*Decision Making Under Climate Uncertainty: The Power of Understanding Judgment and Decision Processes**

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On the importance of descriptive models of judgment and choice processes

The disciplines of economics and political science, as well as applied climate science, have added a great deal to our understanding of the obstacles to the use of climate information. However, in order for climate information to be fully embraced and successfully implemented into risk management, the issue needs to be looked at in terms of risk communication in human decision makers—(as) individuals and (in) groups. What is special about human risk perception and decision making under risk and situations of uncertainty regarding climate? This is where psychology, behavioral economics, and behavioral game theory offer important insights and tools to design effective risk management processes. In this chapter we first discuss uncertainty as a barrier to predictability. We review how normative and descriptive models differ in their postulates about the processes by which people predict the likelihood of uncertain events, choose among actions with uncertain outcomes, and among actions with delayed outcomes. Throughout (this paper we discuss the challenges (and possibly opportunities) that arise from the fact that decision makers employ readily available heuristics, taking advantage of memory and past experience. However, the use of heuristics can also lead to systematic biases, and (b) have multiple and oftentimes conflicting goals, as they are influenced by a range of qualitatively different incentives in their judgments, decisions, and actions. The chapter concludes with suggestions on how to overcome barriers of uncertainty by using insights from behavioral decision research in constructive ways to designing climate risk communication and effective decision environments that will be effective in achieving goals of possible policy interventions.

Uncertainty as barrier to predictability

Humans have a great need for predictability. It makes up an important part of our need for safety and security (Maslow 1943). Predictability has survival value. It provides control, helps avoid threats to physical and material well-being, and frees us from fear and anxiety. Furthermore, it allows to plan and budget for the future. However, our capabilities to predict the outcome of an action or event can be impaired when we are faced with uncertainty, i.e. situations where it is impossible to exactly describe the future outcomes of actions that are taken now. Uncertainty means that there may be unknown outcomes, unknown probabilities, and immeasurable components, leading to a real or perceived lack of control. While the term *risk* is used to describe choices between monetary lotteries, where all outcomes and their probabilities are explicitly described, as in the case of laboratory experiments (*decisions from description*, that are further discussed below), most real world decisions do not provide this level of information and involve *uncertainty* about possible consequences and their likelihoods.

[insert figure 1]

Whether perceived or real, lack of control raises anxiety, individually and socially. Moderate levels of anxiety are desirable, because they motivate behaviors to regain control, observable in protective or evasive action to mitigate risk, information search, and theory building. Science and technology development themselves can be put into this category. The development of forecasts for weather, climate, earthquakes, or financial markets are some of society's way to reduce moderate levels of anxiety about strategic sources of unpredictability.

The positive effect of feeling in control is evident in situations where our need for control is so strong that it leads to wishful thinking. We perceive an "illusion of control" (Langer 1975) in situations that are obviously determined by chance, like predicting the color that the next spin of the roulette wheel will land on. based on past outcomes, which is often described as gambler's fallacy or probability matching (expecting Heads after a run of Tails). Illusory control can have psychological benefits, as in the case of superstitious[1] rituals in sports (Schippers and Van Lange 2006). Superstitious beliefs invoked during instances of uncontrollability may prevent or interrupt subsequent performance impairment (Dudley 1999). Recent studies in health care have shown beneficial physiological effects, such as pain relief (Thompson 1981; Wager et al. 2004) and reduction of stress, and wound healing through illusory control (Alloy 1982), ((Kiecolt-

[1] We use the term superstition broadly, encompassing magic in the anthropological sense, folkloristic beliefs related to all things that are not fully understood or known, as well as in its psychological sense going back to Skinner's concept of reinforcement. Most importantly, we do not intend any value judgment.

Glaser 1995). An increasing number of studies suggest that people tend to turn to superstitious or magic beliefs and strategies when in situations of uncertainty and stress (Felson 1979; Keinan 1994; Keinan 2002; Case 2004). The illusion of control and superstition, although from a scientific point of view irrational, may be an adaptive response to an uncertain world (Haselton and Nettle 2006).

How do we learn about possible outcomes of different actions?

To enable informed decision making under uncertainty, people have two forms of information available to them: a vicarious *description* of possible outcomes, and their likelihoods and personal *experience*, typically acquired over time (see Weber 2008 for more discussion on learning (Weber 2008)). For instance, seasonal climate forecasts for the next growing season, or hurricane warnings issued by the National Hurricane Center describe outcome distributions, possible outcomes and their probabilities, provided numerically or graphically. These are either statistical summaries of the vicarious experience of others or are based on scientific models derived from past data. Yet, we also often draw on knowledge acquired by personal exposure. While in decisions from experience the outcome distribution may initially be unknown, repeated exposure and repeated choices provide us with knowledge of possible outcomes and their likelihood. It can for example lead farmers to make intuitive forecasts of climate in the next growing season based on years of past experience. Similarly, it leads people living in hurricane prone areas to an intuitive assessment of the likelihood of being affected by a hurricane based on past experience with warning symptoms and subsequent events.

The processing of descriptive, statistical summarized information and description-based decision making, require extensive use of the analytic processing system of the brain. Analytic processing involves the neo-cortex, an evolutionary newer structure found only in mammals and in expanded form only in primates, especially humans. Analytic processing is effortful, slow, requires conscious awareness and knowledge of rules, e.g., probability calculus, Bayesian updating, formal logic. It is activated during conscious calculation-based decisions (Marx et al. 2007)

Experience-based decision making relies on the use of a different part of the brain, the experiential processing system. This system is evolutionary older, hard-wired, fast, and automatic. Experiential processing relates current situations to memories of one's own or others' experience. Experiential knowledge has been acquired through trial and error learning, and associates behavior and consequences. There is an emphasis on decision outcomes (probabilities not explicitly represented). Because past experiences often evoke strong feelings, emotions are a powerful class of associations. Risks are represented as a "feeling" that serves as an "early warning system" (Loewenstein 2001). Strong emotions such as pleasure and pain, fear, anger, horror, joy, and awe associated with past events make the experience also more memorable and therefore often dominant in processing (Slovic 2002; Slovic et al. 2007).

The two processing systems interact to some extend and operate in parallel. However, if the output of the two systems is in conflict, behavior is typically determined by the experiential, affective processing system, because it is faster, delivers output earlier, and is very vivid. The discrepancy in output of the two systems often accounts for public controversies and debates about the magnitude and acceptability of risks, as it is the case of nuclear power, or genetic engineering. Technical experts and academics rely more heavily on analytic processing in their definition and evaluation of possible risks, while politicians, end-user stakeholders, and the general public rely more heavily on experiential/affective processing.

A. Predicting uncertain events: normative and descriptive approaches

Normative models (e.g., *Expected Utility Theory and Bayesian Updating*) define how judgments or decisions under risk or uncertainty should best be taken. Assuming an ideal decision maker (perfectly informed and rational, capable of high level calculations,), these models prescribe how optimal decisions *ought* to be made. Normative models have great advantages when dealing with probability updating and deep uncertainty as discussed in this volume's chapters by William Easterling and Steven Schneider respectively. Real-life observations, however, indicate that people do not behave fully rational but instead take shortcuts in their processing by applying heuristics. Theoretical approaches that try to model how people *actually* make decisions are called descriptive, and include *Prospect Theory*, *Theory of Constructed Choice, Theory of Context-Dependent Choice, and others.*

Normative Models

Normative decision theory assumes that each decision is decomposed into four components: a) a set of possible actions; b) a set of possible future states of the world; c) information on the probability of different future states of the world; and d) information about the outcomes of possible actions under future states of the world. Normative approaches to predict uncertain events address therefore the following questions: What will happen in the future? How likely is it? Although not answered by EUT, of equal importance to climate change are the questions of when will it happen? and where will it happen? Rational predictions based on models offer the answers to these questions.

What will happen?

Classical normative approaches assume that there is an observation history of past outcomes y going back in time t (y_t, y_{t-1}, y_{t-2},….y_{t-n}) that are used to predict future outcomes using regression techniques y_{t+1}, y_{t+2},… $y_{t+n.,}$, including time series analysis.

How likely is it?

Classical normative decision models assume separable outcome and probability information. Probabilities can be interpreted on the basis of relative frequencies of events in repeated trials, or as degrees of belief or confidence of a proposition. Based on a normative algorithm called the Bayesian theorem, new pieces of evidence can be incorporated into prior beliefs.[2]

When will it happen?

Traditionally, normative choice models do not include temporal and spatial components, yet in the context of climate variability and climate change time and geography matters. Climate chance predictions usually have long multi-period time horizons. A prominent

[2] Possibly here reference to Bill Easterling's chapter.

technique to make long-range predictions, for instance until 2100 and beyond, is the scenario technique. Combining different parameter constellations (highly, medium, less probable) and differing assumptions about demographic change, consumption patterns, etc., this technique is applied by the Intergovernmental Panel on Climate Change (IPCC), e.g., the IPCC Special Report on Emission Scenarios A1, A2, B1, B2; similarly the "Pileus" Project described by Julie Winkler in this volume. Given a set of assumptions about future developments of explanatory variables and given a model for the relationship between explanatory and explained variables, the time path of the explained variable is predicted (embedded in confidence bands). Different time paths can be established for the different sets of assumptions.

Where will it happen?

Traditionally, normative models do not include a spatial component, yet in the context of climate variability and change, space matters. We want to know where temperatures will increase the most, where sea level rise will have the greatest impact. Geographic Information System (GIS) models of past and present situation-specific areas of the world are combined with spatial models to make spatial predictions (again embedded in confidence bands).

By taking available alternatives of what the future states of the world and their probabilities could be, and what outcomes the different choice alternatives would have under different future states of the world, normative models offer many advantages: (a) they tell us how a rational decision maker should behave, which provides a good benchmark against which actual behaviors can be compared; (b) they have a clear analytic basis which can easily be updated; and (c) the cost and benefit of generation/acquisition of additional information can easily be assessed. However, normative models also have some weaknesses: (a) they do not explain why or how people make the decisions we observe; (b) they expect decision-makers to be fully rational; (c) they assume the decision maker to be well informed about key components of the decision problem; (d) they often assume that there is sufficient knowledge about the outcomes; (e) they assume knowledge of quantitative probabilities and ignore the use of affective reactions and other heuristic processes to assess likelihood; (f) they often consider only one individual decision-maker and not groups; (g) they do not consider the interactive process (the interactions) evolving while decisions are made; (h) utility functions of decision makers are difficult to identify; (i) they often lack a temporal and spatial components, which matter greatly in regard to impacts of climate variability and change.

In sum, normative prediction approaches are important. They help structure information requirements, help structure the decision situation, and can serve as relatively simple benchmarks. Yet, in order to make reliable predictions of how people *actually* decide, descriptive models, which integrate psychological processes into the decision model, are needed as supplements.

Descriptive Reality

Descriptions of decision making take into consideration the multiple modes by which people have been observed to make decisions, namely calculation-based, rule-based, and affect-based decisions (Weber and Lindemann 2007). They assume a combination of analytic and experiential processing of information, and take into account the different effects that personal experience and statistical summary information have on the assessment and management of risks (Marx et al., 2007).

In the remainder of this section, we address two phenomena which play out strongly in the context of decision making under climate uncertainty and climate change communication: (1) Deterministic, causal, and experiential/affective thinking is more prevalent than statistical and probabilistic thinking, and (2) people are overconfident in the accuracy of a prediction or decision.

Experiential processing to predict uncertain events makes use of heuristics, which utilize stored past experience.

The availability heuristic allows people to make likelihood predictions based on what they remember, how easily these memories are retrieved, and how readily available those memories are. Ease of recall serves as indicator of likelihood. People have been found to employ the availability heuristic when asked for probability or frequency judgments, often of a comparative type (Tversky & Kahneman, 1973). When asked to judge whether the probability of thunderstorms is greater for July or August, people will try to recall storms that they remember occurring in either July or August ("on 4th of July weekend," “around my birthday in August”). Whichever category provides more available concrete examples, or for which it feels easier to generate examples, is the one that is judged to be more likely. This rule of thumb works fairly well, because common events are easier to remember than uncommon ones. Yet not all easily-recalled events are very likely. Some events are more available *not* because they occur more frequently, but because they have taken place more recently (*recency effect*), because they have been distorted by the media, which tends to over-report catastrophic rather than chronic risks or because they are associated with strong emotions (*affect heuristic*).

The availability heuristic can play a large role in judging the probabilities of extreme climate events (for instance El Niño), because people can usually recall unusually good or bad seasons. The response to long-term climate change information is different because most of us, unless we live in Alaska or places similarly affected by climate change, have not (yet) experienced that what we associate with climate change, and cannot bring examples (whether frightening or pleasant) to mind. The availability heuristic makes us thus assume that the future will be similar to what we have experienced so far (Sunstein 2006).

Recency effect

Experiential processing gives a lot of weight to recent observations. Since rare events have generally *not occurred* recently, they are underweighted (Weber 2004)..Such underestimation of the risks of rare events based on experiential processing, may contribute, for example, to the neglect of flood control infrastructure by the federal government in recent decades. However, recency weighting also predicts that, if the statistically rare event *has occurred* in the very recent past, people will overreact to it (Hertwig 2004). This makes decisions from personal experience far more volatile than decisions based on analytic processing of statistical information. The devastation caused by the Asian tsunami or by Hurricane Katrina in the Gulf of Mexico are examples where recent rare events may have led people to overestimate the likelihood of subsequent similar events. In summary, when people base their decisions on personal experience with a risky option, recent outcomes strongly influence the evaluation of this risky option. As a result, low-probability events generate more concern than they deserve in those instances where they do occur, and less concern than their probability warrants when they haven't occurred in the recent past. Parallel to individual reactions, the media also have a tendency to over-report catastrophic rather than chronic risks, once they have occurred.

Affect Heuristic

Slovic et al. (Slovic et al. 2007) suggest that the biases in probability and frequency judgment that have been attributed to the availability heuristic may be due, at least in part, to affect. People consult or refer to a repertoire of positive and negative images associated with the object or activity at hand. Affect is linked to risk perception in many ways. Slovic and colleagues have shown that feelings of dread are linked with perceptions of risk by way of risks being seen as uncontrollable, involuntary, inequitable, catastrophic, fatal, etc (Slovic 1980). People turn to their emotions, and positive and negative images, associated with the object or decision at hand.

An aside on psychological risk dimensions

Psychological risk dimensions (Fischhoff 1978; Slovic et al. 1986) address the affective reactions to risky choice option,s which are the determinants of perceived risk. This psychometric paradigm was established through psychological scaling and multivariate analysis techniques to identify the characteristics of hazards that affect people's subjective feelings of being at risk. Affective risk dimensions influence judgments of the riskiness of material, physical, and environmental risks in ways that go beyond their objective consequences. Based on results from multiple, international studies (Slovic 1997), in which people judged diverse sets of hazards, the various hazards were reduced and combined into 2 factors: 1) dread risk and 2) unknown risk. Items grouped under the "dread risk" factor trigger our early (physical) warning systems, such as speeding up our heart rate and make us anxious (e.g., nuclear war or nuclear reactor accidents). This factor addresses whether a hazard is un/controllable, dread/no dread, not/global catastrophic, equitable/not equitable, individual/catastrophic, easily/not easily reduced, risk decreasing/increasing, voluntary/involuntary) and bears fatal/non-fatal consequences, low/high risk to future generations. Factor refers to the degree to which a hazard is observable/unobservable, an old/new risk, known/unknown to those exposed, known/unknown to science, and whether it has a delayed/immediate effect. Example of items on the top are newer technologies such as GMO technology which may have unforeseen consequences.

Weber has looked more closely at climate change within this two-factor space (Weber 2006). Following Slovic's psychometric paradigm, the psychological risk dimensions associated with climate change predict the level of alarm or worry. Assuming that people perceive climate change as a gradual process of temperature and precipitation change, and a gradual change in the frequency and severity of extreme events such as hurricanes, cold-, or heat waves, the risk would appear to be well-known and controllable (at least illusory) to those who can afford to move to safer grounds. Because the effect of climate change is perceived as delayed, many people do not (yet) perceive it as a dread. When people base their decisions on statistical descriptions about the hazard climate change, the time-delayed and abstract nature of the risk does not evoke strong visceral reactions. If climate change is depicted as abrupt/rapid and catastrophic as in the movie "The Day After Tomorrow", the potential for raising a visceral reaction to the risk is much greater (Leiserowitz 2004; Leiserowitz 2006).

As a result of cognitive biases, distorted media coverage, misguiding experience and the fears and pleasures associated with future outcomes, people tend to neglect uncertainty, and underestimate or overestimate risks..

Overconfidence

While overconfidence is often studied using lay people, it is just as commonly found among scientists/experts, as illustrated by the following quotes:

"There is no likelihood man can ever tap the power of the atom." (Robert Milikan, Nobel Prize in Physics, 1923)

"Heavier than air flying machines are impossible." (Lord Kelvin, President of Royal Science Society, 1895)

The *overconfidence bias* was first described by Alpert and Raiffa (Alpert 1969) and is defined as tendency of individuals to overestimate the preciseness of their knowledge, and to express excessive optimism concerning the probability of a certain favorable/unfavorable outcome in the future. While the proportion of time in which an answer/prediction is correct ought to equal the confidence assigned to that estimate, the degree to which confidence matches accuracy is low in most judgments. In these cases we speak of poor *calibration* (Murphy 1984).

People tend to be particularly overconfident in their judgments when it is difficult to make correct judgments. In a classic study by Lichtenstein and Fischhoff (Lichtenstein 1977), people were presented with 12 children's drawings and asked whether they came from Europe or Asia. In a second task participants were asked to estimate the probability that each of their judgments was right. Although only 53 percent of the judgments were accurate (essentially at chance level), people rated their confidence, on average, as 68 percent.

Lichtenstein and Fischhoff (Lichtenstein 1977) conclude that in two-alternative judgments the correspondence between accuracy and confidence is as follows:

- Overconfidence is greatest when accuracy is near chance levels;
- Overconfidence diminishes as accuracy increases from 50 to 80 percent, and once Accuracy exceeds 80 percent, people often become under-confident;
- The gap between accuracy and confidence is smallest when accuracy is around 80 percent, and it grows larger as accuracy departs from this level;

- Degree of overconfidence is greater the more difficult the task.

Over the last three decades many studies have replicated these findings for more commonplace judgments and predictions about behavior in contexts that were much more tailored to the expertise of the respective participant populations (Dunning 1990; Vallone et al. 1990). It needs to be pointed out that low degrees of calibration (discrepancies between accuracy and confidence) are not linked to a decision maker's intelligence. Russo and Schoemaker (Russo 1992) conducted experiments with high-level managers in many industries by asking 10 questions tailored to the industry. Respondents were asked to provide for each question a low and high estimate such that they are 90% certain the correct answer will fall within these limits, aiming for 90% hits and 10% errors. The results showed that typical outcomes fell in the range of 50-60%.

This is not to say that people are *always* overconfident. There is some evidence that expert bridge players, bookies, and weather forecasters exhibit little or no overconfidence, most likely because they receive almost instantaneous and frequent feedback following their judgments (Lichtenstein et al. 1982; Murphy 1984; Murphy 1984; Keren 1987).

There are multiple reasons for overconfidence. Overconfidence can be the result of selective information and memory search. Humans tend to seek or interpret new information in ways that confirm one's beliefs and avoid contradictory interpretations (confirmation bias) (Koriat 1980). There also are motivational reasons. We see a need to appear competent and confident to others and to ourselves.

In conclusion, the downside of confidence exceeding prediction accuracy is that it prevents people from seeking additional information and cues, thus preventing them to consider alternative judgments or decisions. There are also important implications for veridicality of personal recollections of climate information. On the positive side, confidence and optimism help to get the job done. The optimal balance is that one is somewhat “schizophrenic”—accurately assessing the correct probabilities of the success of a plan or decision under consideration, and to develop contingency plans (“Plan Bs”) in the case of lower success probabilities. Once this is done, one can plunge ahead with Plan A with full optimism and enthusiasm.

B. Choosing among actions with uncertain outcomes

This section first discusses two normative models commonly used to predict decision making under uncertainty, and then introduces psychological extensions used to describe how and why people behave differently than they ought to.

Expected Utility Theory (EUT)

Facing uncertainty, decision makers should choose between two options by comparing their expected utility values (the weighted sums of the utility values of outcomes multiplied by their respective anticipated probabilities): $U=\Sigma_i p_i u(x_i)$, where “*i*” is states of the world; in each state of the world (i) the individual receives x_i dollars; the probability of receiving x_i is p_i. People should behave as if they were maximizing the expected utility of choice options. The shape of the utility function serves as a measure of risk aversion (concave) and risk seeking (convex). Risk neutral individuals have linear utility functions.

Many individuals do not seem to have consistent utility functions in the face of risk. A variation of EUT, *subjective expected utility* theory (SEUT) allows for a personal utility function and subjective, or personal, probabilities. SEU can also be applied to problems where objective probabilities cannot be determined in advance, for instance in cases where the outcome will only occur once.

Descriptive Modifications

A psychologically more realistic alternative to expected utility is provided by prospect theory. Kahnemann and Tversky (Tversky 1979; Tversky 1992) modified EUT with a utility, or value function that is defined over gains and losses compared to a reference point (instead of over absolute wealth). The value function is an s-shaped curve that crosses at the reference point. Manipulations of what people use as their reference point determine how outcomes get framed (e.g., as relative gains or relative losses). Reference point framing matters because the prospect theory value function is concave for gains (risk-averse), convex for losses (risk seeking), and steeper for losses than for gains. Losses loom larger than gains of the same amount (loss aversion). Prospect theory predicts the following risk attitudes, as the result of diminishing marginal sensitivity to both gains and losses: risk-aversion over prospects involving gains and risk-seeking for prospects involving losses. However, due to nonlinear probability weighing, where people tend to overweigh small probabilities, it also predicts risk-aversion for small-probability losses (explaining why people buy insurance) and risk seeking for small probability gains (explaining why people buy lottery tickets).

C. Choosing among actions with delayed outcomes

Normative Model: Discounted Utility Theory

The standard normative approach to evaluating possible future consequences of an action is to discount them based on their time delay. The utility of an outcome is discounted as a function of its time delay assuming a constant discount rate for all time periods. Prevailing interest rates serve as a reasonable standard for discounting (the reduction of value per year of delay).

Modification to address the reality of intertemporal choice

Empirical findings show a wide range of deviations from discounted utility theory. In reality, people are impatient and tend to demand much greater premiums for delay when immediate consumption is an option than in situations where all possible outcomes lie in the future (Mischel 1969; Read 2001). Thaler (Thaler 1981) found that people discount gains more than losses and small outcomes more than large ones. Studies by Loewenstein (Loewenstein 1988) and Weber et al. (Weber 2007) show greater discounting when delaying than when accelerating consumption. Furthermore, multiple outcomes are discounted differently than single outcomes. Weber and Chapman (Weber and Chapman 2005) have found evidence for a combined effect of delay and uncertainty, where decision makers equate uncertainty and delay. Several theoretical formulations have attempted to explain these anomalies, such as models of hyperbolic discounting, awareness of future self, utility from anticipation, instantaneous utility function, habit formulation models, reference point models, projection bias, mental accounting models, choice bracketing, multiple-self models, temptation utility, etc. (for a review, see Frederick, Lowenstein, O'Donoghue (Frederick 2002; Frederick 2003). Another view, Query Theory put forward by Weber et al. (Weber 2007) point out that the order in which the individual retrieves different classes of reasons for the decision greatly impacts the discount rate applied. In delay decisions, people focus first on arguments for the default option, immediate consumption, whereas in acceleration decisions, they focus first on the default option, which is later consumption. Weber and Johnson show that, while the non-default option is also considered, argument retrieval is less successful for second queries (Weber 2006). Weber and colleagues show the reversal of the delay-accelerate asymmetry by individual decision makers whose order of query is reversed.

The special (?) case of environmental decisions

Environmental decisions, where both financial and non-financial outcomes are realized at different points in time, bear additional complications: (a) discounting may be domain-dependent (Gattig and Hendrickx 2007). Chapman's studies show greater time discounting for health than for money with large variability and poor correlation across individuals between discount rates for health and money outcomes. This is attributable to as whether or not people think of health as tradable with money or not. (Chapman 1996; Chapman 2002; Chapman 2003). Chapman (2002) noted lower discount rates when the outcome affected a client population rather than oneself. This could be interpreted as less discounting of the future for a social rather than an individual health goal. Treadwell finding zero discount rates for future health (Treadwell 1997); (b) time horizons of environmental outcomes are often much larger than those typically studied with monetary and even health outcomes, e.g., intergenerational goals, or environmental enhancements that are imagined to endure indefinitely; (c) in contrast to the financial scenarios typically studied, environmental outcomes generally have consequences beyond the individual decision maker; (d) they are either purely social goals -- e.g., a livable global climate for future generations -- or have individual (as well as social) aspects that must be pursued with the cooperation of others -- e.g., reducing local air pollution coping with water shortage, etc.; and e) environmental outcomes are typically more uncertain than monetary outcomes.

Few studies have examined intertemporal preferences for non-monetary outcomes. The question of discount rates for different goals has been addressed most systematically in the literature on health outcomes, (Bos et al. 2005), and only a handful have explicitly studied environmental outcomes. Baron (Baron 2000) showed that people were insensitive to the amount of delay in a study of discounting of environmental goods, with significantly lower discounting for longer time intervals than for shorter intervals. Guyse et al. (Guyse 2002) examined preferences for temporal sequences of environmental and monetary outcomes and found that students preferred improving sequences for environmental outcomes (as opposed to those that worsened over time), contrary to the findings for monetary outcome sequences. Studies by Hardisty and Weber (Hardisty 2007) indicate that over a short time period (1 year), when personal consequences are salient, environmental outcomes are discounted similarly to monetary outcomes.

However, longer time periods (20 years or more), when social goals are more salient, environmental/social outcomes can indeed show strong negative discount factors.

To address the special feature of (very) long-term environmental goals, a theory put forward by Krantz and Kunreuther departs from standard economic theories (Krantz and Kunreuther 2007) (for a more detailed description of Krantz and Kunreuther's context-dependent construction of choice theory, hereafter KK theory, see below). The benefit of an enduring enhancement to social or natural environment is not evaluated as a series of utility increments, year by year, rather, it is perceived as a single goal pertaining to an indefinitely long time period. Since one is not integrating over time, there is no mathematical need for something such as exponential discounting. There can still be pure time preference: delaying an achievement of indefinite subsequent duration may change the value assigned to the goal. But such discounting may be slight, and there may even be negative discounting for some long-term goals and some values of delay.[3]

Multiple Goals and Incentives

Both normative and descriptive models ought to include a decision maker's multiple goals and incentives, and need to be able to deal with groups of decision makers and their potentially conflicting objectives, rather than focusing on individual decision makers. The latter point is particularly useful when addressing environmental decisions which are

[3] The application of KK Theory to environmental goals is still in development. We would like to thank David Krantz and his team at the Center for Research on Environmental Decisions (CRED) for sharing their preliminary thoughts and results with us.

most commonly made by groups that are composed of individuals who may have both aligned and conflicting goals.

Normative Model: Multiattribute Utility Theory

Multiattribute utility theory (MAUT) offers a structured approach designed to handle the tradeoffs among multiple objectives by assigning utility to outcomes on each dimension, and weighting them by the relative importance of each dimension. MAUT is usually used to evaluate choice among several decision alternatives in the presence of multiple goals (Debreu 1959; Krantz 1971; Keeney 1976).

MAUT has commonly been applied in public sector decisions and public policy issues that require reconciliation of many interest groups, such as power plant-related decisions, or military innovations, involving tradeoffs of cost, durability, lethality and survivability (for an application to climate-change related decision and deep uncertainty, see the chapter by Steve Schneider in this volume). MAUT aims to separate utility into attributes. For instance, when choosing a medical treatment such as Hormone Replacement Therapy, two attributes (with corresponding goals) to consider are long-term health and quality of life. Each of these attributes has several factors. Long-term health considerations include osteoporosis, heart disease, and breast cancer concerns. The attributes that factor into quality of life are menopausal symptoms, side effects of the treatment, youthfulness. (And so on). For each level in this hierarchy, every factor is weighted by giving them points, which then are being distributed among factors within a given group to indicate the relative importance of that factor in the decision to use or not use the treatment. This method allows to calculate a net weighted utility score for each factor, as well as a composite utility score, by adding the scores for the decision factors in the model. There are tradeoffs between the goals in our example, long-term health and quality of live, plus the many other goals in the same decision. MAUT not only considers all of them, but considers them all in the same way, and all at once.

Deviations from normative model

Multi-attribute utility theory is based on the assumption that the fundamental normative principles of choice, such as transitivity apply, and that decision makers are able to measure utility for combinations of different packages of goals within various outcomes. However, empirical evidence has shown that both of these assumptions are violated systematically and predictably.

<u>Context matters</u>

Normative theory stipulates that our goals should be independent of context, yet context is often a main reason for violation of MAUT principles of transitivity and independence. A decision maker may prefer choice A over B in one context, B over C in another, and C over A in yet a third context leading to intransitivity. Context influences goals and also impacts how goals are bundled and thus how utility is assigned to various outcomes.

Building on Constructed Choice Theory (Slovic 1995; Lichtenstein and Slovic 2006), which states that people's preferences are not stable, but rather constructed with the decision context. Krantz and Kunreuther (Krantz and Kunreuther 2007) recently developed a theory of context-dependent constructed choice, hereafter designated the *KK* theory. KK Theory assumes that decision makers choose among competing plans, each of which is designed to achieve multiple goals.[4] Context influences which goals are active, which resources are available to achieve goals, and which decision rules are considered. Besides context-dependence, KK theory rejects the notion that all goals merely contribute to a single utility. *KK* theory facilitates consideration of multiple types of goals, including emotional, social, environmental and economic, as well as temporal-sequence goals (Loewenstein and Prelec 1993).

This theory has many advantages over traditional multi-attribute utility theory. While originally developed in the context of protective (insurance) decisions, Krantz and colleagues are currently working on an application to environmental decisions where context matters in so far as environmental goals may be activated by new concepts (e.g., carbon sequestration) or by a cooperative plan to which others seem prepared to commit (e.g., Kyoto Treaty).

<u>People dislike tradeoffs (we "want it all")</u>

Some decisions require tradeoffs that people think should not be made, such as trading off human life (or as in discussed in the chapter by Terry Root, animal species) for something else. In these cases, people often use non-compensatory (non-tradeoff) choice processes that avoid conflict (Hogarth 1987; Payne 1993). Or at least they avoid the realization of conflict by editing out elements that remind them of goal conflicts.

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[4] Note that although the KK framework, and the refers to goals, the research just reported concerns health *outcomes*. From the perspective of the *KK* theory, a single health outcome may involve several distinct individual goals (e.g., pleasure, competence, relief of pain, avoidance of anxiety), as well as several social goals (pertaining to specific other individuals or to an abstract civic group).

Decision makers do not admit tradeoffs between the relevant attributes of the choice alternative, they eliminate alternatives without examining all attributes, they make decisions on an attribute-by-attribute basis, and separate utilities are not combined into a single utility value. Some of the more commonly studied non-compensatory simplifying heuristics include elimination-by-aspects, acceptance-by-aspects, and lexicographic-by-features rules.

Two further complications arise in the context of conflicting goal. The difficulty of making tradeoffs often leads to decision inertia, and we end up with the status quo. Conflicting goals also lend themselves to strategic use of uncertainty. This is exemplified by the argument of wind power vs. species protection (birds flying into the wings of wind turbine).

<u>Goal space is broader than assumed by traditional economic view of human nature</u>

Our goals include not only the selfish economic and material goals of the *homo economicus*. but also social goals, emotional goals, and environmental goals An additional complicating factor is that social goals are not easily quantifiable, making it even harder for decision makers to carry out the complex context-dependent measurements of utility required when multiple and often implicit goals are bundled together. .

In sum, tradeoffs among choices are really tradeoffs between goals, which in turn are neither objective nor stable but context dependent, subjective and changing.

Economic and Other Incentives

Most decisions surrounding climate change mitigation and adaptation involve common pool resource dilemmas. While the normative perspective of economics and game theory, and behavioral research suggest bleak prospects for decisions that would sustain the earth's common resources, the picture might not be as bleak as it seems. The "tragedy of the commons" (Hardin 1968) might be better described as a drama, as a tragic outcome is by no means a foregone conclusion.

A better appreciation of the multiple ways in which people can look at information (framing, mental accounting), set goals (individual vs. social goals), and decide upon a course of action (using habits, rules, roles, affect, and calculations), can suggest ways in which environmentally-impactful behavior can be presented to increase the likelihood for people to act in more collective ways, which will then as well increase long-term individual benefits. The same insights can also guide the design and presentation of environmental policy optionsin those cases intervention is considered necessary.

Cooperation can be facilitated by appealing to the social identity of people. Besides economic well-being, social affiliation and social approval are powerful human needs. Modification of economic incentives is difficult and expensive, yet the priming of social goals by the way situations are described or "framed" is often more (cost) effective, ," and more feasible. For instance, giving a group a bonding task prior to the actual decision making process, can imply the goal in question as a communal goal. Arora and Krantz (Arora and Krantz 2007) show that cooperation in a social dilemma game went up when the preceding task required cooperation. Even more subtle stimulations of group affiliation in the form of a decal identifying people as members of one group over another, glued to people's experiment materials can create group identity and subsequent cooperation (Brewer and Kramer 1986; Brewer 2001).

Policy Implications

How to gain stakeholders' (public officials, members of the general public) attention to climate change and variability? Most climate change information is presented in an analytic format, however, analytic appeals have not been proven very effective in the past. Climate change predictions seem to contradict the experience of most people because they lack considerable exposure to actual climate change over the course of their lifetime. Mitigative and adaptive actions often require immediate costs, sacrifices, and losses to achieve time-delayed benefits or gains, but both hyperbolic discounting and loss aversion, argue against taking such actions.

Does this call for more emotional appeals? Is there wisdom in inducing people to worry more about climate change and variability? There are clearly good reasons to engage people's affective information processing system by using visualization or graphic description of catastrophic climate change, or by concretizing future changes in simulations of conditions in local environments (Marx et al. 2007). However, there are important caveats to be considered, namely the *finite pool of worry* and *single action bias.*

Finite pool of worry means that people have a limited budget to spend on worry. As worry about one hazard increases, worry about other hazards decreases. For instance, research by Hansen, Marx, and Weber with farmers in Argentina showed that as worry about climate risks increased due to a forecast of La Nina conditions, farmers rated political situation and economic conditions as lower on the worry scale, even though political and economic risks had not changed since the climate forecast had been introduced (Hansen et al. 2004)[5] [

Single action bias refers to the tendency to engage in only a single corrective action to remove a perceived threat of a hazard, even when a whole range of responses is clearly advantageous. This occurs because the single action removes the "hazard flag." Radiologists have been found to detect a single abnormality, and then stop searching for more and therefore miss other potentially abnormal signs (REF?). Similarly, a study on US Midwestern farmers showed that farmers engaged in only one activity to adapt to climate variability (*either* production practice, pricing practice, *or* endorsement of government intervention) (Weber 1997). In another example from the domain of agricultural decision making, farmers in the Argentina Pampas were less likely to use irrigation or crop insurance, if they had capacity to store grain on their farms (Hansen et

[5] Note: If Bradshaw contributes to this volume, mention his chapter here, referring to the fact that climate not the only thing on farmers' minds. Or just mention above, see fn 2.

al. 2004). To assure that people react on multiple fronts, a more analytic response to situations might be required.

The availability of multiple mental processes (analytic, experiential/affective) and the related multiple decision making modes (calculation, affect, and recognition of rules, roles, or cases), make some processes and modes more suitable for addressing some problems rather than others. This has important implications for institutions, as institutions can shape how decisions are being made. by making use of the different ways in which a problem is addressed (Engel 2007). A problem can be approached by seeking external or internal knowledge (expert advice), by conscious deliberation, or by spontaneous affective reactions. Each problem solving mode generates different outputs. More deliberate reasoning can be achieved by raising the stakes. Similarly, introducing a justification requirement makes people aware of the complexity of the task at hand, and makes accountability more salient, which in turn results in a raising of stakes. When immediate intervention is needed, it makes sense to match the current task with another pre-configured problem-solving mode that triggers emotions, for instance through recall from memory by priming.

If environmental outcomes and goals are discounted in a similar way as health outcomes where, discount rates would tend to be lower when the outcome affects a client population rather than oneself. We may expect less discounting of the future for a social rather than an individual goal. Policy concerning investment in public goods (public health, mitigation of climate change) needs to distinguish between multiple self-regarding goals of individuals, social goals of families and friends, and civic goals.

Risk Communication and Management Challenges and Implications

How can people's experiential and affective processing and their aversion to uncertainty utilized constructively? This section supplements Susan Moser's and Julie Winkler's chapters on risk communication. Winkler demonstrates how scenarios (worst case, best case, most likely case scenarios) can be used to help people plan for uncertainties. Scenarios are often criticized, yet if done well, as in the case of the Pileus project, they provide a good match to the non-probabilistic information processing of experiential system.

Scenario analysis is especially effective if it is presented in association with contingency plans, especially for worrisome worst and bad case scenarios. There are real and psychological benefits: the real benefits being an increased response speed and better responses; the psychological benefits being that perceived preparedness reduces anxiety.

Conclusions

Probabilistic nature of climate (change) forecasts pose both liabilities and opportunities. In the absence of clear action implications (that allow a feeling of control), awareness of climate risk may arouse too much anxiety—resulting in liability. Uncertainty gets edited out, i.e. it is treated as being effectively zero, resulting in procrastination and decision avoidance. Furthermore, uncertainty can be used strategically to justify decisions, which are desired for other reasons (such as hidden agendas). On the positive side, uncertainty does not have to be an “enemy.” The range of outcomes can serve as natural impetus for contingency planning and thereby provide opportunities. If the development of forecast formats takes into consideration human information processing modes and constraints, liabilities can be minimized and opportunities maximized.

Consideration of the combination of analytic and experiential/emotional processes can facilitate correct interpretation of climate forecasts, and motivate forecast usage and adaptive risk management actions.

Forecast formats and risk management processes should be tailored to different segments of users. Users vary by the amount and sophistication of analytic processing, but time periods, incentives, and goals also differ across decision makers. For most users, it will pay to elicit optimal level of worry/concern. It would be recommended to develop visualization tools to concretize the (temporally and spatially distant) impacts of climate change. The majority of decision makers/forecast users would benefit if statistical uncertainty measures were concretized. This could be achieved by the localization of forecasts, the provision of analogies to previously experienced situations, and the discretization of the distribution of different future cases (best , most likely , worst, and likelihood of extreme events). Users of climate variability forecasts and climate change predictions need to be provided with an accurate degree of confidence in forecasts and an explanation of what these degrees of confidence signify.

Actions and choices can be influenced by strategic use of “framing.” Situations can be described in ways that prime cross-group commonalities, social goals, and cooperation vs. differences, selfish goals, and competition. Depending on the desired response, communicators can choose reference points that depict alternatives as involving gains or losses. People tend to be risk seeking in the domain of losses, and risk averse for gains. For instance, protective or mitigative actions can be perceived as either involving costs and losses, or benefits and opportunities. Both perceptions are true, but the attentional focus induced by the problem description often determines responses.

The design of effective risk communication and risk management processes must thus consider the above described constraints on human cognition and motivation, in addition to economic and institutional constraints. Knowledge about human capabilities and constraints provide useful tools. If ignored, numerous problems seem more intractable than they are.

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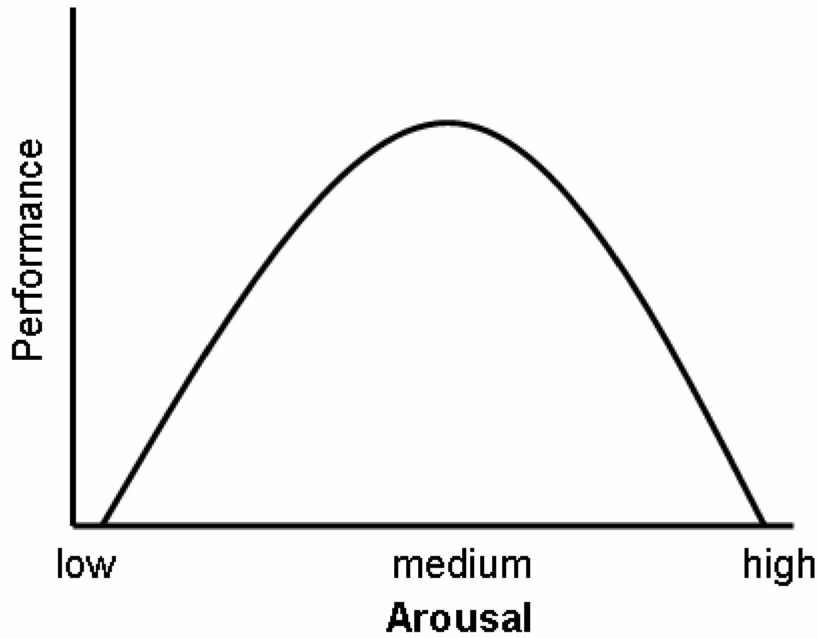

Figure 1: Graph of Yerkes-Dodson Law principle

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