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Communication and mental processes: Experiential and analytic processing of uncertain climate information

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Abstract

People process uncertainty information in two qualitatively different systems. Most climate forecast communications assume people process information analytically. Yet people also rely heavily on an experiential processing system. Better understanding of experiential processing may lead to more comprehensible risk communication products. Retranslation of statistical information into concrete (vicarious) experience facilitates intuitive understanding of probabilistic information and motivates contingency planning. Sharing vicarious experience in group discussions or simulations of forecasts, decisions, and outcomes provides a richer and more representative sample of relevant experience. The emotional impact of the concretization of abstract risks motivates action in ways not provided by an analytic understanding.

Keywords: Risk communication; Environmental decisions; Group decision making; Mental processing; Affective decision making; Climate information; Uncertainty; Probability

1. Introduction

To communicate is to transmit an idea so that it is satisfactorily understood and, typically, used to guide action. The successful communication of climate information, be it a seasonal forecast or the prediction of a long-term warming trend, is complicated by the uncertainties attached to the forecasts. A forecast might assign a probability of 45% to higher-than-normal rainfall in the next growing season and a probability of 15% to lower-than-normal rainfall, or it might state that an increase of at least 1 °C in global temperature is highly probable over the next few decades. Let us use the example of a maize crop farmer, who faces the decision of how much land to allocate to the crop, selection of sowing date, genotype, crop density, and rate and time of fertilizer application. Advance information of the climatic conditions might give farmers an indication of the likelihood of low or high soil moisture and soil temperature (frost) at sowing, flowering, and harvesting. Climate information can influence land assignation, production schedules, and commercialization strategies—decisions that are made long before the sowing season starts (Bert et al., 2006). When the recipient of such climate information acts as though the unusual season or warming trend is certain to occur, or, at the opposite extreme, entirely rejects the forecast because it is uncertain, the probabilities have either not been adequately

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communicated or have been ignored for other reasons, for instance, economic and financial situation, lack of access to labor and machinery, production objectives, managerial skills, or psychological reasons such as risk aversion.

Communication of climate uncertainty may be improved by better understanding how people learn and reason about uncertainty and how climate-related decisions are influenced by uncertainty. The last 15 years have seen considerable progress in understanding how uncertainty and probability or likelihood information is understood by individuals with the help of two very different processing systems, one experiential, the other analytic. More recently, insights from this research are being applied to the special case of climate uncertainty, examining different methods of communicating uncertain forecasts.[1] While behavioral decision research has concentrated mostly on individuals, many climate-related decisions are made by groups or by individuals after group discussion. Thus it seems appropriate to extend research on judgment and decision-making under uncertainty beyond the individual to include the effects of group processes and group-related goals.

We acknowledge that there are many interconnected variables that affect individual and group decisions under climate uncertainty, such as the framing of information, incentives, material and non-material goals. Here we focus on two ways in which people process information, experiential versus analytic processing, a distinction central to understanding the problem of communicating uncertain climate information.

1.1. Outline of the paper

The paper is organized as follows. After defining experiential and analytic processing as part of the Section 1, Section 2 reviews, in more detail, evidence showing that personal experience or vivid descriptions often dominate statistical information, even though the latter typically provides more—and more reliable—information, and explains this as the result of competition between the experiential and analytic processing systems. Section 3 discusses several experientially based heuristics and some biases that may result. Section 4 concludes with implications for research and policy. Throughout this paper, we will refer to a wide range of examples of decisions, in particular two climate-related research projects currently underway at the Center for Research on Environmental Decision (CRED): one project looks at the impact of (vicarious) concrete, experiential information, as exemplified in the movie The Day After Tomorrow, on climate change risk perception and policy; the other project examines the comprehension of statistical information through experiential retranslation by Ugandan farmers' groups, illustrating how the concretization of statistical climate information by examples drawn from one's own personal experience and that of others may be accomplished.

1.2. Experiential and analytic processing: a brief overview

Experiential processing relates current situations to memories of one's own or others' experience. Some high-level abstract concepts may be involved in experiential processing, but others are neglected, particularly those that involve thinking about an ensemble of different experiences together. While the concept "average" can be incorporated relatively easily in experiential processing by bringing to mind a typical situation (more likely a mode than a true mean), concepts such as relative frequency and sample size tend to be neglected because they cannot easily be imagined correctly. Analytic processing, by contrast, includes mechanisms that relate the current situation to processed ensembles of past relevant experience and thus can easily and naturally express statistical constructs such as probability and sample size (Stanowich and West, 1998). Experiential processes are akin to the "concrete operations" (understanding of cause and effect) described by while analytic processes are an example of "formal operations," (abstract thinking, i.e., operations on ensembles of concrete experiences).

Past experiences often evoke strong feelings, making them memorable and therefore often dominant in processing (Slovic et al., 2002; Loewenstein et al., 2001). Strong feelings such as pleasure and pain, fear, anger, horror, joy, and awe involve activation of paleocortical brain structures that are evolutionarily older than neocortical structures and found in all vertebrates. By contrast, analytic processing involves the neocortex, a structure found only in mammals and in expanded form only in primates and especially humans. The extent to which analytic processes occur in lower animals is a subject of active investigation; but it seems clear that some processes, including those that underlie the syntactic structures of human language and the use of extended chains of logic, are uniquely human. Table 1 summarizes the major attributes of the two processes (Piaget and Inhelder, 1962; Inhelder and Piaget, 1958).

There is not a sharp separation between experiential and analytic processing. Even simple reflexes can be influenced by neocortical processes and analytic reasoning can lead to strong feelings of pleasure, fear, anger, joy and awe. A decision process always integrates both kinds of processing. The role of analytic processes in the understanding of (climate) uncertainty and in decisions involving such information, however, has often been overestimated and the role of experiential processes has been ignored. A better appreciation of experiential processing may point us towards improved communication strategies.

[1]For example, see the research conducted at the Center for Research on Environmental Decisions (CRED) at Columbia University, www.cred.columbia.edu.

Table 1
Two processing systems[a]

Experiential processing	Analytic processing
Operations on personal memories (concrete operations)	Operations on sets or ensembles (formal operations)
Causal schemes	Logical rules
Vivid images	Abstract symbols
Strong affective component	Often deliberative

[a] Chaiken and Trope (1999); Epstein (1994); Sloman (1996).

2. Personal and vicarious experience vs. statistical evidence

This section first defines the distinction between experiential and analytic processing in greater detail, then discusses how the two processing systems affect the understanding of probabilistic information, and closes by reviewing the role of both processing systems in groups.

Personal experience is a great teacher, due to the powerful impact on subsequent memory and behavior. A single painful touch of a hot stove produces substantial learning. The ability to understand other people's cautionary tales and anecdotes extends the range of personal experience. The skill to combine the personal experiences of many into statistical summaries is an additional powerful evolutionary accomplishment that dramatically increases our aptitude to learn in less costly ways. Research on the two ways of learning about the possible outcomes of one's decisions and actions has historically been conducted separately, but has recently been compared directly (Hertwig et al., 2004, 2006; Weber et al., 2004). The prominent formal models of human decision-making under risk and uncertainty (e.g., Clemen, 1996; Morgan and Henrion, 1990; Simon, 1956), however, have predominantly focused on analytical decision-making, even though researchers have long been aware that abstract statistical evidence is typically at a disadvantage when people have a choice between it and concrete personal experience. We first review these well-established results and then place the distinction between personal versus statistical evidence within the larger framework of experiential versus analytic processing.

Nisbett and Ross (1980, Chapter 3) were among the first to emphasize the importance of vivid evidence in human judgment and decision-making, while acknowledging that this idea had been widely understood prior to being studied by psychologists. For example Bertrand Russell argued that "popular induction depends on the emotional interest of the instances, not upon their number." Similarly, Joseph Stalin thought vivid images were more important politically than numbers, when he said "the death of a single Russian soldier is a tragedy, but a million deaths is a statistic." For many reasons, people seem more compelled to offer donations and other contributions to save the lives of identified victims than to save equal numbers of unidentified or statistical victims. Jenni and Loewenstein (1997) tested this phenomenon empirically and identified the most important cause of the disparity in treatment of identifiable and statistical lives is that, for identifiable victims, a high proportion of those at risk can be saved.

The same processes can lead people to condemn an identified individual. As an illustration of the role of imagery in cognitive processing, a study by Hamill et al. (1980) found that a single vivid instance was far more effective than extensive "pallid" statistics of much greater evidential value. For example, a vivid description (taken from an actual magazine article of that era) of a single, highly atypical abuser of a social welfare system induced people to make more negative judgments about welfare recipients in general, compared with the judgments of people who did not see any information bearing on the welfare system. By contrast, authoritative statistical summaries (e.g., pointing out that the median stay on welfare was only about 2 years) had negligible effects on people's judgments.

Other studies demonstrate that statistical information is often overwhelmed by vivid anecdotal information. Tversky and Kahneman (1974) showed that relative frequencies (e.g., 15% of taxis in a city are operated by one company, 85% by the other) do influence people's judgments ("which company's cab caused an accident?") when they are presented alone, but have much less influence when anecdotal information, such as an eyewitness account or a vivid personal description is also given.

2.1. Two kinds of processing and how they work together

In experiential processing, a person's current situation is matched against past experience and thereby categorized. Action plans are assembled rapidly from parts previously available and used in similar situations; by adulthood, people have vast experience in adjusting plans rapidly to minor discrepancies between the current situation and those previously experienced. Affect, i.e. spontaneous emotional reactions such as excitement, enthusiasm, joy, anger, or sadness, plays a strong role in this process, because positive feelings elicit strong tendencies toward approach or acceptance, while negative feelings elicit flight or rejection, and these strong tendencies shape the action plans that are assembled and used (Damasio, 1995). Thus, even when the current situation does not match any particular experience very well, if it matches well enough to evoke strong feelings, the general nature of the person's action can be predicted. A sufficiently vivid description of a situation permits listeners or readers to place themselves in the story, thereby to be influenced by strong positive or negative affect, and to imagine the actions that they would take.

Analytic and experiential processing work together in several ways. Importantly, analytic processing can modify how people categorize their current situations relative to past experience, and thereby can modify action plans. Such "retranslation" of concrete experience by analysis may be accompanied by affect: strong emotions may be evoked by analytic processes. A related sort of retranslation occurs when probabilities are given a causal interpretation (Tversky and Kahneman, 1974), which tends to make the relevance of statistical information salient, by providing people with a story of why statistical base rate information needs to be considered. Following up on our previous example of the cab companies in a city: relative frequency, for instance "15% of the taxis in a city are operated by the Blue Cab company," is mostly ignored when people are asked to judge the probability that a 'Blue Cab' caused an accident. However the same relative frequency information *is* integrated with the case-specific evidence when it is stated in a way that lends itself to causal retranslation, namely "15% of the taxi accidents in a city involve the Blue Cab company." The causal interpretation combines readily with other concrete thinking. Further evidence of the importance of causal schemas in judgment is given by Tversky and Kahneman (1982). In the context of climate variability, the role of causal schemas can be seen when a seasonal forecast that assigns a 45% probability for La Niña conditions is translated into "there is a 45% chance that the climatic conditions of the next season will contribute to lower than normal rainfall in the Argentine Pampas and cause crop failures."

To use another example of how the two processing systems operate together, consider the decision process of someone who lost an early-planted maize crop three years ago, when the rains, having begun, halted for three weeks just after planting. On contemplating early planting this year, the person may react with anxiety and be inclined to wait. On the one hand, analysis of climate records or forecasts might well reinforce this experientially based decision—the chance of such a dry spell might be 10% or 20%, and this may seem too high to risk the investment of seed and labor. However, if statistical analysis suggests that what happened three years ago was really quite rare, early planting might make sense analytically, yet the negative affect stemming from the previous year's experience may nonetheless prevail. One sees this response in extreme form in phobic reactions, where people know analytically that their avoidance behavior is unnecessary or even harmful, but they cannot bring themselves to suspend it.

Even in seemingly "objective" contexts such as financial investment decisions, subjective and largely affective factors have been shown to influence perceptions of risk. For business executives studying in a University of Chicago program, emotional reactions (e.g., worry or dread) to investment opportunities of health and safety related activities were just as important as statistical variables (e.g., outcomes and their probabilities) in predicting perceptions of risk in both the financial and the health/safety domain (Holtgrave and Weber, 1993). Likewise, if risk perceptions were driven exclusively by statistics, they would not be influenced by the way a particular hazard is labeled. Yet, reports about incidences of "mad cow disease" elicit greater fear than reports about incidences of bovine spongiform encephalitis or Creutzfeld-Jacob disease, a more abstract, scientific label for the same disorder (Sinaceur and Heath, 2004).

Retranslation by modifying concrete categories may also be promoted through analogies between novel probabilistic assertions on the one side, and situations that arise in everyday life where people already take chance into account in their planning on the other side. Such analogies play an important role both in classroom teaching of statistical thinking and in communication of probabilistic information relevant to decisions. The following two examples illustrate how analogies can be used to convey probabilistic climate forecasts. Phillips and Orlove (2004) conducted an exercise that helped Ugandan farmers evaluate forecasts for seasonal climate conditions provided by the Ugandan Department of Meteorology. The exercise compared the meteorological forecasts with traditional predictions and forecasts based on a cultural system of "signs" that are empirically observable (Orlove and Kabugo, 2005). Farmers were presented with a common prediction scenario: they were asked to consider a forecast of the sex of an unborn child based on a common local sign. They were then asked to indicate the chances that the child would turn out to be of the sex indicated by the sign, by distributing ten dots on a piece of paper under two pictures, one of a boy, the other of a girl, according to the likelihood of the outcome (see Fig. 1). A large majority of discussants (77% pooling data from four focus groups ($n = 252$)) allocated dots to both pictures, showing that they understood that the prediction, though deterministic (a certain shape of a woman's belly indicates a son, for example), was uncertain, and its forecasted outcome might

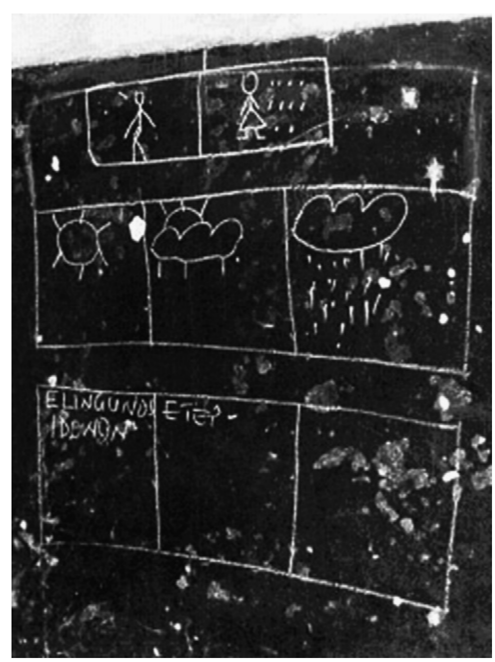

Fig. 1. Explaining the prediction "Game", Kumi, Uganda, July 2004 (*Photo credit*: Jennifer Phillips/Ben Orlove).

not take place. In the case of rainfall forecasts (based on e.g., observations of shifts in wind direction or arrival of migratory birds) the percentage of those who indicated the uncertain nature of the forecast was even higher, with 82% pointing to the possibility of more than one outcome. Presented with a government-issued seasonal forecast that mentioned a most probable outcome, 88% of the participants allocated dots to more than one outcome.

In their research with farmers in Zimbabwe, Suarez and Patt (2004) introduced conditional and joint probabilities by linking seasonal forecast uncertainty (whether El Niño would weaken or gain strength over the next few months) with the more familiar example of betting on a soccer game. Analogous to the benefits of improved El Niño information and higher-skilled forecasts becoming available if one waited a month or two (until October or November), Suarez and Patt suggested that the national soccer teams from Zimbabwe and Argentina would be facing each other in a game, yet one of the star players was supposedly injured and no one knew for sure whether it was Argentina's or Zimbabwe's star. Clearly, the likely winner would depend on which player was injured. A poll of the workshop showed that most participants thought Argentina would win in either case, however, if the Argentine star player Diego Maradona was injured many people thought Zimbabwe had a better than even chance of winning. Based on the following conditional probabilities: 80/20 Argentina if Maradona plays, and 60/40 Zimbabwe if the Zimbabwean star Peter Ndlovu plays, workshop participants calculated the overall probabilities for either Argentina or Zimbabwe winning as 60/40 Argentina. The climate forecast in Zimbabwe was not dissimilar: forecasters simply did not know yet what role El Niño would play. Assuming a probability of 50/50 for intensifying/weakening El Niño conditions, workshop participants were asked to develop a forecast of the impact of such conditions on Zimbabwe's climate. Most farmers understood very well the analogy of the lack of knowledge about whose star player would be injured, on the one side, and the lack of information about El Niño's increase of decrease at the time of the seasonal forecast available in October on the other side. Farmers saw the value of waiting for additional information and were able to provide the calculations for the November forecast.

In summary, research on people's processing of statistical information suggests that analytic information is best understood when it is used to recategorize or recontextualize the decision maker's current situation. In turn, this is best accomplished when the analytic results can be translated into concrete images, strong emotions, or stories.

2.2. Experiential vs. analytic processing of probabilities

The two processing systems described above affect the processing of all sorts of information to influence all sorts of behaviors. Concrete, personal or vicariously related experience is processed by the experiential system and the generated affect is an effective motivator of action. More pallid statistical information is processed by the analytic system, whose output tends to have less weight in actions or decisions, unless decision makers have been trained to pay conscious attention to statistical information and its implications. Here, we focus specifically on the way in which information about the likelihood of events is acquired, comparing the experiential route (involving affective and other associative processes) to the analytic route (involving statistical and other abstract information processes).

In daily life, decision makers often learn about outcomes and their probabilities as a function of their profession or role. Doctors, for example, learn about health outcomes of treatment decisions in a different way than the lay public. Consider the decision whether to vaccinate a child against diphtheria, tetanus, and pertussis (DTaP). Parents who research the side effects of the DTaP vaccine on the National Immunization Program web site will find that up to 1 child out of 1000 will suffer from high fever and about 1 child out of 14,000 will suffer from seizures as a result of immunization. Although doctors have these same statistics at their disposal, they also have access to information not easily available to parents—namely, the personal experience, gathered across many patients, that vaccination rarely results in side effects; few doctors have encountered one of the unusual cases in which high fever or seizures follow vaccination. If the importance assigned to rare events differs as a function of how one learns about their likelihood, then doctors and patients might well disagree about whether vaccination is advised (Ball et al., 1998).

Several papers have examined how people combine statistical and experiential information about likelihoods (Birnbaum and Mellers, 1983; Tversky and Koehler, 1994; Jenni and Loewenstein, 1997; Clemen and Winkler, 1999; Kraemer and Weber, 2004; Fagerlin et al., 2005). The bottom line is that experiential information overwhelms statistical information, unless statistical information is re-expressed (visually, narratively, or otherwise) in ways that can be combined with personal experience.

Related to the distinction between analytic and experiential *processing* is a recent distinction between *decisions* made from description vs. decisions made from experience (see Table 2). An example of a description-based decision is a choice between two lottery tickets, where each ticket is described by a probability distribution of possible outcomes (i.e., statistical summary information). In contrast, when people decide whether to back up their computer's hard drive, cross a busy street, or invest in a new water system to irrigate their crops, they often do not know the complete range of possible outcomes, let alone their probabilities. Instead people typically decide based on past personal experience. Research has shown that the weight given to small-probability events differs dramatically in the two processing systems (with much greater weight given to small-probability events when small probabilities are

Table 2
Two forms of decisions

Description-based decision	Experience-based decision
Decide on taking a drug based on drug package insert information. Invest in a mutual fund based on the information in its prospectus.	Decision to back up computer's hard drive. Invest in a system to irrigate crops based on personal memory.
When small-probability (rare) events are involved, people choose as if they over-weigh the probability of the rare event (Kahneman and Tversky, 1979)	People choose as if they under-weigh the probability of the rare event… unless the statistically rare event occurred in the very recent past (*recency effect*) (Hertwig et al., 2004, 2006)

provided as a statistic than in decisions from experience). People purchase a lottery ticket despite the miniscule chance of obtaining the winning ticket; yet people cross a street assuming the rare event of a car hitting them will not occur. This suggests that the way in which information is communicated and the processes that this communication triggers are important determinants in the outcome of decisions that involve small probability events (Hertwig et al., 2004, 2006; Weber et al., 2004).

The acquisition of probability information by repeated, personal experience has been shown to have a number of desirable consequences. Chu and Chu (1990) showed that it can eliminate preference reversals, i.e. a systematic tendency of people to pay more than they should for less attractive choices in specific situations (people indicate a preference for option A over option B in a direct choice situation, but are nonetheless willing to pay a higher price for option B). Evidence of another positive effect is provided by Koehler (1996) and Hertwig and Ortmann (2001) who showed that direct experience of base rates can strongly improve Bayesian reasoning. For instance, doctors use base rate probabilities acquired through personal experience in a normative fashion, which is not true for numerically described base rates (Weber et al., 1993).

2.3. *Effect of affective/experiential vs. statistical evidence in groups*

Research on risk amplification (Pidgeon et al., 2003) and emotional contagion (Barsade, 2002) suggests that groups—just as individuals—are more motivated by concrete (affective and experiential) information than statistical information when they decide which risks to pay attention to and when to take protective action.

We may, however, expect to see differences in the way that groups (compared to the average individual) utilize statistical information. First, groups sometimes include members with some level of statistical training and aptitude. More sophisticated group members may educate and tutor the less sophisticated group members. Secondly, affective vs. analytic presentation or representation of information can be a special case of framing, in which a group with multiple members is more likely to reframe the issue from the initial attention-grabbing affective frame to an analytic one than a single individual. The opposite may also be true, however, i.e. one member of a group may translate statistical or analytic information into a more affect-laden and persuasive format, perhaps based on past personal experience with the described outcomes. Research in this area of study bears contradictory results, making it difficult to generalize. Findings do however show that these group processes are highly context specific and depend on the domain of the decision, such as health (e.g., public health, personal medical treatment), finance (e.g., monetary decisions of a company, personal monetary decision (Paese et al., 1993), or category judgments (Argote et al., 1990). For an overview of the vast literature see Kerr et al. (1996), and for an updated review, refer to Kerr and Tindale (2004).

Researchers at CRED are currently investigating the influence of group discussion on the reframing of analytical, experiential, and affective arguments in the context of losses and gains associated with disease prevention scenarios. While we expected group discussion to reduce, or at least balance, affective arguments, so far we find evidence that group discussion neither eliminates reference to affect and experience, nor does it diminish emotional and personal arguments (Milch, 2006). This appears to be true at least for public health scenarios (e.g., strategies to prevent an outbreak of West Nile Virus) that are presented in a loss frame (worded in terms of lives lost). Most people perceive the certain loss as worse than an uncertain loss with the same expected value and are more risk-seeking in order to prevent the occurrence of deaths (Kahneman and Tversky, 1979; Tversky and Kahneman, 1981, 1986; Cohen et al., 1987). Results of the experiment with the public health scenario in Milch's study, a loss frame triggered more experience-based arguments, affect, and worry in group members than a gain frame; even after group discussion the loss frame maintained its emotional connotations.

3. Consequences of the experiential processing of (climate) risk information

Most decisions require the evaluation of events that are known to occur only probabilistically. These are referred to as decisions under risk, when the likelihood of different events is known precisely, e.g., the probability of getting a "head" when tossing a fair coin, or as decisions under uncertainty, when the likelihoods themselves are uncertain, e.g., the probability of precipitation tomorrow. Decisions from description, described in the previous section, typically specify the probability of events as precisely as possible; decisions from experience are typically made under some uncertainty. More important than this rather technical distinction between risk and uncertainty, however, is the differentiation, made in the previous section, between an analytic vs. experiential basis for the detection of a risk, e.g., the risk of changing or varying climatic conditions, and the decision to take defensive or mitigating action.

When risk information is not processed analytically, processing often takes the form of simplifying heuristics. A heuristic is a rule of thumb, a replicable approach for directing one's attention in problem solving. In this section, we describe three heuristics that all utilize concrete images and emotional reactions. Heuristics influence judgments, choices, and decisions. While heuristics are generally beneficial, i.e. provide pretty good results most of the time while minimizing processing effort (Payne et al., 1992), they typically also have some downside. In the following pages, we describe three heuristics of the experiential processing system, drawing on examples of climate information use ranging from Ugandan farmer communities to the general public in the United States and Europe. At the end of this section we also point to some limitations that can make the use of heuristics problematic.

3.1. *The affect heuristic or "risk-as-feelings"*

Many, if not most decisions and actions under risk and uncertainty are driven by how we feel about the situation (Slovic et al., 2002, 2004; Loewenstein et al., 2001). Slovic et al. (2004) define affect as a "'faint whisper of emotion', referring to the specific quality of goodness or badness (1) experienced as a feeling state (with or without consciousness) and (2) demarcating a positive or negative quality of a stimulus. Affective responses occur rapidly and automatically—note how quickly you sense the feelings associated with the stimulus word 'treasure' or the word 'hate.' We argue that reliance on such feelings can be characterized as the affect heuristic." It is important to note that affect does not equal bias.

If something worries us, we try to reduce the source of worry. If something scares us, we may leave or avoid the scene of the scare. Similarly, negative feelings can greatly influence risk perceptions and behavior. For example, a national (US) survey found that negative feelings (affect) about global warming were stronger predictors of public risk estimates and policy preferences than sociodemographic variables, values, or political variables (Leiserowitz, 2006).

Likewise, another study found that differences in worry about global warming were associated with differences in willingness-to-pay more for gasoline, if such price increases would result in less harm to the environment (Hersch and Viscusi, 2006). The affect heuristic describes the fact that our emotional reactions to a situation strongly influence the way we subsequently act, i.e. that we use our affect as short-cut guide to action. If factors unrelated to the statistical risk of the situation reduce our feeling of risk, use of the affect heuristic can result in biases, i.e., in inappropriate willingness to take on such risks. Klos et al. (2005) show, for example, that people are generally willing to take greater risks in situations where they have greater familiarity with the risky options (e.g., the home bias observed in investors in financial markets), which can be explained by the fact that familiarity with a risk reduces the feeling of being at risk. Use of the affect heuristic also predicts that misattributions of the sources of feeling at risk will affect decisions and actions. Thus, Hirshleifer and Shumway (2003) found a positive relationship between morning sunshine at a country's leading stock exchange and market index stock returns that day at 26 stock exchanges internationally from 1928 to 1997, a finding that is difficult to reconcile with fully rational price-setting, but perhaps indicative of emotional mediation.

Let us turn to a more detailed example of how the affect heuristic applies to climate forecast use among Ugandan farmers. Farmers' concern with seasonal variability is particularly strong because of its effects on agricultural livelihoods. In rain-fed agriculture, a rainy season that is either scanty or excessive can lead to economic hardship. Past research has shown a tendency for climate professionals and the lay public alike in the region to translate probabilistic forecasts into deterministic information, leading to potential increases in risks associated with responses; this translation is often due to the affect heuristic, granted the great concern over crop failure in the region.

In an ongoing project, Orlove and Roncoli (2006) are studying group processing of climate forecasts, a project motivated by an interest in improving the communication of probabilistic seasonal climate forecasts to rural communities in Nakasongola and Kumi districts in Southern Uganda (Phillips and Orlove, 2004). Phillips and Orlove project developed and broadcasted a series of radio programs in local languages, including background information on climate and climate variability and presenting the seasonal forecast for the upcoming season. Semi-formal groups of farmers were established to listen to the programs and discuss them, often with a facilitator from the project. A "farmer-listening-group" program, including broadcasting of forecasts, interviews with farmers before and after the forecast meeting, as well as household surveys, are currently being repeated in a second district, Rakai (Orlove and Roncoli, 2006).

Based on preliminary analysis of interviews and group discussions, the affect heuristic, or risk-as-feelings, appears in the ways that farmers anticipate and respond to the scientific seasonal forecasts, which is presented in analytical terms as a set of probabilities. Farmers voice their fear that unusually scarce or heavy rains could cause hunger for them and their households, evidenced by statements that are strongly experiential. After hearing the probabilistic forecasts, individuals mention similar years that they recall, describe the coming agricultural season that they anticipate, and express relief or fear in relation to expected production outcomes. Farmers sometimes draw directly on personal experience, often echoed by other farmers. They also make strongly analytical statements, including discussion of the relative merit of different proposed courses of action (choosing certain crop varieties or planting dates, allocating labor to reduce the risk of landslides from nearby hills, reallocating labor from social and leisure activities to field preparation and planting during critical weeks, requesting specific forms of assistance from government agencies). Thus, the affect heuristic may direct attention to a topic, but does not necessarily block analytical processing.

3.2. *Availability heuristic*

Similar to the affect heuristic, personal experience also plays a role in the availability heuristic, which is a rule of thumb that allows people to solve problems based on what they remember and how easily their memory is retrieved, how readily available that memory is. People have been found to employ the availability heuristic when asked for probability or frequency judgments, often of a comparative type (Tversky and Kahneman, 1983). 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 ("just after the 4th of July," "on my birthday, which is August 22"). 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. It is quite likely that the opposite process is also at work. When given the numerical probability of a climate event, farmers may generate concrete examples of this event from their own experience. The ease or frequency of generating such examples will then influence their intuitive understanding and interpretation of the numeric probability information.

To draw on our example of Ugandan farm communities again (Orlove and Roncoli, 2006), the availability heuristic can also contribute to the tendency to translate probabilistic forecasts into deterministic information. When faced with statistical information about general properties (timing, amount) of precipitation, Ugandan farmers often turn to the familiar pattern of the two annual agricultural seasons. To understand how a particular forecast may relate to personally significant outcomes, farmers draw on their personal experience with previous climate scenarios, agricultural strategies, and food security impacts. An interesting interaction of availability heuristic and affect heuristic can be seen, for instance, in the recollection of specific years. For example, older farmers in Nakasongola district remembered the drought of 1961, because there was considerable tension in the region between ethnic groups during that year, a time when Uganda was moving towards independence from British rule; they spoke of the flags that flew at the time, a vivid image still associated with the drought. Farmers in other districts mentioned the droughts of 1967, the year when a new president abolished the traditional royal courts and associated institutions that had continued under the British colonial rule and in the first years of independence. In both these cases, the affective charge of these experiences was probably underscored by its symbolic significance, since it is an established belief in Uganda, as in many other parts of the world, which a stable legitimate ruler can assure not only social and political order, but cosmological and natural order as well. Farmers mark certain years as particularly salient if extraordinary climatic conditions co-occurred with other affectively charged events. In turn, the affective charge of the year may make the year more readily available for recollection.

The availability heuristic can play a large role in judging the risk posed by climate variability (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, especially the younger generation, do not (yet) have experiences that we associate with climate change, and cannot bring examples (whether frightening or pleasant) to mind. The availability heuristic makes us assume that the future will be similar to what we have experienced so far (Sunstein, 2006).

However, in the absence of personal familiarity people might draw on second-hand experience. A study of the movie "The Day After Tomorrow" suggests that movies, which integrate vivid imagery, strong emotions, and vicarious experience, speak directly to the experiential processing system, in some cases bypassing critical analysis altogether (Leiserowitz, 2004). The vicarious experience provided through cinema can, at times, have a significant effect on how people perceive, interpret and respond to risk. Movies often provide vivid, emotionally laden and memorable images that can easily be brought to mind, which drives the availability heuristic. For example, anecdotal evidence suggests that the intense images and theme music from the movie *Jaws* (1975) continue to affect people's intuitive assessments of the risk of shark attacks. Several other studies have addressed the power of images, versus verbal or other information formats, in eliciting affective responses (e.g., Golding et al., 1992; Loewenstein, 1996; Slovic et al., 1998; Jenkins-Smith, 2001; Leiserowitz, 2006), yet this is not the place for an extensive review of that literature.

3.3. *Recency heuristic*

In decisions based on summary statistical information people often overweight rare events, i.e. give them more weight than they deserve by probability alone (Kahneman and Tversky, 1979). Yet in decisions based on personal experience, people tend to underweight rare events, i.e. give them less weight than they deserve based on their probability of occurrence. This results from the fact that the experiential processing system gives a lot of weight to recent observations. Since rare events have generally not occurred recently, they are underweighted in subsequent decisions. 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. By the same process (i.e. recency weighting) if the statistically rare event has occurred in the very recent past, people tend to overreact to it. This makes decisions from personal experience far more volatile than decisions based on analytic processing of statistical information. The terrorist attacks of 11 September 2001 and the devastation caused 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 the risky option. As a result, low-probability events generate less concern than their probability warrants on average, but more concern than they deserve in those instances where they do occur.

O'Connor et al. (2005) provide evidence of the operation of both the recency heuristic and the affect heuristic in a survey of water managers in two eastern US states. The survey was motivated by concern that weather and climate forecasts are being underutilized in the risk management of community water systems. O'Connor et al. found that managers who reported feeling at risk with respect to weather events were far more likely to indicate use of weather and climate forecasts. Feelings of risk, in turn, resulted from recent personal experience, i.e. the experience of adverse weather events over the past 5 years. Similarly, Orlove and Roncoli (2006) found in their work with farmers in the Ugandan Rakai district that farmers describe climate variability largely in terms of the previous 5 years or so, though, as indicated above, farmers also recall a few years from previous decades that were marked by other events. Farmers in Rakai are particularly concerned by recent years in which the rains started unusually early or late, contrasting with their beliefs about the normal seasonal cycle; they are far less likely to report unusual onsets further in the past, though these had also occurred. Other factors may have also reinforced this recency effect, particularly the strong emphasis that NGOs and government environmental agencies have placed on the link between deforestation and regional climate change in the course of environmental awareness campaigns implemented in the last decade.

This tendency to give recent events a lot of weight is, of course, adaptive in non-stationary environments. More recent observations are more predictive of future occurrences when the relationships and patterns in one's environment can be expected to change. In this sense, people appear to be well equipped to detect and adapt to climate change, if we can provide them with sufficient personal experience. Group discussions and the sharing of personal experiences and outcome feedback among group members is one way of broadening the exposure to experiential information, though there is evidence that vicarious experience is not as powerful as personal experience (Schotter and Sopher, 2003), probably because it fails to elicit the strong emotional reactions experienced in the face of positive or negative outcomes of one's own actions.

3.4. Limitations of heuristics of the experiential system

While ways of presenting information about (climate) risks that engage the experiential processing system have clear benefits, they also have their downsides that argue for careful usage. As concern about one type of risk increases, worry about other risks frequently decreases, as if people had a limited budget to spend on worry (Linville and Fischer, 1991). Hansen et al. (2004) found evidence for a *finite pool of worry* among farmers in the Argentine Pampas. As concern with climate risk increased in the course of a decision simulation exercise that provided climate information, concern with political risk went down even though the level of political risk had not changed. Concern and worry seemed to be a finite resource also in the case of each individual farmer. Those who stated greater worry about political risk worried less about climate risk. Knowing that people's capacity for worry or concern is finite places important limitations on attempts to raise greater concern and thus motivate more protective or mitigative action against some risk, for example by providing concrete images of possible damages. Raising concern about some aspect of a situation comes at the cost of potentially reducing concern about another. The costs of worry also appear to be cumulative, i.e. the pool of worry appears to take time to regenerate. Emotional numbing as the result of repeated exposures to emotionally draining situations is a commonly observed reaction in individuals living in war zones or being subjected to repeated hurricane threats within a season—especially in the modern media environment where people experience a bewildering number and diversity of vicarious experiences each day, ranging from news stories, television dramas, educational programs, confessional talk shows, movies, novels, video games, etc. One may be moved by a movie one day, but the feeling may be replaced by a new vicarious experience the following day.

Another suboptimal consequence of affective processing is the *single-action bias* (Weber, 1997). It describes a propensity to take only one action to respond to a problem in situations where a broader set of remedies is called for. Taking the first action to respond to the problem at hand seems to reduce or remove the feeling of worry or concern. With this affective marker, motivation for further action is reduced. For example, malaria-control efforts in regions with wide-spread chloroquine resistance might focus on procurement of alternative drugs such as artemisinin-based combination therapy, but omit other protective actions such as insecticide-treated bednets or indoor residual spraying (Marx, 2006). Weber (1997) found that

Midwestern farmers engaged in only one of three plausible protections against the negative consequences of climate change. Hansen et al. (2004) similarly found that farmers in Argentina employed only one of several adaptations to climate variability and climate change. If they had the capacity to store grain, for example, they were less likely to also irrigate and invest in crop insurance.

A way to overcome some of these limitations associated with affective processing in decision-making under uncertainty, namely the finite pool of worry and single-action bias, is group discussion. For example, the Uganda case (Nakasongola) shows that participation in group discussion helped elicit a wider range of adaptive responses to climate forecasts than when forecasts were presented to individual farmers (Orlove and Roncoli, 2006). The total number of possible responses that were mentioned by all the participants increased from four mentioned by individuals before the group meeting to ten when interviewed after the group session. This increase cannot be explained alone by mechanisms of sharing or pooling of information in groups (Stasser, 1992; Larson et al., 1998). Moreover, the percentage of participants mentioning specific responses increased. The percentage who responded that they would alter the timing of planting increased from 16.0% to 24.8% between the two surveys. In the pre-program survey, none of the respondents mentioned the selection of particular varieties or the use of fertilizer as responses; in the post-program survey, 13.3% and 3.7%, respectively, indicated these actions. While these results are preliminary and we do not know yet if farmers followed their suggestions with real actions, this difference in the number of responses before and after group discussion indicates that farmers considered, or at least spoke about, a much larger number of alternatives after participation in a group.

4. Research and policy implications

Based on the observation that experiential and analytic processing systems compete and that personal experience and vivid descriptions are often favored over statistical information, we suggest the following research and policy implications.

Communications designed to create, recall and highlight relevant personal experience and to elicit affective responses can lead to more public attention to, processing of, and engagement with forecasts of climate variability and climate change. Vicarious experiential information in the form of scenarios, narratives, and analogies can help the public and policy makers imagine the potential consequences of climate variability and change, amplify or attenuate risk perceptions, and influence both individual behavioral intentions and public policy preferences. Likewise, as illustrated by the example of retranslation in the Uganda studies, the translation of statistical information into concrete experience with simulated forecasts, decision-making and its outcomes can greatly facilitate an intuitive understanding of both probabilities and the consequences of incremental change and extreme events, and motivate contingency planning.

Yet, while the engagement of experience-based, affective decision-making can make risk communications more salient and motivate behavior, experiential processing is also subject to its own biases, limitations and distortions, such as the finite pool of worry and single action bias. Experiential processing works best with easily imaginable, emotionally laden material, yet many aspects of climate variability and change are relatively abstract and require a certain level of analytical understanding (e.g., long-term trends in mean temperatures or precipitation). Ideally, communication of climate forecasts should encourage the interactive engagement of both analytic and experiential processing systems in the course of making concrete decisions about climate, ranging from individual choices about what crops to plant in a particular season to broad social choices about how to mitigate or adapt to global climate change.

One way to facilitate this interaction is through group and participatory decision-making. As the Uganda example suggests, group processes allow individuals with a range of knowledge, skills and personal experience to share diverse information and perspectives and work together on a problem. Ideally, groups should include at least one member trained to understand statistical forecast information to ensure that all sources of information—both experiential and analytic—are considered as part of the decision-making process. Communications to groups should also try to translate statistical information into formats readily understood in the language, personal and cultural experience of group members. In a somewhat iterative or cyclical process, the shared concrete information can then be re-abstracted to an analytic level that leads to action.

Risk and uncertainty are inherent dimensions of all climate forecasts and related decisions. Analytic products like trend analysis, forecast probabilities, and ranges of uncertainty ought to be valuable contributions to stakeholder decision-making. Yet decision makers also listen to the inner and communal voices of personal and collective experience, affect and emotion, and cultural values. Both systems—analytic and experiential—should be considered in the design of climate forecasts and risk communications. If not, many analytic products will fall on deaf ears as decision makers continue to rely heavily on personal experience and affective cues to make plans for an uncertain future. The challenge is to find innovative and creative ways to engage both systems in the process of individual and group decision-making.

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References

Argote, L., Devadas, R., Melone, N., 1990. The base-rate fallacy: contrasting processes and outcomes of group and individual judgment. Organizational Behavior and Human Decision Processes 46, 296–310.

Ball, L.K., Evans, G., Bostrom, A., 1998. Risky business: challenges in vaccine risk communication. Pediatrics 101, 453–458.

Barsade, S.G., 2002. The ripple effect: emotional contagion and its influence on group behavior. Administrative Science Quarterly 47 (4), 644–675.

Bert, F., Satorre, E.H., Toranzo, F., Podestá, G., 2006. Climatic information and decision-making in maize crop production systems of the Argentinean Pampas. Agricultural Systems 88, 180–204.

Birnbaum, M.H., Mellers, B.A., 1983. Bayesian inference: combining base rates with opinions of sources who vary in credibility. Journal of Personality and Social Psychology 45 (4), 792–804.

Chaiken, S., Trope, Y., 1999. Dual Process Theories in Social Psychology. New York, Guilford Publications.

Chu, Y.P., Chu, R.L., 1990. The subsidence of preference reversals in simplified and market-like experimental settings: a note. The American Economic Review 80, 902–911.

Clemen, R.T., 1996. Making Hard Decisions: An Introduction to Decision Analysis. Duxbury Press, Belmont.

Clemen, R.T., Winkler, R.L., 1999. Combining probability distributions from experts in risk analysis. Risk Analysis 19 (2), 187–203.

Cohen, M., Jaffray, J.Y., Said, T., 1987. Experimental comparison of individual behavior under risk and under uncertainty for gains and for losses. Organizational Behavior and Human Decision Processes 39, 1–22.

Damasio, A., 1995. Descartes' Error: Emotion, Reason, and the Human Brain. Harper Collins, New York.

Epstein, S., 1994. Integration of the cognitive and the psychodynamic unconscious. American Psychologist 49, 709–724.

Fagerlin, A., Wang, C., Ubel, A.P., 2005. Reducing the influence of anecdotal reasoning on people's health care decisions: is a picture worth a thousand statistics? Medical Decision Making 25, 398–405.

Golding, D., Krimsky, S., Plough, A., 1992. Evaluating risk communication: narrative vs. technical presentation of information about radon. Risk Analysis 12 (1), 27–35.

Hamill, R., Wilson, T.D., Nisbett, R.E., 1980. Insensitivity to sample bias: generalizing from atypical cases. Journal of Personality and Social Psychology 39, 578–589.

Hansen, J., Marx, S., Weber, E.U., 2004. The Role of climate perceptions, expectations, and forecasts in farmer decision making: the Argentine Pampas and South Florida. IRI Technical Report 04-01. International Research Institute for Climate Prediction, Palisades, NY.

Hersch, J., Viscusi, W.K., 2006. The generational divide in support for environmental policies: European evidence. Climatic Change 77 (1–2), 121–136.

Hertwig, R., Ortmann, A., 2001. Experimental practices in economics: a methodological challenge for psychologists. Behavioral and Brain Sciences 24, 383–451.

Hertwig, R., Barron, G., Weber, E.U., Erev, I., 2004. Decisions from experience and the effect of rare events. Psychological Science 15, 534–539.

Hertwig, R., Barron, G., Weber, E.U., Erev, I., 2006. Rare risky prospects: different when valued through a window of sampled experiences. In: Fiedler, K., Juslin, P. (Eds.), Information Sampling as a Key to Understanding Adaptive Cognition in an Uncertain Environment. Cambridge University Press, New York, pp. 72–91.

Hirshleifer, D., Shumway, T., 2003. Good day sunshine: stock returns and the weather. Journal of Finance, American Finance Association 58 (3), 1009–1032.

Holtgrave, D., Weber, E.U., 1993. Dimensions of risk perception for financial and health and safety risks. Risk Analysis 13, 553–558.

Inhelder, B., Piaget, J., 1958. The growth of logical thinking from childhood to adolescence. Basic Books, New York.

Jenkins-Smith, H., 2001. Modeling stigma: an empirical analysis of nuclear images of Nevada. In: Flynn, J., Slovic, P., Kunreuther, H. (Eds.), Risk, Media and Stigma. Earthscan, London, pp. 107–131.

Jenni, K.E., Loewenstein, G., 1997. Explaining the "identifiable victim effect". Journal of Risk and Uncertainty 14, 235–237.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica 47, 263–291.

Kerr, N.L., MacCoun, R.J., Kramer, G.P., 1996. Bias in judgment: comparing individuals and groups. Psychological Review 103 (4), 687–719.

Kerr, N., Tindale, R., 2004. Group performance and decision making. Annual Review of Psychology 55, 623–655.

Klos, A., Weber, E.U., Weber, M., 2005. Risk perception and risk behavior in repeated gambles. Management Science 51, 1777–1790.

Koehler, J.J., 1996. The base rate fallacy reconsidered: descriptive, normative, and methodological challenges. Behavioral and Brain Sciences 19, 1–53.

Kraemer, C., Weber, M., 2004. How do people take into account weight, strength and quality of segregated vs. aggregated data? Experimental evidence. Journal of Risk and Uncertainty 29 (2), 113–142.

Larson, J., Christensen, C., et al., 1998. Diagnosing groups: the pooling, management, and impact of shared and unshared case information in team-based medical decision making. Journal of Personality and Social Psychology 75 (1), 93–108.

Leiserowitz, A., 2004. Surveying the impact of "the day after tomorrow". Environment 46 (9), 23–44.

Leiserowitz, A., 2006. Climate change risk perception and policy preferences: the role of affect, imagery, and values. Climatic Change 77 (1–2), 45–72.

Linville, P.W., Fischer, G.W., 1991. Preferences for separating and combining events: a social application of prospect theory and the mental accounting model. Journal of Personality and Social Psychology Bulletin 60, 5–23.

Loewenstein, G., 1996. Out of control: visceral influences on behavior. Organizational Behavior and Human Decision Processes 65 (3), 272–292.

Loewenstein, G., Weber, E.U., et al., 2001. Risk as feelings. Psychological Bulletin 127 (2), 267–286.

Marx, S.M., 2006. Climate and decision making: the case of malaria control in sub-Saharan Africa. Center for Research on Environmental Decisions and International Research Institute for Climate and Society, Columbia University. Working paper.

Milch, K., 2006. Framing effects revisited. Master Thesis, Department of Psychology, Columbia University.

Morgan, M.G., Henrion, M., 1990. Uncertainty. Cambridge University Press, Cambridge.

Nisbett, R.E., Ross, L., 1980. Human Inference: Strategies and Shortcomings of Social Judgment. Prentice-Hall, Englewood Cliffs, NJ.

O'Connor, R.E., Yarnal, B., Dow, K., Jocoy, C.L., Carbone, G.J., 2005. Feeling at risk matters: water managers and the decision to use forecasts. Risk Analysis 25, 1265–1273.

Orlove, B.S., Kabugo, M., 2005. Signs and sight in southern Uganda: representing perception in ordinary conversation. Etnofoor 18 (1), 124–141.

Orlove, B.S., Roncoli, C., 2006. Integration of Climate Information from Multiple Sources through Group Discussion in Ugandan Farm Communities 〈www.cred.columbia.edu/research/projects/uganda/〉

Paese, P.W., Bieser, M., Tubbs, M.E., 1993. Framing effects and choice shifts in group decision making. Organizational Behavior and Human Decision Processes 56, 149–165.

Payne, J.W., Bettman, J.R., Coupey, E., Johnson, E.J., 1992. A constructive process view of decision making: multiple strategies in judgment and choice. Acta Psychologica 80 (1–3), 107–141.

Phillips, J., Orlove, B.S., 2004. Improving climate forecast communications for farm management in Uganda. Final Report to NOAA Office of Global Programs.

Piaget, J., Inhelder, B., 1962. The Psychology of the Child. Basic Books, New York.

Pidgeon, N.F., Kasperson, R.K., Slovic, P., 2003. The Social Amplification of Risk. CUP, Cambridge.

Schotter, A., Sopher, B., 2003. Social learning and convention creation in inter-generational games: an experimental study. Journal of Political Economy 111 (3), 498–529.

Simon, H.A., 1956. Rational choice and the structure of the environment. Psychological Review 63, 129–138.

Sinaceur, M., Heath, C., 2004. Emotional and deliberative reactions to a public crisis: mad cow disease in France. Psychological Science 16 (3), 247–254.

Sloman, S.A., 1996. The empirical case for two systems of reasoning. Psychological Bulletin 1 (119), 3–22.

Slovic, P., MacGregor, D.G., Peters, E., 1998. Imagery, Affect, and Decision-Making. Decision Research, Eugene.

Slovic, P., Finucane, M., Peters, E., MacGregor, D.G., 2002. The affect heuristic. In: Gilovich, D.G.T., Kahneman, D. (Eds.), Intuitive Judgment: Heuristics and Biases. Cambridge University Press, New York.

Slovic, P., Finucane, ML., Peters, E., MacGregor, D.G., 2004. Risk as analysis and risk as feelings: some thoughts about affect, reason, risk, and rationality. Risk Analysis 24 (2), 311–322.

Stanowich, K.E., West, R.F., 1998. Individual differences in rational thought. Journal of Experimental Psychology, General 127 (2), 161–188.

Stasser, G., 1992. Pooling of Unshared Information During Group Discussion. Sage Publications, Thousand Oaks.

Sunstein, C.R., 2006. The availability heuristic, intuitive cost-benefit analysis, and climate change. Climatic Change 77 (1–2), 195–210.

Suarez, P., Patt, A., 2004. Cognition, caution, and credibility: the risks of climate forecast application. Risk Decision and Policy 9, 75–89.

Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: heuristics and biases. Science 185, 1124–1130.

Tversky, A., Kahneman, D., 1981. The framing of decisions and the psychology of choice. Science 211, 453–458.

Tversky, A., Kahneman, D., 1982. Evidential impact of base rates. In: Kahneman, D., Slovic, P., Tversky, A. (Eds.), Judgment Under Uncertainty: Heuristics and Biases. Cambridge University Press, New York, pp. 153–160.

Tversky, A., Kahneman, D., 1983. Extensional vs. intuitive reasoning: the conjunction fallacy in probability judgment. Psychological Review 90, 293–315.

Tversky, A., Kahneman, D., 1986. Rational choice and the framing of decisions. Journal of Business 59, 251–278.

Tversky, A., Koehler, D., 1994. Support theory: a nonextensional representation of subjective probability. Psychological Review 101, 547–567.

Weber, E.U., 1997. The utility of measuring and modeling perceived risk. In: Marley, A.A.J. (Ed.), Choice, Decision, and Measurement: Essays in Honor of R. Duncan Luce. Lawrence Erlbaum Associates, Mahwah, pp. 45–57.

Weber, E.U., Böckenholt, U., Hilton, D.J., Wallace, B., 1993. Determinants of diagnostic hypothesis generation: effects of information, base rates, and experience. Journal of Experimental Psychology: Learning, Memory, and Cognition 19, 1151–1164.

Weber, E.U., Shafir, S., Blais, A.R., 2004. Predicting risk sensitivity in humans and lower animals: risk as variance or coefficient of variation. Psychological Review 111, 430–445.