a reference point in evaluating the outcome of the considered option, in each state of the world. Accordingly, preference for prospects yielding better outcomes than the alternatives in more states of the world will be higher if complete resolution of uncertainty is expected.

Two experiments examined choice between statistically independent lotteries for which the chances of being better off with the high-risk alternative were nearly as high, or even higher than the chances of being better-off with the low-risk alternative. Expectations concerning complete resolution of uncertainty were manipulated between subjects. In accord with the proposed hypothesis, subjects in the complete resolution conditions chose the high-risk high-gain option more often than subjects in the other conditions.

Uncertainty and the reversal of time preference

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A time value function represents the subjective value of differential timing of outcomes. According to conventional economic theory, this function is subject to exponential decay. That is, if time values are discounted rationally, the discount rate should be constant. The validity of such a "rational" economic model for *describing* intertemporal decisions have recently been reexamined by several researchers (Hernnstein, 1990; Ainsly, 1991). They criticize the rational model by stating that an exponential declining function does not explain the finding of reversals of preference as a function of elapsing of time.

Following an example suggested by Hernnstein, our first study illustrates such an intertemporal preference reversal. When asked for their preference: Receive Fl 100 immediately or Fl 110 in four weeks, most subjects report that they would rather have Fl 100 immediately. Yet, a large majority prefers receiving Fl 110 in 30 weeks to Fl 100 in 26 weeks. These results further support the inadequacy of an exponential time value function as a descriptive model for intertemporal choice.

Two additional experiments were run to test the robustness of this effect. We show that the reversal of time preference results from preference for certain over uncertain outcomes.

Confidence Intervals for Individual Utilities

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In the clinical decision sciences the measurement of individual utilities has been given great attention (Torrance, 1976, 1982; Llewellyn-Thomas et al, 1982, 1984; Boyd et al, 1990, Nord, 1992). Although the reliability and validity of the methods (standard gamble, time trade-off, conjoint measurement, rating scale) is discussed, little attention has been given to the implications for the decision.

Many examples have been given in the literature for the possible benefits of a risky decision or for the trade-off between quantity and quality of life in the treatment of cancer. Expected values for therapy based on utility measurement are used to decide what course of action is preferred by the patient.

The aim of this paper is to show that individual confidence intervals (Huber, 1973) may be used to discriminate patients having a clear preference for a certain treatment from patients having uncertain attitudes towards treatment options. Clinical examples will be used to demonstrate the computation and implications for single and joint utility distributions. It will be argued that the statistical confidence level $1 - \alpha$ may be replaced by the degree of certainty the clinician wishes to have about the preference of his patient.

Effects of Uncertainty on Relative Attribute Weights in Preference Ratings

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Research on preference reversals has commonly found a disproportionate influence of outcome probability on preference ratings and choices (e.g. Schkade & Johnson, 1989). This was interpreted by Slovic, Griffin, and Tversky (1990) as reflecting the prominence effect originally demonstrated for riskless choice. The aim of the present study was to investigate how outcome probability added to a riskless choice between pairs of options (medical treatments) with one prominent (effectiveness) and one nonprominent attribute (pain-relief) would change the relative weights of those attributes. If outcome probability replaces effectiveness as the prominent attribute, the relative weights placed on effectiveness and pain-relief were expected to differ less. In one session 32 undergraduates who participated as subjects performed a matching task which allowed independent determination of weights for effectiveness and pain-relief. In a second session half of the subjects were assigned to one condition in which they made preference ratings of medical treatments constructed by factorial combination of levels of effectiveness and pain-relief. In the other condition subjects judged the same medical treatments but were informed that their specified degrees of effectiveness and pain-relief would only occur in 25% of treated cases. A prominence effect was observed in the certainty condition for preference ratings in that the weight of effectiveness relative to the weight of pain-relief exceeded the weight ratio inferred from the matching task. The results in the uncertainty condition furthermore indicated in line with the expectation that the weights of effectiveness and pain-relief differed less.

"The Psychology of Expertise: A New Paradigm"

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Since the earliest days of experimental psychology, researchers have focused on an idealized representation of the subject in behavioral research -- the "Generalized Normal Adult Human Mind" or GNAHM. Researchers have been particularly interested in failures or inconsistencies of GNAHM. One consequence of this paradigm is that outliers are assumed to be the product of random variation in a normal distribution of subjects. In Judgment and Decision Making research, investigators have found that behavior is guided by heuristics, or mental rules of thumb. These heuristics frequently lead to unavoidable errors or biases, cognitive illusions, that seemingly effect everyone. "There is much evidence that experts are not immune to the cognitive illusions that affect other people" (Kahneman, 1991). The purpose of this paper is to present three lines of evidence from studies of expert that question the universality of this GNAHM argument.

First, research with auditor reveals little evidence of heuristics, such as representativeness (Shanteau, 1989). Based on a literature review, Smith and Kida (1991) conclude that "biases found readily in other research are not evident in judgments of professional auditors." Second, studies of calibration have reported that virtually everyone is overconfident. Yet, research with professional weather forecasters has revealed that the judgments of these experts are accurately calibrated, at least for short-term forecasts (Steward, et al, 1992). Finally, numerous studies have concluded that human judgment is unreliable. However, analysis of livestock judges reveals a steady increase in reliability with higher levels of judging skill (Shanteau & Phelps, in press).

In each case, studies of experts failed to support the assumption of universality. Instead, these studies suggest that the GNAHM approach does not extend to experts. Researchers have unknowingly adopted an overly narrow view of the range of human decision behavior. An alternative paradigm which recognizes the special ability of experts is needed.

ASYMMETRIC INFORMATION AND COMPETITIVE BEHAVIOR

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A major characteristic of insurance markets is information asymmetry. This may lead to adverse selection which is the tendency of those who seek to buy insurance to be a non-random selection from the population-more particularly, to be those who expect to have the highest expected claims. Another aspect of markets with asymmetric information is self-selection which refers to the pattern of choices that individuals with different personal characteristics make when facing a menu of contracts or options. For example, workers who face a choice between a job with a fixed hourly wage and one with piece rate incentives will tend to prefer the former if they expect to be relatively unproductive and to prefer the latter in the opposite case.

Self selection constraints are often invoked in Spence's signalling model. Basically, self selection constraints ensure that signals are credible. When self selection constraints hold, employers in the labor market for example can rely on workers' signals. It can be shown that if self selection constraints hold regarding education for example, it will not be to the advantage of a low-productivity worker for to send a (false) signal as if he is a high-productivity worker.

Can self selection constraints lead to credible signalling in insurance markets? This may depend on the ability of those receiving the signals to identify the self selection constraints.

Their research reports the results of 3 studies that examined the degree to which people comprehend intuitively the self selection notion. In the first two experiments subjects played the role of insurers and insurance buyers, respectively. The third study was a replication of the second experiment with underwriters in a real insurance company. The results of all studies cast doubt as to whether the belief in the self selection assumption is an integral part of decision makers cognitive "map" of insurance markets. Implications for decision making in competitive situations are discussed.

THE NON-MONOTONICITY EFFECT IN RESOURCE DILEMMAS UNDER UNCERTAINTY

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Considered in this article is a resource dilemma game involving both strategic and environmental uncertainties. Groups of n members are asked to share a common resource whose exact size, x, is not know. Rather, x is sampled randomly from a uniform probability distribution which is common knowledge.

Each group member j (j=1, ..., n) requests rj units from the resource. If (r1+r2+....+rn) ≤ x, each member is granted his/her request; otherwise, group members receive nothing. All request are made independently and anonymously and no preplay communication is allowed during the entire game.

The Nash equilibrium solution derived for this game by Rapoport & Suleiman (1992) exhibits a "non-monotonicity effect" predicting that individual requests will first decrease linearly as a function of the uncertain resource range, and then will increase linearly with further increase in the range.

The present article reports the results of an experiment designed to test the existence of this effect. The date are also used to analyze individual differences in harvesting the uncertain resource.

Yes, but it is uncertain: Direction and communicative intention of verbal probabilistic terms.

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Verbal probabilities, in contrast to numerical p values, are characterized by their direction, or attentional focus. Whereas expressions like "probable", "a possibility", or "there is a chance" focus upon the occurrence of an event, other expressions, like "uncertain" and "doubtful", focus upon its non-occurrence. This aspect has been overlooked in most studies designed to translate verbal probabilities into numbers.

In three studies, this directionality was studied by:

(1) Asking subjects to complete sentences of the form: "It is a possibility that we will have rain, because ..", or "It is uncertain that we will have rain, because ..". In the first example, most people will give arguments for the occurrence of rain, in the second they will give arguments for its non-occurrence (regardless of probability magnitude).

(2) Asking subjects to evaluate the appropriateness of answering words like "yes", "no", "yes, but", and "no, but" in sentences containing probability expressions. For instance, it is considered OK to answer a positive assertion with "yes, it is a possibility", or "no, it is doubtful", but not the other way around.

(3) Asking subjects to judge the attitude of the speaker (encouragement, optimism, or recommendation vs. discouragement or pessimism) associated with the use of different terms. It turns out that some expressions are more appropriate for judging the chances of an achievement, whereas others apply both to achievement and failures.

Results from all studies showed a clear directionality effect, independent of p level. Verbal probabilities have been characterized as vague or fuzzy from a numerical perspective, but they surpass numbers in having a focused communicative intention.

THE ROLE OF EXPERIENCE AND DOMAIN OF EXPERTISE IN USING VERBAL VERSUS NUMERICAL PROBABILITY TERMS IN MEDICAL DECISIONS

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Verbal probability terms are frequently used in medical practice. Research has shown that people vary widely in their interpretations of verbal probability terms (Bryant & Norman, 1981) and that the interpretation is influenced by context (Weber & Hilton, 1990) and experience (Nakao & Axelrod, 1983), but that presentation mode does not have to affect the quality of the decision (Budescu et al., 1988; Erev & Cohen, 1990). Unfortunately, hardly any research is done on the use of verbal versus numerical probability terms in specific domains of expertise. In this study we investigated the ambiguity of verbal probability terms by asking physicians differing in expertise with respect to domain (i.e., surgeons and internists) and years of experience (i.e., specialists, residents, interns) to assign numerical values to verbal probability statements for three constructed cases, and to decide upon the most appropriate treatment. The first case referred to a problem more familiar to surgeons (i.e., acute appendicites), the second case to a problem more familiar to internists (i.e., angina pectoris), and the third case concerned an imaginary disease, and was not familiar to any of the subjects in the experiment. Subjects were also asked to give a numerical interpretation of verbal probability terms without context. A few weeks later subjects were asked to judge the same cases with numerical probabilities. Results show no effect of context, nor of years of experience or domain of expertise on the interpretation of verbal terms. Presentation mode did affect the decision, especially of the residents in surgery. More residents agreed with experienced surgeons when information was presented in numerical terms as opposed to verbal terms. Confidence in the decision made was also affected by presentation mode. Most physicians were less confident when verbal terms were presented, but only for the less familiar decision problems. Finally, physicians turned out to be better in Bayesian reasoning when numerical terms were used. Experienced physicians were quite accurate in estimating the posterior probability in the appendicitis case, but not in the imaginary disease.

Influencing risk-preference: Framing decisions versus emphasis on a specific outcome

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Alternative descriptions of a decision problem can affect preferences. A specific example concerns the impact of framing a problem either in terms of gains or in terms of losses. The common finding is that choices involving gains are usually risk averse, and choices involving losses are often risk seeking. This 'reflection effect' (Kahneman & Tversky, 1979) is most pronounced when subjects have to choose between one certain and one risky option. Prospect theory explains this effect on the basis of a nonlinear value function, which is assumed to be S shaped, concave for gains and convex for losses.

Prospect theory's reflection effect has initiated research investigating framing effects in a variety of judgmental tasks. A number of studies investigated the impact of emphasizing the probability of the positive outcome of a risky option versus the probability of the negative outcome. Most of these studies related their findings to the reflection effect, but frequently tended to use prospect theory inaccurately to explain the effects. It will be argued that the effects of emphasizing a specific outcome might be best understood in terms of salience or selective attention.

In three experiments the effects of selective attention are studied in combination with the effects of framing a problem in terms of gains or losses. We test the assumption that emphasizing the positive outcome of a risky option leads to increased risk preference as compared to emphasizing the negative outcome. This effect is (seemingly) in contrast with prospect theory's reflection effect. Results indicate that both framing and salience affect risk preference, that the effects can be additional, and that the effects of selective attention or salience can counteract the reflection effect. Results will be discussed in the context of prospect theory and the literature on salience.

TESTING RANK-DEPENDENT UTILITY AND NEW PROSPECT THEORY

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The most popular stream within nonexpected utility is presently the rank-dependent stream, which models distortions of probabilities. This allows for the modeling of risk attitudes through the processing of probabilities, which is more natural than through the processing of utilities, as in the classical expected utility. We show that "comonotonic independence" is the critical test for all presently existing rank-dependent forms, and that other existing differences with classical models are "cosmetic". An experiment is described where comonotonic independence is tested, and is not confounded with other principles such as regret, the reduction principle, etc.

The finding of this experiment is negative. Comonotonic independence does not contribute descriptively to classical theories. Given the present popularity of rank-dependent utility, this is a remarkable finding. Cumulative prospect theory, recently introduced by Tversky and Kahneman (1992, JRU), does perform somewhat better.

UNREALISTIC OPTIMISM AND GENETIC RISK.

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For many personal risks people tend to believe that they are at less risk than comparable others. If the proportion of individuals who claim that their risk is below average is much larger than the proportion of persons who estimate that their own risk is above average, then the group as a whole is demonstrating an optimistic bias. This phenomenon, called "unrealistic optimism" is not related to sex, age, education or occupation. The bias emerges more easily for problems (1) that are perceived as less frequent (2) as more preventable or controllable by individual action and (3) with which subjects have less experience (Weinstein, 1982, 1987, 1989). It is not clear whether unrealistic optimism will be observed in the context of genetic risk perception. On the one hand the lack of experience with specific genetic diseases as wel as their low frequency may lead to an optimistic bias. On the other hand it is not known whether genetic disease is seen as preventable by individual action.

In a study assessing knowledge about genetic risk and attitudes towards genetic testing, specific attention was paid to "unrealistic optimism". A group of adult women (N=169 ; 21-35 years old) answered a multiple-choice question about the risk that an average couple would have a newborn with a genetic disease or a congenital malformation. Thereafter, their own risk of having such a child was assessed using the same multiple-choice format. To test whether unrealistic optimism occurs, we analyzed the intra-individual differences and found that 43% of the respondents were convinced that their own risk of having a baby with a genetic problem was lower than the risk of an average couple, while 15% thought that their own genetic risk was higher. Even in the subgroup who reported the occurrence of a genetic disease or congenital handicap in the (extended) family, still 38% considered their own risk as lower than the risk of an average couple and merely 26% estimated their own risk as higher. These findings show that unrealistic optimism indeed occurs in a situation of genetic risk.

In a new study unrealistic optimism with regard to genetic risk is evaluated in a group of adolescents. Hereby direct as well as indirect measurement is used. During the meeting the results of this adolescent group will be presented and compared to the findings of the adult group.

Editing and Cumulative Prospect Theory: Ordinal Independence and Outcome Cancellation

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The recent development of axiomatic and non-axiomatic choice models has largely left unstudied the editing phase of Kahneman and Tversky's (1979) prospect theory. In this paper, we examine one particular editing operation, cancellation of outcome-probability pairs (e.g., .20 chance at $100) that are common to two competing prospects. We study cancellation of outcome-probability pairs by testing the Ordinal Independence (OI) axiom (Green and Jullien 1988), an axiom necessary for rank-dependent expected utility (RDEU). In a within-subject design, we find systematic violations of OI (violation rates of almost 60%) and strong evidence that outcome-probability pairs are cancelled *only* when the commonality is transparent. Although the patterns of choice cannot be explained by any RDEU theory alone, they are well-explained by cumulative prospect theory (Tversky and Kahneman 1992) preceded by a formal editing phase: when an outcome-probability pair is common to both gambles, it is cancelled when the commonality is transparent; otherwise, it is not cancelled. These violations suggest that the choice set can determine which decision rules are used, in particular when various editing operations are applied.

POSTERS

POSTERS

Carl Martin ALLWOOD and Pär Anders GRANHAG
Considering the knowledge you have: realism in confidence judgements.

Linda BABCOCK, Henry FARBER, Cynthia FOBIAN and Eldar SHAFIR
On the role of uncertainty and risk in the formation of beliefs about adjudicated outcomes.

Jane BEATTIE and Joshua KLAYMAN
Testing causal hypotheses in a dynamic interactive environment.

Lehman BENSON and Ola SVENSON
Post-decision consolidation following the debriefing of subjects about experimental manipulations affecting their prior decisions.

Fergus BOLGER and Nigel HARVEY
The rationality of expectations in judgmental extrapolation of time series.

Ann BOSTROM
Decision making about global climate change: The role of risk perceptions in risk control.

Jozé BRASPENNING
The validity of a patient vignette in a judgement analysis study on mental health problems in the general practice.

Wibecke BRUN
Lay perception of risk: The importance of qualitative risk characteristics for perceived risk magnitude, signal potential and preferences for regulatory agents.

Jean-Paul CAVERNI, Fernand FARIOLI and Jean-Luc PÉRIS
Self-anchoring in evaluation: Bias or expertise ?

Mark CLAESSEN
The competitive St. Petersburg game: An assessment of choice behaviour under uncertainty.

Cess de BONT
The magazine test, an instrument to facilitate the interpretation of conjoint-analysis results.

Anne EDLAND
Time pressure and the application of decision rules: Choices and judgments among multiattribute alternatives.

Andras FARKAS
Inverse scenario: reasoning backwards on the dangerous outcomes of political processes.

Ilan FISCHER and David BUDESCU
Desirability and hindsight biases in predicting the results of the 1992 Israeli parliamentary elections.

John FOX
Essentials of symbolic decision theory.

Tommy GÄRLING and Joakim ROMANUS
Integration and segregation of prior outcomes in risky decisions.

Nigel HARVEY and Peter AYTON
When are people more overconfident in their own decisions than in those of others ?

Julie IRWIN
Buying/selling price preference reversals: Preference for environmental changes in buying versus selling modes.

Anders JANSSON
Strategies in dynamic decision making: Does learning of heuristic strategies by instructions affect performance ?

Oleg LARICHEV
Do experts use unconscious decision rules and how they do it ?

Laura MACCHI and Vittorio GIROTTO
Conditional probabilities and the three boxes problem.

Siegfried MACHO, Oswald HUBER and Stephan ZYSSET
Chunking-by-similarity model: Empirical text.

Nils MALMSTEN
Post decision processes in human decision making: The significance of attribute importance.

Alastair McCLELLAND and Fergus BOLGER
The effects of changes in difficulty on calibration: Where is the locus of the bias ?

Alexander MECHITOV
Field and Lab studies of experts' performance in diagnostic tasks.

Mary OMODEI, Noël OLVER, Jane GILBERT and Alexander WEARING
Controlling real time dynamic environments: Relevant task and person characteristics.

Wilma OTTEN and Joop VAN DER PLIGT
The additional value of relative risk appraisal compared to absolute risk appraisal.

Alan PEARMAN, John MAULE and Lisa MASON
Managers'intuitive understanding of their decision making and its relevance for decision skills training.

Huub PIJNENBURG and Eric de BRUYN
The feasibility of self-coding versus experimenter-coding as a tool for analyzing clinical decision-making.

Rob RANYARD and Gill CRAIG
Evaluating and budgeting with instalment credit: An interview study.

John ROHRBAUGH and Patricia REAGAN-CIRINCIONE
Improving the accuracy of group judgment: Collective performance that excels individual achievement.

Gad SAAD and Jay-Edward RUSSO
Stopping policies in sequential decision making.

Stefanie SCHMEER
The significance of need for justification for response mode effects.

Thomas STEWART
Analyzing the performance of expert judges: Aids to judgment and components of skill.

Mia STOKMANS
The effect of response mode on structural modelling results.

Ola SVENSON, Amparo ORTEGA RAYO, Ingrid SVALIN and Mikael ANDERSEN
Effects of memory and justification instructions on post decision consolidation.

Manfred THÜRING
Computer supported cooperative work: New ways for group decision making.

Mitsuhiko TODA
A framework of information transformation for decision processes: A model of information structuring and its formalization.

Karen van DAM
Realism within the information board approach. Strategy use as a function of ambiguity and meaningfulness of information.

Jelle van LENTHE
Using proper scoring rules for eliciting uncertain knowledge.

Anders WINMAN
Calibration of hindsight judgments.

George WRIGHT and Kees VAN DER HEIJDEN
Scenario planning and judgmental probability forecasting: Alternative ways of dealing with uncertainty ?

Dan ZAKAY
Perceived risk in the presence of a real traumatic threat.

CONSIDERING THE KNOWLEDGE YOU HAVE : REALISM IN CONFIDENCE JUDGEMENTS

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Previous studies successful in affecting the level of subjects' confidence judgements have often utilized their spontaneous knowledge activation (i.e., Griffin & Tversky, 1992). The purpose of our study is to analyse the effect on the realism of subjects' confidence judgements by making them heed content which might be expected to lower their confidence ratings. This was implemented by making subjects actively consider the limits of their knowledge in a domain.

The study involved 40 subjects, half in the control condition and half in the experimental condition. All subjects answered 60 general knowledge questions by choosing one of two answer alternatives. Next, they rated their confidence in the chosen answer on a scale ranging from 50 % (guessing) to 100 % (absolutely sure).

Before each question the subjects in the experimental condition rated their knowledge in a knowledge domain which included the question which followed. This was done on a scale ranging from 1 (very little knowledge in the area) to 5 (very great knowledge in the area). Each subject rated two types of knowledge domains: broad (for example, history) and narrow (for example, Swedish history), where the broad definition always included the narrow.

We assumed that the domain knowledge rating would lead the subjects to consider the limitations of their knowledge in the domain in question and that this consideration would lead the subjects to give more moderate confidence ratings. In line with this, our hypothesis was that the confidence judgements in the experimental condition would show a higher degree of realism compared to those made in the control condition.

However, our data analysis showed no significant differences between the control and the experimental conditions with respect to our dependent variables: calibration, over/under confidence, resolution, proportion correct and confidence.

The results suggest that the scale on which the subjects rated their domain knowledge was not efficient as a means to realize the goal of the manipulation. In an ongoing experiment the subjects are asked to estimate how large a percent of the total knowledge currently existing in an domain they master on a scale from 0 % to 100 %. We expect this scale to be more efficient in making the subjects consider the limitations of their knowledge.

From a normative point the subjects' ratings of their knowledge should be lower in broad compared to narrow knowledge domains. This is due to the fact that the broad domains encompassed more knowledge than the narrow domains since the broad domains always included the narrow domains. However, our analysis showed that the subjects were insensitive to this dimension in the experiment. The mean ratings for broad domains and narrow domains were 2.60 and 2.29, respectively ($df=19$, $p>001$). A possible explanation for this finding is that the subjects diagnosed their knowledge level through an activation process where the outcome results from an "availability-effect". If the subjects used this strategy, it seems reasonable that they would have been able to activate as much of their knowledge (and/or lack of it) in for example, Swedish history as in history.

ON THE ROLE OF UNCERTAINTY AND RISK IN THE FORMATION OF BELIEFS ABOUT ADJUDICATED OUTCOMES

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In negotiations where impasse is resolved via a dispute resolution mechanism in which a third party makes a binding decision (e.g., the court system, arbitration), beliefs about a potential adjudicated outcome are central in determining the bargaining environment. Thus, the manner in which beliefs are formed and then come to influence reservation values in the negotiation will affect the terms of the negotiated settlement or whether an impasse occurs. The present research examines how negotiators use available information about adjudicated outcomes in cases similar to their own in forming beliefs about what will happen in their case. In particular we examine how negotiators' reservation values influenced by uncertainty about the adjudicated outcome.

Economists generally assume that if both negotiators receive identical information about adjudicated outcomes in similar cases, they will reach the same beliefs about what would happen if their case reached an impasse. However, experimental evidence suggests that when negotiators are given identical information about the facts of their own case and no information about adjudicated outcomes in previous cases, they reach different beliefs about the potential adjudicated outcome (Thompson & Loewenstein, 1991, Babcock, Loewenstein, Issacharoff & Camerer, 1992). The present research investigates how negotiators form beliefs when given identical information about adjudicated outcomes in similar previous cases. Further, we examine how changing the dispersion of the information about outcomes in similar cases affects the parties' beliefs. Specifically, we compare how the parties' beliefs differ between situations where previous similar cases have resulted in very similar adjudicated outcomes and situations where previous similar cases have resulted in varied adjudicated outcomes.

Expected utility theory makes predictions about how negotiators bring to bear beliefs about an adjudicated outcome in arriving at their reservation values. If bargainers are risk averse, they will accept less in the negotiation than their expected adjudicated outcome. Furthermore, an increase in uncertainty about the adjudicated outcome will increase the likelihood that the two bargainers' reservation values will overlap. Ashenfelter, Currie, Farber and Spiegel (1992) provide some indirect evidence which is consistent with this view, where uncertainty is measured by the variance of the distribution of previous adjudicated outcomes is more salient to the negotiators than the variance. We focus on how variance and range, as distinct characteristics of the distribution of previous outcomes, affect 1) the expected adjudicated outcome, 2) the reservation values, and 3) the differences between the expected outcome and the reservation values.

In our experiment, we present subjects (trial attorneys as well as undergraduate students) with a distribution of previous adjudicated outcomes in cases similar to their own. Subjects' beliefs about the adjudicated outcome if their case were to reach an impasse, as well as their reservation values, are ascertained. The range and the variance of the distribution are independently manipulated to determine if these parameters affect subjects' beliefs and reservation values. The implications of this research for the negotiation process and bargaining outcomes are discussed.

TESTING CAUSAL HYPOTHESES IN A DYNAMIC INTERACTIVE ENVIRONMENT

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This paper examines how subjects go beyond the observation that two variables are correlated, to impute a causal relationship. Seventy-two college students were told that scientists had observed a positive correlation between a certain species of grass and a species of rabbits in a wildlife reserve. Subjects were randomly assigned to one of six groups, the independent variable being the true underlying causal relationship between the grass and rabbit levels (necessity; sufficiency; necessity and sufficiency; spurious; contributory; and mutually affecting). In some conditions the level of a third hidden control variable varied between different test plots (e.g., spurious and necessity conditions). Half the subjects were also told that the rabbits and grass were desirable, while the other half were told that they were undesirable. They were asked to experiment by changing the levels of grass and/or rabbits over 20 trials to try to establish the causal relationship (if any). After each trial they obtained immediate feedback (through computer display) of the effects of their actions on the two populations. We observed the types of experiments that subjects conducted and collected their hypotheses concerning the presence and type of causal relationship after each trial. Subjects were given monetary incentives to arrive at the correct hypothesis.

The strategies that subjects used were fairly successful, with most subjects arriving at hypotheses that were at least partially correct. The most difficult condition for subjects to learn was that the two variables were spuriously correlated. We also found significant differences in strategy depending on whether the species were described as "good" or "bad". Subjects in the "good" condition carried out more raising actions and gave greater attention to testing sufficient causes. Subjects in the "bad" condition carried out more lowering actions and gave greater attention to testing necessity relations. We are presently conducting a follow-up experiment to replicate and extend these results. This research has implications for understanding how people test causal hypotheses in everyday life, and the kinds of errors that are likely to occur.

Post-Decision Consolidation Following the Debriefing of Subjects About Experimental Manipulations Affecting Their Prior Decisions

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Subjects were administered a choice task similar to the Asian disease problem (cf., Kahneman & Tversky 1979) and were divided into two groups. In the first group, subjects were given no information about the experiment immediately after having made their decisions. In the second group, (the experimental group) subjects were debriefed immediately after the decision about the experiment. Both groups were told that the experimenter would come back one week later and that the subjects would be required to mark again, on new identical answer sheets, the responses that they had marked one week earlier. The results showed that debriefing influenced how subjects remembered the markings made the first time when they made their decisions. These results have implications that relate to Differentiation and Consolidation Theory. Debriefing subjects about the fact that their preferred alternative was equal to the non-preferred alternative, from a decision theoretical point of view was associated with a change of the non-chosen alternative on one attribute in parallel with stronger consolidation favoring the chosen alternative on other attributes.

The rationality of expectations in judgmental extrapolation of time series

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A major assumption upon which current macroeconomic theory is based is that expectations are rational. Specifically, judgmental forecasts make use of all relevant available information and are consequently optimal. An alternative approach, taken from forecasting practice, is that expectations are adaptive. In other words, forecasts are made so as to minimize previous error. Adaptive forecasts may be suboptimal if the error minimizing strategy is inadequate. A third judgmental forecasting strategy which has been proposed is that a trend apparent in historic data is extrapolated into the future.

Within psychology the rationality of judgment and decision making has been assessed relative to normative models, namely Bayes' theorem and Expected Utility theory. Judgment and decision making have generally been found to be irrational in these terms. The widely accepted explanation for these findings is that, due to capacity limitations, people reason using heuristics which usually work, but sometimes lead to biases. One type of heuristic, the anchor-and-adjust heuristic, can be used to form expectations in a manner consistent with both the adaptive and the extrapolative hypotheses.

We report some experiments designed to test whether judgmental forecasts are made according to the rational expectations hypothesis or by using heuristics. Subjects viewed graphs of simulated sales over a 45 day period and forecast sales for the next five days. The graphs were varied according to the trend and serial dependence they contained. Autocorrelation and trend were varied in order (a) to simulate forecasting conditions in the real world and (b) to allow for critical tests of the different models.

Our results revealed that forecasts were suboptimal and biased. This leads us to reject the rational expectations hypothesis and conclude that people make judgmental forecasts through the use of heuristics. However, the precise nature of the heuristic used, for example, adaptive *versus* extrapolative, depends on specific features of the stimulus series. We suggest that although expectations themselves may not be rational, the selection of appropriate forecasting heuristics may be.

Decision making about global climate change:
the role of risk perceptions in risk control.
by Ann Bostrom

Numerous studies of lay perceptions of global climate change illustrate both the sophistication of lay thinking about complex risks, and its susceptibility to errors. Misconceptions include erroneous beliefs, but more commonly are due to missing details or a misunderstanding of the relative importance of subprocesses in a hazardous process. One prevailing misconception is that stratospheric ozone depletion caused by chlorofluorocarbon release is the primary cause of an increased greenhouse effect. Recent investigations show how risk control decisions and attitudes can be affected by misconceptions such as this, sometimes leading to support for ineffective risk control measures. Because addressing misconceptions and knowledge gaps with incomplete information appears to increase concern, risk communicators should balance completeness with careful attention to the possible effects of misconceptions, biases and heuristics on decision making.

THE VALIDITY OF A PATIENT VIGNETTE IN A JUDGEMENT ANALYSIS STUDY ON MENTAL HEALTH PROBLEMS IN THE GENERAL PRACTICE

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One of the major problems of the Judgement Analysis (JA) studies in the field of medical decision making is the extern validity of the results, because the judged objects are usually represented in a rather artificial way. In a JA study on mental health problems we have used patient vignettes in order to be able to describe the policies of several (n=28) General Practitioners (GPs). Although the results of this study were satisfying, it was found desirable to perform a supplementary study on the extern validity of the results.

Material came available for this purpose in the form of video tapes of numerous visits (n=474) and additional data such as judgements made by the GPs about the visits (five point scale: 1= purely organic, 5= purely psycho-social) and scores of the patients on the General Health Questionnaire (an instrument to measure the mental health state of a patient). A selection (n=90) was made (a) in accordance with the general information of the patient vignettes and (b) based on the presented problems itself, i.e. about 2/3 of the patients were labeled by their GP as someone with mental health problems (psychological or social problems) and the other 1/3 as patients with only organic or somatic problems, and half of the patients reacted positive to the General Health Questionnaire and the other half negative.

The video tapes have been scored -by observation- in the same terms (cues) that had been used for the patient vignettes. If the observation cues can be qualified as good predictors of the judgements made by the video taped GPs the patient vignettes in the JA study will loose lots of their artificiality.

Preliminary results will be reported on the validity of patient vignettes in a JA study on mental health problems in the general practice, using video taped visits.

LAY PERCEPTION OF RISK: THE IMPORTANCE OF QUALITATIVE RISK CHARACTERISTICS FOR PERCEIVED RISK MAGNITUDE, SIGNAL POTENTIAL AND PREFERENCES FOR REGULATORY AGENTS

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Studies of risk perception within the psychometric paradigm have normally let one group of subjects rate several different sources of risk with regard to perceived magnitude of risk while another group has rated the same hazards on several more qualitative risk characteristics, like dread and familiarity. Through factor-analytic procedures these risk characteristics have been reduced to a few more basic dimensions, allowing for the construction of a "factor-analytic" space where the given risks can be plotted. The subjects estimates of perceived risk magnitude, the signal potential of the hazards and regulatory preferences have been found to be predicted reasonably well from the given risk's location in this "factor space". This has been taken to indicate that the lay concept of risk is based upon these more qualitative risk characteristics, rather than upon the more objective risk components, like probability and size of loss. But the correlational nature of these studies has engendered some criticism and calls for a supplementary experimental approach. This poster presents the results from a study where the subjects were confronted with a set of ecologically valid scenario descriptions of hazardious events, where relevant risk characteristics (control, voluntariness, knowledge and dread) were systematically varied. The subjects' task was to rate these hazards regarding risk magnitude and to indicate whether they felt that an accident should be considered a signal that new and possibly worse accidents could happen. Further they stated their preferences for regulatory agent for the given hazards. The study gives an experimental support for some, but not all of the psychometric findings.

SELF-ANCHORING IN GRADING: BIAS OR EXPERTISE?

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Anchoring is a well-known bias, initially described by Tversky and Kahneman (1974) in both evaluative and probabilistic judgement tasks. When making estimates, people start from an initial value that is ajusted to yield the final answer. The initial value, or "anchor" may be suggested by the formulation of the problem or it may be the result of a partial computation. In either case, adjustments are typically insufficient: that is, different starting points yield different estimates, which are biased toward the initial values. T and K (1983) claim that this bias is irrepressible and based on natural assessments which are automatically employed.

Two mains objections have been made about biases, dealing with their artifactual (e.g. Evans, 1983) and non explanatory (e.g. Carlson, 1990) characters.

To examine these objections, we have been studying a non-laboratory task: grading compositions by experts. An anchoring effect has been shown to exist in touch with information about the author of the composition: the same composition is given a lower grade, on the average, if its author is considered to be a poor student, and a higher grade if its author is considered to be a good student (Caverni, 1982; Freedman, 1983).

A question is: when no external initial value is given, are initial values processed from information taken in the beginning of the composition able to produce anchoring effects? If yes, is this effect irrepressible?

Secondary school language teachers participated in an experiment. They graded (out of 20) original 6th grade students' compositions which had been recomposed so as to present, in selected places, only desired types of errors corresponding to criteria most often said to be used in grading. Compositions were virtually divided into four equal quarters in which errors were distributed. Four versions of a same composition have been compared: V1 (++-- sequence, ie correct use in the two first quarters followed by incorrect use of a given rule in the two last quarters), V2 (--++ sequence, ie incorrect use followed by correct use), V3 (+--- sequence) and V4 (-+++ sequence).

A repeated measures design was used with each subject seeing each of the four versions (V1, V2, V3, V4), however only one version of a given composition (a, b, c, d). All compositions were seen in all four possible versions. The orders of presentation of the versions (o1, o2, o3, o4) were determined as followed:

	o1	o2	o3	o4
a	V1	V2	V3	V4
b	V2	V1	V4	V3
c	V3	V4	V1	V2
d	V4	V3	V2	V1

The results are : versions V1 are graded higher than versions V2 only in the o1 and o2 orders. Versions V3 are graded lower than versions V4 in all the orders.

The conclusion is: the initial value plays as an anchor only if confirmed. It does play as an anchor when the context in which it occurs is such that it is obvious that the initial value is not a good prediction for the whole composition value. So this effect appears not to be an irrespressible one. It depends on the context. As it appears when V1 and V2 preceed V3 and V4, one can conclude that usually the initial value computed from the beginning of the composition is good to predict the grade the teacher gives to the whole composition. If this is true, in such a task, the anchoring effect comes from the teacher's expertise, not from an irrepressible bias.

THE COMPETITIVE ST. PETERSBURG GAME: AN ASSESSMENT OF CHOICE BEHAVIOUR UNDER UNCERTAINTY

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The St. Petersburg paradox led Bernoulli to the formulation of his well known theory of marginal utility. The paradox is that people will only value a bet of infinite expected value as being worth several dollars. The bet involves tossing a fair coin until tails comes up, and the revenue is 2^n, where n is the length of the series of tosses.

The puzzle applied in this paradox, played by one person, was transformed into a two person - zero sum competitive game, played via two computer terminals. Both players start with the same amount of play money and have to set stakes. Subjects are rewarded with two percent of play money owned after 80 rounds, totalling Dfl 10.44 .

In the positive condition the highest bidder is to play the bet, looses his stake, and wins back the revenue of the bet. In the negative condition, players have to indicate the amount of money they want to receive, the lowest 'bidder' gets to play, receives the indicated amount, and has to pay the (negative) revenue of the bet.

The object of this study is to see how people use feedback to adjust their stakes, both strategically and tactically. The outcomes were compared with rational staking behaviour. Rational players adopt the strategy of staking halfway between the two players' expected values. This rational behaviour is based on the assumption found in the literature that one rational player assumes that the other player is also rational. Rational behaviour means that the player with the highest score (amount of play money owned at a certain time) has an expected loss. Because both rational players stake the same amount in every round, the one who is to play has to be randomly assigned (just as in the game when both players stake the same).

In reality, subjects were unable to calculate the expected value of the bet. This indicates that even for moderately difficult situations, people are unable (not necessarily unwilling) to behave rationally, and adopt ways of action that are based on feedback and short- and long-term objectives. A framing effect was found, in that stakes in the negative condition were significantly higher than in the positive condition. There also seemed to be an illusion of control, in that playing the bet was viewed positively, although money can equally likely be won by not playing.

This research makes evident the need for theories of choice behaviour that do not account if and why real behaviour does not adhere to rationality, but rather explain why humans behave the way they do.

The magazine test, an instrument to facilitate the interpretation of conjoint-analysis results

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Conjoint analysis is a market-research technique which is applied to obtain insight in the preference structures of consumers. As can be learned from many studies (e.g. Cooper, 1986), this insight is crucial to the success of new-product development projects. In a review article, Green and Srinivasan (1990) discuss the topics related to conjoint analysis which have been investigated. In addition, De Bont et al. (1993) mention 65 studies have been performed to assess the reliability and the validity of conjoint-analysis results.

In spite of the large quantity of studies on conjoint analysis, practiononers still face major problems in interpreting conjoint-analysis results. To illustrate: if eighty percent of the respondents strongly prefer a low price to a high price in the case of a consumer durable, does this mean that eighty percent of the consumers would reject a highly priced alternative in an actual buying situation?

In this paper we introduce the magazine test as an instrument to faciltate the interpretation of conjoint-analysis results. The magazine test is a purchase simulation. The alternative chosen in the purchase simulation can be used to detect artifacts in individual part-worth utilities. To test the contribution of the magazine test, a comparison is made between choices in the magazine test and those in an actual purchase situation. From the empirical test of the magazine test, it becomes clear that this instrument does facilitate the interpretation of the part-worth utilities of the attribute price, but that, nevertheless, further improvements can be obtained.

TIME PRESSURE AND THE APPLICATION OF DECISION RULES: CHOICES AND JUDGMENTS AMONG MULTIATTRIBUTE ALTERNATIVES

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The effects of time pressure on decisions and judgments were studied and related to the applicability of decision rules to data collected in a multiattribute decision task. The decision alternatives were student candidates described by their high school grades in Swedish, Psychology and Natural Science. The subjects were asked to choose candidates that they thought would be more able to follow a university program and graduate as a school psychologist. On the basis of earlier findings using the same kind of decision task (Svenson, Edland and Slovic, 1990; Edland, 1992) it was hypothesised that subjects under time pressure will choose more candidates having the maximum grade across all attributes than the subjects with no time pressure. Furthermore, it was hypothesised that the subjects under time pressure will focus more on the most important attribute and choose the alternatives being best on that attribute. The results supported the hypotheses.

INVERSE SCENARIO: REASONING BACKWARDS ON THE DANGEROUS OUTCOMES OF POLITICAL PROCESSES

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An extended survey was made on the occasion of the first free general election in Hungary in 1990. We were interested in the judgements of political concepts and tried to reveal the complex political thinking of university students. Among others we applied scenarios (in the internal sense, Kahneman & Tversky, 1982; Biel & Montgomery, 1989) and a methodological novelty, which was called as "reasoning backwards". Scenario analysis starting from the present state of the world studies the person's anticipations of the future states and gives the causal chains between the starting conditions and the possible outcomes. This procedure typically results in rather cascades than nets with positive time direction. We propose a procedure, where starting from the possible outcomes (in this case the possible most dangerous outcomes of the Hungarian political system change) we tried to reveal the causal chains among the events, conditions, etc. and to gain cascades or nets with negative (reversed) time direction.

A comparison was made between the results of scenario analysis and reasoning backwards technique, and some typical differences could be demonstrated. In the case of the reasoning backwards there were more interconnections among the cascades than we found in the case of the scenarios, thus the results of the new method can be considered as rather nets than cascades.

On the basis of the results of the scenario analyses and the reasoning backwards techiques a complex model of the causal thinking could be elaborated with reach connections among the events and the conditions.

Desirability and Hindsight Biases in Predicting the Results of the 1992 Israeli Parliamentary Elections;

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The 1992 Israeli Parliamentary Elections provided a valid ecological setting to study two robust judgment biases: (i) The desirabilit bias, i.e. the existence of a positive relationship between political preference and expectations regarding the elections (e.g. Babad & Yacobos, 1993). (ii) The Hindsight Bias, i.e. people's tendency to exaggerate what could have been anticipated in forshight (Fischhooff, 1983).

Three weeks before the 1992 elections to the Knesset, the Israeli parliament, 250 students were asked to predict the election outcomes. In addition, they rated their confidence in the predictions and their degree of identification with each of six political blocks participating in the elections. These data were used to test the existence of a desirability effect and to compare two alternative explanations: Wishful Thinking / Bandwagon and Social Interaction. The respondents' political identification was positively correlated with their predictions for three of the six blocks. However, with one exception, this relation vanished when the respondents' predictions for their favorite block were eliminated. We conclude that the relation between political identification and the election predictions reflects primarily bias due to selective Social Interaction.

Three weeks after the elections, the same subjects were asked to reconstruct thier original predictions of the results. The reconstracted predictions were much closer to the actual outcomes than the original predictions, across all political blocks, revealing a significant hindsight bias.

Essentials of symbolic decision theory

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At SPUDM83 I surveyed knowledge based frameworks for decision support systems, contrasting these with methods based on classical expected-utility theory. While recognising the promise of knowledge based methods I concluded that they were weakened by their failure to incorporate a well-understood decision theory. The expected utility model, on the other hand, provides a well-understood, normative theory for evidence assessment but it does not address important problems in practical decision making, such as deciding when decisions should be made, how a decision should be structured, and how a decision may be taken in the absence of quantitative data.

This critique stimulated a concerted attempt to develop a theory which would address these issues, and unify knowledge based and numerical approaches. Clark et al presented a progress report at SPUDM 89, using medical decision making to illustrate methods for hypothesis formation, decision structuring, and semiqualitative evidence assessment. Since then the theory has been extended and refined, and given a formal mathematical foundation within the framework of *Labelled Deduction Systems* (LDSs).

LDSs offer a general framework for formalising reasoning systems. In essence, reasoning is viewed as a two-step process in which (1) information is linked to competing interpretations and (2) the links are "flattened" to determine which interpretation to accept. Our system, ***LA***, is a LDS for applying knowledge in the construction and justification of *arguments* for and against decision options (hypotheses, actions) and methods for combining arguments to determine the preferred option. ***LA*** formalises a number of intuitively familiar reasoning strategies. Classical logic, probabilistic inference, and other quantitative and qualitative reasoning methods, can be viewed as special cases of argumentation.

In most decision frameworks the space (of evidence and options) in which the decision is to be taken must be pre-defined, usually by a human decision analyst. A feature of ***LA*** is that it yields a method for progressive, automated construction of the decision space, as information is acquired. Other *autonomous* decision making techniques which are under development include methods for reasoning about when decisions are needed; reasoning about the application of different classes of knowledge, and determining whether decisions are "safe". The concepts of autonomous decision making may offer a useful advance for understanding human decision making behaviour and for engineering decision support systems.

The foundations of symbolic decision theory will be reviewed, addressing questions of normativeness and the possible role of the theory in psychological studies of decision making.

Demonstration

Symbolic decision theory is being used in a number of projects in medicine and elsewhere. The DILEMMA project of the European Community's *Advanced Informatics in Medicine* programme is evaluating it in decision technology for general medical practice, oncology, cardiology and shared care. Time permitting, the benefits of the symbolic approach will be illustrated with software developed for DILEMMA.

INTEGRATION AND SEGREGATION OF PRIOR OUTCOMES IN RISKY DECISIONS

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Rather than being isolated choices, decisions often form part of a sequence. When the utilities of prior outcomes in such a sequence are experienced, they are sometimes integrated with, sometimes segregated from the predicted utilities of the outcomes of the current decision. A number of factors accounting for whether integration or segregation occurs have been disentangled in previous research. A study was conducted to test the prediction based on a version of "hedonic editing" (Linville & Fischer, 1991; Thaler & Johnson, 1990) that prior losses are integrated with gain outcomes whereas prior gains are integrated with loss outcomes. In one within-subject condition 32 undergraduates participating in the study used rating scales to evaluate the option not to gamble respectively the loss and gain outcomes of mixed gambles (race track bets), in another condition they expressed their willingness to chose the gamble. The ratings of the gambles were in one between-subject condition performed for no prior bet, a prior loss, or a prior gain. In a second between-subject condition subjects instead gained or lost the same amount of money without betting. In analogy with previous findings (e.g. Tversky & Griffin, 1991), due to a contrast effect weaker integration was expected when both events were outcomes of race-track bets than when they were unrelated. The results showed that choices were largely consistent with the evaluations of options/outcomes, and that, as expected, prior gains were integrated with current loss outcomes and prior losses with current gain outcomes. However, no clear evidence of the predicted contrast effect on integration was obtained. Furthermore, there were some unexpected effects on the evaluations of the options/outcomes suggesting that subjects differentiated the options more than predicted.

WHEN ARE PEOPLE MORE OVERCONFIDENT IN THEIR OWN DECISIONS THAN IN THOSE OF OTHERS?

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A medical scenario was used as a frame to study the effects of formulating a decision on confidence in its efficacy. Controllers (doctors) made decisions (about drug dosages) to bring output (a diagnostic index) of a dynamical system (a simulated patient) into a target range (corresponding to health). Each controller was paired with an observer (a nurse). After each decision, both subjects in a pair independently estimated its probability of being effective. In previously reported work, we have shown that both controllers and observers are overconfident in decision efficacy but that overconfidence is lower in observers.

In later experiments, we have asked the observers to make treatment decisions as well. These decisions were also assessed by both subjects. Observers' decisions were not implemented but we could calculate the effects that they would have had if they had been implemented. Under these conditions, observers and controllers no longer differed in their overconfidence in controllers' decisions. However, overconfidence in the observers' decisions was greater in observers than in controllers. This pattern of results was maintained when the observers' decisions were made before rather than after those of controllers and when the observers' status was made higher (consultants) rather than lower (nurses) than that of controllers.

The asymmetry in the way controllers' and observers' decisions were assessed may have arisen because subjects were only given feedback about the effects of implementing the controllers' decisions. Hence, we ran an experiment in which subjects were also informed of the effects that the observers' decisions would have if they were to be implemented. Both controllers and observers were now more overconfident in their own decisions than in those of their partners. Also, observers were just as overconfident in their own decisions as controllers were in their own decisions. Thus, subjects' levels of overconfidence were not influenced by whether or not their decisions were implemented.

Buying/Selling Price Preference Reversals:

Preference for Environmental Changes in Buying versus Selling Modes

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Many studies have shown that the most people are willing to pay to obtain an object often is significantly less than the least they will accept to relinquish the object (i.e., selling prices tend to be higher than buying prices). Most tests of the buying/selling price discrepancy have elicited values either for everyday market items (e.g., mugs, candy bars) or for environmental changes (e.g., a decrease in air quality, a landfill clean-up). The literature indicates a possible interaction between buying/selling prices and commodity type; buying/selling price differences seem greater for environmental improvements than for market items. In other words, people show more relative preference for environmental improvements in selling modes than they do in buying modes. A significant difference in preference due to elicitation mode is commonly termed a "preference reversal".

The four experiments presented here establish a new preference reversal and examine the reasons for it. The results from these studies provide information about the nature of preference reversals, the valuation process as a whole, and the unique problem of valuing complex and risky items such as environmental changes.

STRATEGIES IN DYNAMIC DECISION MAKING: DOES LEARNING OF HEURISTIC STRATEGIES BY INSTRUCTIONS AFFECT PERFORMANCE ?

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Within research on dynamic decision making, several studies have reported about a special ability among some subjects when subjected to systems characterized as complex, opaque and dynamic. This ability has been referred to as heuristic competence, i.e. a general competence for coping with complex, dynamic systems. The concept of heuristic competence has two important implications for research on dynamic decision making. First, those subjects who possess such an ability, seem to be able to organize their behaviour in a better way. Second, it suggests a strategy for approaching the task which will improve one's chances to understand and control the particular system. The aim of the present study was to investigate whether the behaviours associated with heuristic competence were possible to convert into naive subjects through heuristic instructions. Subjects in three experimental groups were subjected to the moro–system, i.e. a microworld frequently used within the research paradigm. Two groups of subjects received instructions with two different heuristic strategies emphasizing either a systematic – elaborate approach (SEI), or a goal – planning approach (GPI). A control group (GI), received a general instruction of the kind used in earlier experiments with Moro. The results showed that the SEI–group had the overall best performance and that the subject's behaviours were altered according to the a priori hypothesis. In the GPI–group, subject's performances were not as good compared with the SEI–group, but still much better than for the control group. It thus seems possible to have people to act according to heuristic instructions and that this often leads to a better performance. Further, the results of a post–experimental form assessing the task knowledge of the subjects suggest that the reason for the improvements should be sought for in terms of better models of the system within the subjects in the SEI–group and in terms of redundancy, leading to a better orientation in the system for the subjects in the GPI–group. A framework within which it is possible to develop a theory for strategies in complex, dynamic systems is proposed.

Do experts use unconscious decision rules and how they do it?

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According to H. Simon's estimation (H. Simon, 1978) after 10 years work in the field, good experts possess big knowledge: 20-50 thausands situations. How do experts use this knowledge in the process of solving a particular task?

This problem is under investigation in the paper for the case of classification tasks. Classification tasks are typical for the everyday work of a physician, an engineer, a geologist, and so on.

Previous experiments with lay-people (O. Larichev & H. Moshkovich, 1988) demonstrated that in the process of solution subjects use so-called structured information units (SIU). SIU are something like patterns for the comparison in the process of classification.

The recent experiments have been undertaken during the construction of expert's knowledge base using CLASS system (Larichev et al., 1991). Preliminary results are:

1.The experts also use SIU in the classification task. Unlike the lay-people, experts possess a relatively small number of complex SIU.

2.The experts use SIU unconsciously (J. Kihlstrom, 1987): they do not realize the fact of SIU utilisation and they can not verbalize the majority of decision rules. The real decision rules and SIU can be found only by detail analysis of the output of experts work.

The connection of the results with previous hypotheses is discussed in the paper.

CONDITIONAL PROBABILITIES AND THE THREE BOXES PROBLEM

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The three boxes problem (and the analogous three prisoners problem) is such a counterintuitive probability puzzle for most of the subjects, both naive and expert in statistics (Bar-Hillel & Falk, 1982; Falk, 1992; Mosteller, 1965; Shimojo and Ichikawa, 1989), that it has been presented as a piece of evidence of the irrational nature of human intuitive reasoning (Piattelli-Palmarini, 1993). The problem requires the computation of the posterior probabilities to find a gift in one (A) or in another (C) of two sealed boxes, given the evidence that a third box (B) is empty. Most subjects judge that the two probabilities are equal, ignoring the fact that the evidence (opening the empty B box) has different likelihoods of occurence as a function of the presence of gift in one of the two other boxes. According to our interpretation, the apparent paradoxical nature of the problem and the erroneous solutions produced by most subjects, depend on the failure to consider these likelihoods, due to the problem presentation, rather than on a supposed counterintuitive nature of Bayesian solutions to probability problems. In Experiment 1 we showed that the majority of subjects (60% to 73%) were able to compute the indicated likelihoods. In Experiment 2 we showed that most of the subjects who solve the problem requiring the computation of the likelihoods were also able to solve the original problem, at a significantly higher rate than subjects in a control condition. These results will be discussed with reference to the current debate on the probabilistic reasoning abilities of naive people.

Chunking-by-Similarity Model: Empirical test

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The Chunking-by-Similarity Model is a computer simulated model of multidimensional decision making. It predicts the process of decision making in detail. In Phase 1 of the process the decision maker is assumed to construct an evaluation for each alternative. A Chunking-process based on the similarity between the alternatives selects the short list of alternatives which is processed further. A top-alternative test (also a chunking process) tests whether at the moment there is one alternative which is distinctly better than all others. If the short list consists of maximally two alternatives, Phase 2 begins. If a top alternative exists, it is evaluated on the remaining relevant dimensions. Whenever possible, in this phase negative aspects of the top-alternative are neutralized. If no top alternative exists, the Weighted-Pros-heuristic is applied with the two alternatives in the short list.

A first series of qualitative simulations replicated the most stable results from multidimensional decision theory, as summarized in Ford, Schmitt, Schechtman, Hults & Doherty (1989).

In order to get more detailled data for a test of the model two experiments were performed. In the first experiment, 8 subjects had to make 8 decisions. Independent variables were the number of alternatives (2, 5, 8, 11) and the number of dimensions (4, 10). For each subject the weighths of the dimensions were measured individually. Dependent variables are: chosen alternative, percentage of used information, measures of information acquisition patterns.

In experiment 2 (24 subjects) the similarity of the alternatives was varied as independent variable.

Data from the experiments are compared quantitatively to simulated data, which were produced with the simulation program for the Chunking-by-Similarity model. The same dependent variables as in the experiments are computed from the simulated data.

At the time of writing this abstract (February 1993), data analysis has just begun. First results are encouraging: In experiment 1, the Chunking-by-Similarity Model predicts 80% correct choices in tasks with more than two alternatives, whereas the Additive-utility-Model predicts only 70% correct choices. In tasks with 2 alternatives the predictions of the model are 100% correct.

Post decision processes in human decision making
The significance of attribute importance

Nils Malmsten, Ph.D.-student

In a multiattribute decision task the subjects were asked to choose between two different types of batteries. Subjects rated how important each of the four attributes describing the two decision alternatives were for their decision. Twenty-four hours later, the subjects were asked to rate the attractiveness of the alternatives and importance ratings of the attributes were collected again. The results were related to Differentiation and consolidation theory (Svenson 1992) and indicated post decision consolidation processes. To specify, the choosen alternative was in retrospect considered to be more attractive than when the decision was made. Based on earlier findings it was hypothesized that the degree of post decision consolidation should be greater on the two most important attributes. The result supported this hypothesis.

THE EFFECTS OF CHANGES IN DIFFICULTY ON CALIBRATION: WHERE IS THE LOCUS OF THE BIAS?

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The locus of the overconfidence bias and the hard/easy effect observed in studies of probabilistic judgment is currently the focus of considerable debate. Authors favouring an ecological approach to the issue have attributed the bias to the test materials. They claim that when test materials are selected, rather than randomly sampled from a particular domain, an apparent bias is induced in subjects because the materials are not representative of their natural environment. In contrast, authors favouring a Bayesian approach attribute the bias to irrationality located within individuals, in the sense that they behave in a sub-optimal manner relative to Bayes' Theorem.

We will report the results from two experiments, both employing a computer simulation of a medical decision-making task. Subjects were asked to decide whether or not a drug had led to a change in white blood cell count in a series of patients. The data from each patient was presented as a time series plot of cell count against days, and subjects had to express their confidence (from 0% to 100%) that a change in the mean of the series was present. We manipulated task difficulty in two ways; in the first experiment by changing the size of the drug effect holding base rate constant (at 50%) and in the second by changing the number of trials on which an effect was present whilst holding discriminability constant. In both experiments, the times series were randomly generated so as to be representative of the stimulus domain.

The results supported the Bayesian approach, and provided no support for the ecological approach. Despite the fact that the stimuli were not selected, an overconfidence bias and hard/easy effect were observed. Changes in base rate also led to systematic changes in calibration performance, indicating that subjects ignored the base rate information provided. Proponents of the ecological approach might argue that although the stimuli were randomly selected, the task was novel to the subjects, and therefore not representative of their natural environment. To investigate this possibility, we hope to report the results from an experiment examining the effects of prior experience of the stimulus materials on calibration performance in this task.

FIELD AND LAB STUDIES OF EXPERTS' PERFORMANCE IN DIAGNOSTIC TASKS

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There can be different formulations of expert classification tasks: nominal classification or diagnostic tasks and ordinal classification or ranking tasks. While decision makers' abilities in ordinal classification tasks were thoroughly investigated, less attention was paid to diagnostic tasks peculiarities.

This study analyzes the experts' abilities to make consistent judgments while solving different types of diagnostic problems in both field and laboratory settings. Both types of experiments included medical diagnostic problems with different level of complexity, solved by experienced physicians.The obtained results clearly indicate better experts' achievements in solving diagnostic problems in comparison with ranking problems.

A special descriptive model which explains these differences, is proposed. It is based on two dichotomies: differentiation of decision making problems between unique and routine ones, and differentiation between tasks with subjective and objective models. Our studies indicate that in diagnostic problems, which usually can be considered as more objective and routine ones, experts use different type of rules than in ranking problems.

The possibility to use these peculiarities while developing and implementing decision support and expert systems is discussed.

Controlling Real Time Dynamic Environments: Relevant Task and Person Characteristics

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What are the characteristics of the environment and of the decision maker which are important for the control of real time dynamic decision making (RT-DDM) environments? In two studies Fire Chief, a computerised microworld generator, was used to create realistic dynamic decision making scenarios. Subjects assumed the role of a chief fire control officer responsible for deploying various firefighting appliances to control the spread of forest fires.

Study 1 investigated (a) the extent which engaging in a series of Fire Chief tasks allows for the reliable assessment of decision performance, behaviour, and experience and (b) the extent to which these task environments are sufficiently sensitive to reveal meaningful and consistent individual differences in such person factors. Subjects were administered five consecutive trials using one task scenario. Each trial automatically generated data on overall performance and on micro-aspects of decision behaviour such as the timing and the type of decision. Self-reports were obtained on a variety of on-task motivational and affective experiences and on global decision making styles. Although a high level of consistency was found from trial to trial in both overall decision performance and in more micro aspects of behaviour and experience, significant within-subject variability in overall performance was observed over the five-trial sequence. Among other findings, those subjects whose performance changed the most, whether up or down, were more motivationally and affectively engaged in the task. Performance and changes in performance, however, were unrelated to self-reported competence and flexibility in real-life decision making.

Study 2 exploited the Study 1 findings to investigate (a) the extent to which decision performance, behaviour, and experience are sensitive to experimental manipulation of the decision making environment and (b) the extent to which individual differences reflect the operation of stable person characteristics. The task scenario used in Study 1 was varied to create a completely crossed factorial combination of the following complexity dimensions: rate of change, number of variables, and number of competing goals. A within-subjects design was adopted and data obtained, as in Study 1, on on-task performance, behaviour, and experience and on global decision making styles. Field dependence and a range of personality traits were also assessed. Among other findings, significant performance effects were obtained for all three task complexity dimensions, with that for rate of change and goal structure being (a) interactive and (b) in theoretically unexpected directions. Although significant performance effects were not obtained for many of the person characteristics assessed, field dependence was found to be negatively related to performance. Several theoretically predicted interactions between person and task characteristics were examined and impulsivity, but not extraversion, was found to be associated with poorer performance under slow conditions. We discuss the implications of these and other findings for the theoretical understanding of the control of dynamic systems.

THE ADDITIONAL VALUE OF RELATIVE RISK APPRAISAL COMPARED TO ABSOLUTE RISK APPRAISAL.

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In the past decade research on relative risk appraisal, i.e. appraisal of own probability as compared to the probability for a similar other, has revealed a considerable optimism: people tend to expect that controllable negative events will happen to others and not to themselves. In the literature this phenomenon is reffered to as "unrealistic optimism" (Weinstein, 1980). Some researchers argue that this optimism or perceived invulnerability could hinder behavioral change or the adoption of preventive action. The present paper deals with the issue whether relative risk appraisal has an additional value to the measurement of (in)vulnerabilty or that absolute risk appraisals are sufficient operationalizations of (in)vulnerabilty.

To validate this question we looked into the relationship between risk appraisal and expectations of preventive behavior. Based on previous research we expected that these behavioral expectations would be taken into account to appraise absolute and relative risks: more preventive expectations are related to lower absolute risk appraisal and more optimistic relative risk appraisals. We expected that this relationship would be stronger for absolute risk appraisal than for relative risk appraisal. Moreover, we hypothesized that relative risk appraisal would not be related to behavioral expectations if the absolute risk appraisal was partialed out.

In study 1 ($\underline{N} = 80$) absolute and relative risk appraisals were assessed for ten negative events. For three of these events behavioral expectations were assessed by four different preventive behaviors for each event. Results showed that (1) absolute and relative risk appraisals were related, (2) across and within subjects the absolute risk appraisals were stronger related to behavioral expectations than the relative risk appraisals, and (3) relative risk appraisals were no longer associated with behavioral expectations if absolute appraisals were partialed out.

In a second study ($\underline{N} = 450$) we also examined the role of appraising the absolute risk of similar others. Following a similar design as study 1 the results indicated that (1) own and other's risk appraisals were related, and (2) own absolute risk appraisal was much stronger related to relative risk appraisal than the absolute appraisal of others' risk. The other results were in accordance with the results of study 1.

Both studies support the conclusion that relative risk appraisals do not significantly add to the measurement of (in)vulnerability. In addition, study 2 demonstrated that assessing the risk of a similar other has a minimal impact on relative risk appraisal indicating the importance of own risk as a starting-point in both absolute and relative judgements.

Managers' intuitive understanding of their decision making and its relevance for decision skills training.

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There is a large body of research indicating that the quality of human decision making is limited in important and predictable ways. Errors and biases have been catalogued and demonstrated in both laboratory and real world situations. As our understanding of these limitations increases, there is a corresponding increase in potential for developing training courses designed to help people recognise and overcome them. Recently, there have been several texts on training decision skills (Russo & Schoemaker, 1990) and a successful stream on teaching decision making at the recent Judgement & Decision Making Society meeting. The academic research that underpins these courses considers human decision making in terms of concepts highlighting structure and process. In contrast, our experience suggests that people reflect on their own decision making in a different way, using concepts highlighting such aspects as content and outcome. Einhorn (1980) argues that learning to make better decisions requires people to focus on structure. This mismatch between ways of representing decision making is, at best, likely to reduce the efficiency of courses. At worst, it will make the course appear irrelevant, and lead participants to reject the procedures for improving decision making. This problem is particularly acute for the short courses we are interested in developing, since there is insufficient time to allow participants to develop new ways of conceptualising their decision making. The present study uses Kelly's repertory grid technique to understand better the ways in which managers conceptualise their decision making. This technique allowed us to identify the dimensions used by managers to construe their decision making and the extent to which this could be matched with the language and content of procedures and programmes for improving individual decision making based on decision research. Initial analysis revealed a wide range of constructs used by the managers, though some were common to most individuals e.g. individual/group, time pressured/not time pressured. Categorisation of constructs revealed many more related to the content and outcome of decisions and few related to structure and process. In the second part of the study, 'laddering' is being used to identify the core constructs for each individual and to use these to develop a set of concepts around which courses can be constructed. In addition to providing a sound basis for developing training in decision making, the research reveals some interesting and important differences between practising managers and academic decision researchers in terms of their conceptions of the nature of human decision making. These differences and their implications are explored in the final part of the paper.

The feasibility of self-coding versus experimenter-coding as a tool for analyzing clinical decision-making

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This study focused on the validity and reliability of the Coding System for Protocols of Clinical Conferences (CSPCC), a coding system for the evaluation of clinical team decision-making. This system, developed by the present authors, enables a reliable and sensitive analysis of clinical team decision-making, as was reported at SPUDM 12 (De Bruyn, 1990).

What remained to be demonstrated more directly was congruence between experimenter-coding of the team decision-making process and the intentions of the team members themselves. This investigation was inspired by a recent publication by Stephens and Russo (1992), in which the authors concluded that self-coding of prompted internal reactions to a TV commercial proved more feasible (i.e. more reliable and more predictive of post-advertisement attitudes) than experimenter-coding. In view of these findings, the present authors evaluated the feasibility of self-coding in analyzing clinical decision-making.

CSPCC-coding of the verbatim protocols of team decision-making conferences resulted in main category codes (Complaint Formulation, Problem Definition, Diagnosing, Indication for Treatment, Other) being assigned by the experimenters to each line of the protocols (Condition 1) . In Condition 2, directly after the clinical conference team members were interviewed on their intentions relating to each of their contributions to the decision-making process. These interview data were in turn converted into CSPCC main categories by trained coders. In Condition 3, the actual team members were instructed to code each of their remarks by means of the CSPCC, again immediately following the clinical conference.

The results indicate a high level of agreement between conditions 1 and 2, in contrast to a lesser agreement between conditions 1 and 3. Based upon these results, the authors suggest that self-coding is less feasible than experimenter-coding. This suggestion is in contrast with the abovementioned conclusion of Stephens and Russo (1992). The present authors hypothesize that the feasibility of self-coding versus experimenter-coding depends on at least four factors: a) whether the prompted material is a response to self- or other-produced stimuli; b) the formal language of the coding-data (numerical versus verbal); c) the scope of the coding-data (affective or valence oriented), and d) the complexity of the coding system.

EVALUATING AND BUDGETING WITH INSTALMENT CREDIT: AN INTERVIEW STUDY

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This paper examines the role of instalment credit in personal budgeting, and the way people evaluate it. Evaluation is considered in terms of two important theoretical notions: discounted utility and psychological, or mental accounts. The problem is considered from a dynamic decision making perspective: personal budgeting is characterised as an example of a dynamic decision problem where the goal is to control the balance of income and expenditure over an indefinite time period.

An empirical study is reported, in which mature adults were presented with current advertisements for in-store credit. These were the focus of interviews aimed at eliciting people's spontaneous evaluations, and their views on the role of instalment credit in personal budgeting. A systematic content analysis of the responses has been carried out. This revealed a number of ways in which a psychological accounting perspective furthers our understanding of attitudes and preferences regarding instalment credit. For example, the analysis showed how mental accounts help people to anticipate and evaluate the future consequences of their credit choices.

Fiinally, the application of the above theoretical framework to consumer policy is discussed, with respect to the information that should be provided to consumers for informed credit choice.

Improving the Accuracy of Group Judgment: Collective Performance that Excels Individual Achievement

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Interacting groups fail to make judgments as accurate as those of their most capable members due to problems associated with both interaction processes and cognitive processing. Group process techniques and decision analytic tools have been used with groups to combat these problems. While such techniques and tools do improve the quality of group judgment, they have not enabled groups to make judgments more accurate than those of their most capable members on tasks that evoke a great deal of systematic bias. A new intervention procedure that integrates group facilitation, social judgment analysis, and information technology was developed to overcome more fully the problems typically associated with interaction processes and cognitive processing.

The intervention was evaluated initially by testing the hypothesis that groups using this new procedure can establish judgment policies for cognitive conflict tasks that are more accurate than the ones produced by any of their members.[1] An experiment involving two cognitive conflict tasks and 16 four- and five-member groups of unpaid participants was conducted to compare the accuracy of group judgments with the accuracy of the judgments of the most capable group member. Results indicated that the process intervention mediated by volunteer facilitators enabled 13 of the 16 small, interacting groups to outperform their most capable members; group policies were significantly more accurate than the best individual policies ($p < .05$).

The proposed paper will review this study and present the results from a second, on-going investigation intended to replicate and extend the previous research findings by employing two new cognitive conflict tasks, a staff of professional group facilitators, and a different population of paid participants with monetary incentives for successful groups.[2] Altogether 24 groups sessions are being convened, 12 for each task. As before, the research hypothesis is that the integrated use of an external facilitator, a decision model, and information technology will improve interaction processes and cognitive processing, so that collective performance is significantly better than the most proficient individual members.

[1]This study by Patricia Reagan-Cirincione is soon to be published in *Organizational Behavior and Human Decision Processes* under the title "Improving the Accuracy of Group Judgment: A Process Intervention Combining Group Facilitation, Social Judgment Analysis, and Information Technology."

[2]This research is supported by a grant (IRI-9122447) from the National Science Foundation's Program for Information Technology and Organizations.

STOPPING POLICIES IN SEQUENTIAL DECISION MAKING

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In multi-attribute choices, decision makers typically do not search the full attribute space. Rather they sample information until they feel they have collected enough to make a choice. In our sequential decision making task, a decision maker acquires information one attribute at a time (across all competing alternatives) and decides whether enough cumulative discrimination among the alternatives has occurred to permit a choice.

Using a computer interface, we investigated the stopping rules that subjects use in deciding when to stop sampling additional information. The amount of information that a subject has requested prior to making a choice is recorded, as is the final cumulative confidence in favor of the chosen alternative. For 8 of the 12 subjects, there was a declining trend in the cumulative confidence at the stopping point as the number of attributes sampled increased. In other words, the longer subjects waited before deciding in terms of number of attributes acquired, the lower the confidence threshold required for stopping. This is contrary to the constant threshold proposed by Aschenbrenner, Albert and Schmalhofer (1984, Acta Psychologica) in their formulation of the criterion-dependent choice model.

During post-experimental debriefing, the following stopping heuristic was mentioned by several subjects: stop and choose the favored alternative immediately after the last of a core set of most important attributes has been seen. We call this the "core attributes" heuristic.

THE SIGNIFICANCE OF NEED FOR JUSTIFICATION FOR RESPONSE MODE EFFECTS

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An experiment will be presented that tested the effects of implicit and explicit need for justification on information processing and decision strategies. Two hypotheses which have been put forward to account for response mode effects (e.g., choice vs judgment) refer to the importance of justification processes. Slovic, Fischhoff & Lichtenstein (1988) assume that in choice, justification processes play an important role, but less so in judgment. They relate this to the prominence hypothesis (Tversky, Sattath & Slovic, 1988) which states that more important attributes weigh more heavily in choice than in judgment. As a consequence, choice can often best be explained by a lexicographic decision rule whereas judgments are rather based on trade-offs. Since a lexicographic procedure is easy to apply and to justify, it is likely to be selected in a choice task.

Another approach that takes a similar view is the Differentiation and Consolidation Theory by Svenson (1992). Svenson assumes that a decision is preceded by differentiation processes from which one alternative is to emerge as so much better that the decision can withhold future threats. After the decision, consolidation processes follow which serve to maintain or increase the achieved degree of differentiation. According to Svenson, choice is associated with a higher degree of commitment than judgment, therefore the necessary degree of differentiation is higher and differentiation and consolidation processes will be more pronounced.

Need for justification as postulated above is implicit and needs to be distinguished from an explicit need for justification that is the result of explicitly asking a person to justify a decision later. For explicit need for justification, there are indications that it has an effect contrary to that assumed by the prominence hypothesis. Knowing that a decision has to be justified, results in more use of compensatory strategies and more information considered (Billings & Scherer, 1988).

The effects of implicit and explicit need for justification on information processing were tested in a process-tracing study that used information boards (Payne, 1976). Subjects had to choose, select, reject or judge summerhouses. These response modes were hypothesized to induce different degrees of implicit need for justification. In addition, explicit need for justification was manipulated by either telling or not telling subjects that they had to justify their responses later. To test for differentiation and consolidation processes, partial utilities and weights were elicited three times, before, immediately after, and one day after the respective task.

ANALYZING THE PERFORMANCE OF EXPERT JUDGES : AIDS TO JUDGMENT AND COMPONENTS OF SKILL

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The performance of expert judgement depends jointly on a) the system about which judgments are made, b) the information system that brings data about the environment to the expert, and c) the cognitive system of the expert. Judgmental performance can be decomposed into seven components: environmental predictability, fidelity of the information system, reliability of information acquisition, reliability of information processing, match between environment and forecaster, conditional bias, and unconditional bias. This paper examines the relation between these components of performance and a number of judgment aids that have been proposed in the literature. It is argued that methods designed to improve one component of performance (e.g., bias) can have important positive or negative effects on other components. A framework for selecting and evaluating aids to judgment is proposed.

The effect of response mode on structural modelling results

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In this paper two structural modelling approaches to study preference formation are compared. The two approaches are conjoint analysis (Green & Srinivasan, 1978, 1990; Wittink & Cattin 1989) and the multinomial logit model (Louviere 1988a, 1988b; Louviere & Woodworth, 1989; Louviere & Timmermans, 1990; Timmermans, 1984). Both approaches take as a starting point objects which are systematically varied in their attributes (the independent variables). The dependent variable in conjoint analysis is a preference ranking or rating. In the case of a multinomial logit model, on the other hand, it are choice data. It is expected that both structural modelling approaches give the same estimates of the relative importance of an attribute in preference formation (Elrod, Louviere and Krishnakumar, 1992).

On the other hand, research regarding procedural invariance (Payne, Bettman & Johnson, 1992) indicate that different response modes can lead to differential weighting of attributes and different preference assessments (Westenberg, 1991). The main objective of this study is to compare both approaches on the basis of two research question:

1. Is a non-compensatory structural model a better approximation of preference formation in the case of choice data and is a compensatory structural model a better approximation in the case of preference data?
2. Are the ranking of the estimated relative importance of attributes similar regardless the approach used (conjoint analysis versus multinomial logit model) to estimate them.

In order to answer the second research question preference and choice data should be gathered. But it is very hard to answer the first research question on the basis of these preference and choice data. First of all, the linear additive model (which is a compensatory model) is a very robust model (Dawes & Corrigan, 1974; Green & Srinivasan, 1978; Curry & Faulds, 1986; Johnson, Meyer & Ghose, 1989; Stokmans, 1991). Consequently a linear additive model has almost always the best fit. Furthermore, the number of objects needed to estimate structural models is extremely large if no restrictions are made regarding the model which describes the preference formation best (Anderson, 1981). Consequently, process-tracing data (gathered by means of a computer-based information display board) which specify the sequence of transitions, are used to determine whether a compensatory or non-compensatory rule is used during preference formation. Results will be discussed in the light of the two research questions stated.

EFFECTS OF MEMORY AND JUSTIFICATION INSTRUCTIONS ON POST DECISION CONSOLIDATION

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This study explores the effects of instructions to memorize and justify a decision some time after the decision was made. The decisions were medical decision problems involving a resource allocation problem. The first experiment indicated that with no particular information about a later memory test, subjects consolidated their prior decision on the two most important attributes only. That is, in retrospect these attributes seemed to have supported the prior decision to a greater extent than they actually did. When subjects were informed that they were later going to be asked to memorize their earlier decisions, consolidation was stronger and showed up on all four attributes. In the second experiment subjects were asked to later justify their decisions. This caused a more complex response pattern involving net effects of both regret and consolidation. The results were interpreted in relation to the framework of Differentiation and Consolidation Theory.

Computer Supported Cooperative Work: New ways for group decision making

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During the last few years, a variety of computer systems have emerged under the label of 'CSCW' (Computer Supported Cooperative Work) which offer new and fascinating ways for decision support. In contrast to systems such as MAUD or Highview, they do not incorporate formal decision models or quantitative techniques, but focus on idea generation, knowledge elicitation, problem structuring, argumentation and the documention of the decision process. Moreover, they are not limited to be used by individual decision makers but provide support for decision making in *groups*.

One of these systems is SEPIA which is designed for the Structured Elicitation and Processing of Ideas and Authoring. Based on Newell's approach to complex problem solving, the system consists of four 'activity spaces' which appear as separate windows on a graphical interface each offering a specific functionality that can be used to support different activities in the context of decision making: The **content space** enables the user to store, retrieve, combine and display data or documents that might be important for a decision. The **planning space** can be used to specify and decompose the decision problem by specifying relevant issues and alternative positions. The **argumentation space** lends support for developing and visualizing argumentation structures concerning the issues and positions of the planning space. The **rhetorical space** provides a convenient text editor which can be used for annotating or for formulating the exact wording of arguments and statements.

SEPIA can be employed by individual decision makers as well as by decision groups. For group decision making, the system provides additional audio and video facilities on workstations connected by a network thus allowing real-time conferencing and simultaneous data exchange between decision makers at remote locations. In the present paper, the usage of the system will be illustrated for a specific application: the development of scenarios which are based on arguments that are derived from causal models.

A FRAMEWORK OF INFORMATION TRANSFORMATION FOR DECISION PROCESSES : A MODEL OF INFORMATION STRUCTURING AND ITS FORMALIZATION

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The author considers decision making in a wide sense, and proposes a theoretical framework for designing systems aimed at supporting decision makers throughout decision processes. The framework consists of a model of information structuring throughout decision processes (MISDP), and a formalization of the process of information transformation. This model specifies states, inputs, outputs, and transformations for each phase of the processes, and clarifies information bases (database, knowledge-bases, etc.) stored for decision making. Therefore, it can be instrumental in designing functions of supporting systems. In order to validate it earlier research results (decision analysis, structured modeling, and optimization methods, etc.) are described with the variables and transformations defined in the model. Decision Process Support Systems (DPSS) which will be implemented based on the model will provide unified supporting functions to decision makers throughout decision processes. The author also sketches a prototype DPSS which he has developped, and shows its correspondence with MISDP.

REALISM WITHIN THE INFORMATION BOARD APPROACH

Strategy use as a function of ambiguity and meaningfulness of information

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Generalizing results of information board studies to real life situations might be a problem because of a lack of realism. In our study we have tried to assess the effects of realism by varying three conditions: 1. operationalization of 'task complexity', 2. meaningfulness of the task, and 3. judgment skills of the subjects.

Information board studies have shown that an increase in task complexity leads to a reduction of the amount of information sought, which is often associated with an increased use of non-compensatory judgment strategies. In these studies task complexity usually is manipulated by information load (number of dimensions and/or options) and available decision time. However, in real life situations complexity can arise from other factors as well. One factor is the composition of information. A judgment task will be less complex when the information about each of the alternatives is unambiguous, being either positive or negative. On the other hand, a task will be more complex when the information is ambiguous, containing both negative and positive values. Note, that the operationalization of task complexity as 'ambiguity of information' leads to a different prediction. Instead of using less information the judge might require more information when task complexity increases. To assess the influence of ambiguity all subjects were randomly presented with both an ambiguous and an unambiguous task.

In real life judgment tasks the dimensions on which the options are evaluated are known. Some information board studies, however, use tasks in which the dimensions have no meaning but are only numbered (e.g. Westenberg, 1991). In order to assess the impact of this manipulation subjects were presented with either tasks in which the dimensions were numbered (meaningless) or tasks in which the dimensions were labeled (meaningful). We predicted that labeling would lead to a concentration on certain dimensions thereby increasing the variability of search.

The effect of judgment skills was assessed by using both students and professional judges (personnel selectors) as subjects. We expected the judgment strategies of these two groups to differ, although we did realize that experts working on an unfamiliar task (i.e. the information board) are no real experts any more (Shanteau, 1988).

Most of our predictions were confirmed. For instance, ambiguity of information did lead to an extended search of information. In this paper we present the results of this study. Their implications for generalizations of information board studies will be discussed.

Using proper scoring rules for eliciting uncertain knowledge

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It is common practice to use the language and concepts of probability theory for expressing uncertainty numerically. Uncertain knowledge about continuous quantities is usually expressed through **Subjective Probability Distributions (SPD's)**. Unfortunately, as we know from past research, the human being has several shortcomings in acting as an intuitive statistician. And considering the problems assessors might have interpreting (distributions of) probabilities, it is probably better to use another representation of uncertain knowledge.

The ELIcitation technique ELI is a graphically oriented interactive computer program which supports the assessment of SPD's. However, in its interaction with assessors, ELI uses a score representation of uncertain knowledge instead of its internal probability representation. This score representation is an important spin-off of the implementation of **proper scoring rules**. Scoring rules can be used for computing scores that reflect the correspondence between the assessed SPD and the value that actually occurs. ELI uses proper scoring rules for transforming SPD's into more manageable score functions. The score functions return scores for all possible actual values of the unknown quantity. In other words, score functions provide **feedforward** information about possible scores. ELI provides the assessors with several graphical displays of score functions (the score curves) and the assessors can indicate their uncertain knowledge by selecting a score curve that corresponds most closely to their subjective beliefs.

The implementation of a proper scoring rule has several advantages. First, because the scoring rule is proper, assessors are encouraged to report their honest uncertainty. Second, the score curve provides an alternative score representation of uncertain knowledge which is probably more compatible with the abilities of the human judge. Third, the visualized feedforward information on possible consequences (scores for all possible actual values) might stimulate assessors' reflection on the implications of their assessments. Fourth, with training items it is possible to give scoring-rule accuracy feedback which links up properly with the scoring-rule feedforward interpretation of the score curve.

The paper will start with a brief discussion of the development and empirical evaluation of the ELI elicitation procedure. In the remainder of the paper we will focus on the outcomes of two empirical studies in which the effectiveness of using proper scoring rules for eliciting uncertain knowledge was the subject matter of interest. The results showed that feedforward according a proper scoring rule is an effective method for improving the quality of SPD's. This feedforward approach appeared to be robust with respect to different types of proper scoring rules. A second study revealed that the ELI procedure with trial-by-trial scoring-rule feedback is an effective procedure for training the probability assessors. So, for ELI the positive effects of proper scoring rules are twofold. In addition to a positive effect of scoring-rule feedforward there also appears to be positive effect of scoring-rule feedback.

Calibration of hindsight judgments

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Hindsight bias is a tendency to react as one "*would have known it all along*" when having the benefit of outcome feedback. In a meta-analysis using data from 122 independent experiments (Christensen-Szalanski & Willham, 1991) the authors show that unusually large hindsight bias is found in studies using almanac items (The bias is almost three times larger in these studies compared to the bias in case history experiments.). Recent calibration studies (Juslin, in press; Gigerenzer, Hoffrage, and Kleinbölting, 1991) have shown that the way in which such trivia material is created has a strong effect on calibration of subjects. A sample of questions selected by an experimenter in a traditional way typically leads to overconfidence while letting the computer do the selection in an unbiased, random manner eliminates subjects' bias.

An experiment was designed to study effects of item sampling on hindsight bias in a general knowledge task. The result shows that hindsight bias generally appears in an informal sample of items, but in a random sample the effect is significantly *reversed*. Thus, when answering randomly selected items subjects react more often in an "*I would never have known that*", rather than an "*I knew that all-along*" fashion. The same items that give overconfidence in foresight also lead to hindsight bias, both phenomena are clearly related. Increasing levels of surprise was found to go together with larger bias. No significant differences in response times were found between judgments in foresight and hindsight. No hindsight effect was found on subjects' confidence ratings. Resolution of hindsight judgments improved in both conditions, implying that subjects are unable to ignore outcome feedback although this does not always lead to subjects having an unjustifiably optimistic view of their previous knowledge state. The results are interesting in that the findings of a reversed effect does not follow from any of the proposed explanations of hindsight bias.

Scenario Planning and Judgmental Probability Forecasting : Alternative Ways of Dealing with Uncertainty?

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This paper discusses scenario planning and judgmental probability forecasting. The latter has been studied extensively by cognitive psychologists and, currently, there is much debate about the conditions under which people are able to make valid judgments of probability. A current major concern is the contrast between judgemental performance in the laboratory and judgemental performance in real-world, work-a-day settings.

Subjective probability forecasts are a major input into many management technologies, including decision analysis, cross impact analysis, fault free analysis and, more recently, influence diagram adjustments to extrapolative and econometric forecasting models. However, in practice, techniques such as decision-tree analysis are seldom used by managers. By contrast, scenario planning is more appealing, on an intuitive basis, to managers concerned with improving their decision making.

This paper analyses the reasons for the intuitive appeal of scenario planning over decision tree analysis for decision making under uncertainty. Contrasts are made on the basis of 1) the axiom base of the latter but not the former, 2) the predominance of causal reasoning in the former, 3) human limitations in probabilistic thinking and 4) uncertainty being bounded across scenarios in the former rather then being assessed directly, as in the latter.

Overall, scenario planning is a technique for dealing with the future which downplays probabilistic thinking but facilitates causal thinking about the processes which lead to the enactment of future events. Scenario planning integrates easily into an iterative approach to decision making. It is a process tool, inviting rethinking of the definition of the problem and the decision options. In addition, it is effective in widening the organisational range of vision and helps alleviate the perception narrowing effect of group think. Scenario planning enables the decision maker to test the robustness of a strategy under a range of alternative futures. If no single decision option can be found which "satisfices" under all scenarios, then new decision options need to be generated. Alternatively, a plausible, "first step" decision can be taken which leaves open further decision options in the short term. We argue that it is often rational to decide not to decide now.

Perceived Risk in the Presence of a Real Traumatic Threat

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The research investigated the perceived risk of 16-17 year old Israeli adolescents in the presence of a threat of missile attacks during the gulf War. The control comparison conducted in the study was of perceived risk of traffic accidents. The level of situational anxiety and degree of pre-cautious behaviour during missile attacks were also examined. Factor analyses yielded a two-factorial structure of perceived risk. Regarding missiles, one factor signified the level of knowledge about the threat, and the second signified the dread and severity of the threat. The factor of knowledge was also found for traffic accidents but the dread factor was not as coherent and related mainly to the sense of helplessness in the hazardous situation. The level of situational anxiety in the presence of the missile threat was higher than that found under normal conditions. The degree of pre-cautious behaviour was better explained by level of situational anxiety and not explained at all by perceived risks' parameters. In a recent study conducted 15 months after the war it was found that only the dimensions of the perceived missile risk were rated differently than during the war. Two measures were used to assess the magnitude of perceived risk. The first was the Probability of Familial Harm (PFH) and the second was the Societal Risk (SR) measure. The two measures correlated significantly with each other but different aspects of perceived risk were associated to each, respectively. The theoretical significance as well as the practical implications of these findings are discussed.