THE PSYCHOLOGY OF DECISION MAKING UNDER UNCERTAINTY
A LITERATURE REVIEW
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A LITERATURE REVIEW

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EXECUTIVE SUMMARY

Climate science poses a problem known as deep uncertainty. In deep uncertainty, the inherent uncertainty is not likely to be reduced by additional research within the timeframe needed for decision-making. Decision-making under deep uncertainty is one of the most crucial and unresolved problems in policy making in general, and for climate-related decision-making in particular is further complicated by uncertainty about the actions required to adapt to and cope with new climate conditions and impacts. To better understand the psychology of how people make decisions under deep uncertainty, this literature review unpacks psychological aspects of individual and group decision-making, and documented strategies for dealing with uncertainty.

Awareness of the various theories and research findings outlined in this report is valuable for those communicating directly with decision makers through websites, publications, or reports. However, to get beyond awareness of theories and research findings on the psychology of deep uncertainty, the need for more research on their application in the climate information decision space is evident. This is particularly the case for application in the field of climate change adaptation in the global south, for which research is largely absent.

The purpose of this literature review is to inform the development of a research study that aims to improve the communication of uncertain climate information to decision makers by: 1) exploring how users make decisions when knowledge of an issue is not clear; and 2) using existing knowledge to explore how climate information can be better used in decision-making.

FACTORS IMPACTING INDIVIDUAL DECISION-MAKING

A set of influential factors needs to be taken into account when evaluating an individual’s response to uncertainty. Some of the more prominent factors are presented briefly below:

HEURISTICS AND BIASES

Availability heuristic suggests that people make judgments about the likelihood of an event based on how available relevant memories are. For example, if they have recently experienced a drought they may ascribe a higher likelihood to a repeat drought event in the future.

Representativeness refers to the tendency to judge the frequency or likelihood of an event by the extent to which it resembles the “typical” case. For instance, one might judge it more likely that a homeowner in California will suffer a loss due to an earthquake than a landslide, because California is very representative of the kind of place that suffers earthquakes.

Affect heuristic represents a reliance on good or bad feelings experienced in relation to a stimulus. The way people feel (their affect) toward a particular stimulus will influence the decisions they make. For example, because many climate change impacts are perceived as happening in the future, they are not viewed with feelings of dread by many people, and thus many people delay their decisions on course correction.
The framing effect describes the effect that emphasizing certain dimensions of an issue over others has on decision-making. For example, suggesting that a treatment has a 20 percent chance of death emphasizes a negative outcome, while suggesting that it has an 80 percent chance of survival highlights the chances of a positive outcome.

EXPERIENTIAL VERSUS ANALYTICAL DECISION-MAKING

Decades of research in social, cognitive, and clinical psychology show that the human brain processes information using two systems: one experiential, the other analytical. While these two systems act together to guide judgment and decision-making, experiential thinking is, on the whole, more dominant than analytical thinking. Physiological hardwiring supports the case for using experiential information to support decision-making. However, when using experiential information, it is important to take note of caveats introduced through concepts such the “finite pool of worry” notion (as worry about one type of risk increases, worry about other risks decreases), the “recency effect” (recent personal experience strongly influences the weight a risk is assigned), and the “description–experience gap” (when decision makers are faced with essentially the same information in a different manner, their decisions will be different).

DELAY AND PROBABILITY DISCOUNTING

Discounting refers to how much the value of a reward (or punishment) is decreased when its occurrence is either delayed or uncertain. People tend to prefer what they have now versus having more in the future and what is certain over what is uncertain. From this theory, it can be expected that the focus on climate change projections for the distant future may inhibit action, as the value of adaptation action now decreases the longer into the future the subsequent benefits are expected to materialize.

While climate change projections are increasingly focusing on near-term time scales when a climate change signal is evident in the near term, the strongest messages about projected change tend to appear in the medium term (mid-century) and distant future (end of this century). Discourse among scientists, the media, and policy makers has mostly considered the future consequences of climate change over varying time scales (e.g., 50 to 150 years). Research has found that many people view climate change as a psychologically distant, future threat (Leiserowitz, 2005; Spence et al., 2012), which therefore inhibits action.

The role of temporal delays in influencing decision-making related to prioritization and implementation of climate change adaptation provides an interesting area of research to which the delay (temporal) discounting lens could be applied. In this regard, Frydman & Camerer (2016) note, in the context of decision-making under uncertainty in the financial field, that when people think about future rewards that are timed to personally important events, it increases their patience, likely because such events make the future more salient.

VALUES

Decision-making is not value-neutral. Social values and worldviews play an important role in risk perception and behavior, and this translates into the ways in which decisions are made. Studies demonstrate how values and worldviews strongly condition the way people think about the risk of climate change and policy options to mitigate it.
FACTORS AFFECTING GROUP DECISION-MAKING

Decisions in the climate information space are not solely the prerogative of individuals but often involve group decision-making. Several biases can occur in a group decision-making context. Some of the prominent biases are outlined briefly below:

GROUPTHINK BIAS

Groupthink occurs when the members of highly cohesive groups or “in-groups” try to minimize conflict and reach consensus without critically testing, analyzing, and evaluating ideas. Groups suffering from groupthink are unwilling to search for or discuss discrepant or unsettling information relevant to the decision context, or to bring in outsiders with different information. Group members are also afraid or unwilling to express ideas or opinions that contradict those of the leader.

GROUP POLARIZATION

Group polarization occurs when, after discussion, the attitudes held by individual group members become more extreme than they were before the group began discussing the topic.

SHARED INFORMATION BIAS

Decision-making discussions are influenced by the way the relevant information is originally shared among group members. Group members tend to discuss information to which they all have access (i.e., shared information), while ignoring equally important information that is available to only a few members (i.e., unshared information).

BRAINSTORMING AS AN INEFFECTIVE GROUP DECISION-MAKING TECHNIQUE

Despite the widespread use of brainstorming, research that has tested its effectiveness provides very little evidence to suggest that it works. The overwhelming majority of individual studies and meta-analyses of those studies find that brainstorming groups 1) do not generate as many ideas as one would expect, and 2) the ideas that are generated are usually of lesser quality than those generated by an equal number of individuals working alone who then share their results.

STRATEGIES TO DEAL WITH UNCERTAINTY

Three broad classes of strategies are used to cope with uncertainty:

- **Strategies of suppression** refer to the denial of uncertainty, such as ignoring uncertainty, relying on intuition, or taking a gamble.

- **Strategies of reduction** involve trying to increase information or predictability. Some examples of reduction tactics include collecting more information, asking for advice, or delaying action until more information is available.

- **Strategies of acknowledgement** take uncertainty into account in selecting a course of action or preparing to avoid possible risks.
Normative models of decision-making explore how people should make decisions. One of the most commonly used normative models to predict decision-making under uncertainty is expected utility theory. Normative-based expected utility theory states that in the face of uncertainty, decision makers should behave as if they are maximizing the expected utility of options. Given that, in reality, people behave differently than the available information suggests, a descriptive variation of expected utility theory is offered, called prospect theory. Prospect theory assumes that the threat of a loss is generally given more weight than the opportunity to gain, and that people are more inclined to take risks (act on uncertain information) to avoid losses than they are to take risks when considering gains. Therefore, a number of studies argue that a solution to the possible inaction resulting from uncertainty articulated in climate change communication may to some extent lie in the framing of uncertain messages.

For example, this implies that decision makers’ response to rainfall projections, for which the timing and direction of change may be highly uncertain, will be influenced by whether the projections are communicated in terms of economic losses that can be avoided through adaptation actions or economic gains that can be realized from action. According to prospect theory, decision makers are more likely to act on uncertain projections if they are framed in the context of possible economic loss than in terms of the possible economic gains.

**CONCLUSIONS**

This literature review reveals the need for a better understanding and application of the psychology of decision-making in the field of climate services. The literature shows that experiential information takes precedence over analytical information in decision-making processes. Taking advantage of this finding may have significant positive implications for increasing the uptake of climate information in decision-making.

The two theories that appear to provide some of the greatest potential for testing in a scenario-based survey and workshop and for informing the academic discourse on the use of uncertain climate information, are prospect theory and delay discounting.

Prospect theory, as explained above, assumes that the threat of loss is given more weight than the opportunity to gain, and that people are more inclined to take risks (act on uncertain information) to avoid losses than they are to take risks when considering gains. If this is the case, then uncertain climate change projections framed in terms of possible losses are more likely to result in action than uncertain climate change projections framed in terms of possible gains.

Delay discounting deals with how the value of an award decreases with time and, hence, the further into the future the reward is set to materialize, the less valuable it is. Accordingly, with the climate change signal being most evident in the medium to distant future, and the subsequent focus on mid- to end century, the value of acting (adapting) now is potentially discounted if the reward is only expected to materialize in the distant future.

The results of scenario-based testing and further academic study should help foster more effective decision-making for climate change policy, planning, and action.
1. INTRODUCTION

A disconnect exists between research on climate change and its robust implementation and application on the ground. One barrier to the integration of climate information into decision-making is the confusing array of climate data, which can be contradictory and associated with large uncertainties about future climate. Combined with the lack of guidance on the use and uptake of this information, these challenges create a major obstacle to the use of climate information.

To fully understand the role that uncertainty does or does not play in the uptake of climate information, one first needs to fully understand the context in which users are making decisions – who is making the decisions, their operational environment, competing stressors and priorities, and what level of information is required to trigger decisions. Understanding the decision context allows for identification of barriers and gaps in information flow and critical points in the decision-making process. Research on whether these barriers and gaps can or should be addressed may facilitate better climate-related information sharing. However, it is important to note that while greater understanding of where climate information fits into the decision-making process is a critical factor for the integration of this information, it is only one aspect that drives decision makers to act. Other factors that drive decision makers are outlined in the academic literature around the psychology of decision-making.

The literature on the psychology of decision-making is extensive, rooted in diverse fields of investigation, and has a long history - rendering it nearly impossible to investigate every concept in this review, or to engage with each concept exhaustively. Therefore, the scope of this literature review was confined to an analysis of the major psychological concepts related to decision-making under uncertainty, with a focus on psychological concepts that influence decision-making. Selection of theories was based on relative prominence in the research space, as an indicator towards validation, as well as their potential thematic links to climate change.

The purpose of this literature review is to unpack psychological concepts that may inform decision-making processes in general, with a focus on climate-related decisions where possible. Decision makers are often called upon to make important decisions involving uncertainty in domains in which they are not experts, from financial planning to preparing for extreme weather events. Much influential research in psychology has demonstrated a range of psychological factors that impact the decision-making processes of both individuals and groups. For example, over the last few decades, principles and methods from the cognitive psychology of judgment and choice have increasingly been incorporated into the finance field (e.g., Hirshleifer, 2015) and the medical field (e.g., Chapman & Sonnenberg, 2003).
The practical purpose of this literature review is to inform a forthcoming research study that aims to test these psychological concepts in a climate information decision space. Alongside an understanding of the decision context, concepts from this psychological literature were used to inform scenario cases aimed at analyzing how decisions using uncertain climate information change when information that is sensitive to core psychological concepts is presented.

With the above purpose in mind, this review is structured as follows:

1) Context setting: the psychology of decision-making under uncertainty
2) Factors affecting decision-making: separated into the individual and group context
3) Strategies for dealing with uncertainty
2. THE PSYCHOLOGY OF DECISION-MAKING UNDER UNCERTAINTY

INTRODUCTION

In everyday life individuals and groups often have to make decisions with uncertain consequences. Increasingly, situations of “deep uncertainty” prevail – these are situations where there is: 1) a high level of unfamiliarity about the phenomena that is posing potential threats to human societies; 2) poor scientific understanding by decision makers; and 3) extensive reliance on modelling and subjective judgments in lieu of estimates based upon experience with actual events and outcomes (e.g., Lempert et al., 2003). Making effective decisions in the context of deep uncertainty is a reality in order to effectively respond to real-world problems. What makes deep uncertainty challenging is that the uncertainty is not likely to be reduced with additional research, at least within the time period in which a decision must be made (IOM, 2013). With regard to the context of climate change, the major impacts of climate change pose a higher quantity of uncertainty (climate change as a new source of uncertainty) and novel quality of uncertainty (changing patterns and magnitude of damages) to decision makers in various spheres and sectors. Decision-making under deep uncertainty in this context is one of the most crucial and still unresolved problems in policy making, and is complicated by the presence of uncertainty about the actions required to adapt to the new climate conditions and impacts. Better understanding of these dynamics is thus crucial.

Psychological research into decision-making has been approached in various ways:

- **Normative** approaches (Marx & Weber, 2012) explore how people *should* make decisions. Starting from formal mathematical models (e.g., Bayesian probability theory, expected utility theory), general principles and constraints on making rational decisions are derived, and mainly laboratory experiments are employed. Normative models assume an ideal decision maker (perfectly informed and rational, capable of high-level calculations) and prescribe how optimal decisions ought to be made. Real-life observations, however, indicate that people do not behave in a fully rational manner, but instead take shortcuts in their processing by applying heuristics, which lead to biases, in decision-making under uncertainty (e.g., Tversky & Kahneman, 1974, 1986).

- 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 (Marx & Weber, 2012).
Since the primary interest of this review is to better understand how people in the real-world make climate-related decisions under uncertainty, focus is given to descriptive approaches. However, given their centrality for understanding the emergence and relevance of descriptive approaches, as well their role in unpacking how a “rational” decision maker should behave, normative approaches to decision-making are included.

THE CONSTRUCT OF “UNCERTAINTY” IN DECISION-MAKING

A few uncertainty constructs are relevant to the decision-making literature:

- **Probability, or randomness.** Much of the behavioral decision literature treats uncertainty as synonymous with probability, and accordingly, decision-making is assessed according to how well it conforms to the rules of probability theory. Experimentally manipulating “uncertainty” generally equates to manipulations of probabilities in gambles (Smithson, 2008: 207).

- **Delay in consequences or outcomes of acts.** Generally, human beings behave as though good outcomes are better the sooner they happen, and as though bad outcomes are worse the sooner they happen. Delays are therefore treated as uncertainties. Delay discounting and probability discounting are dealt with under section 2.1.3.

- **Absence or lack of clarity in information.** Substantial confusion exists in the large literature surrounding this construct, with concepts such as ambiguity, incomplete information, vagueness, and non-specificity discussed in different ways (Smithson, 2008).

For the purposes of this review, Lipshitz & Strauss’s (1997) classifications of uncertainty are followed. These authors empirically investigated how decision makers conceptualize the uncertainty they encounter in their work. Prior to their work, few studies had directly addressed this question. Lipshitz & Strauss’s findings suggest that uncertainty can be distinguished along two dimensions (Table 1). Incomplete information is the most frequently cited source of uncertainty. Sometimes it can be resolved (through research, e.g.), but not always. Uncertainty can also arise from disagreement between information sources. This disagreement may be caused by the sources themselves having incomplete information, or even, in extreme cases, by purposive disinformation (consider the case of the anti-climate change lobbies).

<table>
<thead>
<tr>
<th>1. Uncertainty issue – i.e., what a decision maker is uncertain about</th>
<th>2. Uncertainty source – i.e., what causes the uncertainty</th>
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<tr>
<td>a. The nature of the situation</td>
<td>a. Incomplete information</td>
</tr>
<tr>
<td>b. The alternatives of the decision</td>
<td>b. Inadequate understanding</td>
</tr>
<tr>
<td>c. The potential outcomes of a decision</td>
<td>c. Overwhelming information or undifferentiated alternatives</td>
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Source: Lipshitz & Strauss (1997)
FACTORS AFFECTING DECISION-MAKING

INDIVIDUAL DECISION-MAKING CONTEXT
The importance of normative approaches to decision-making has been recognized, as these approaches can help structure information requirements as well as the decision situation. However, to make reliable predictions of how people actually decide, descriptive models are needed as supplements. Descriptive approaches to decision-making integrate psychological processes into the decision model. The psychological research that accompanied descriptive approaches provided a basis to suggest that when evaluating a decision maker’s response to uncertainty, various influential human factors need be taken into account. Some of these are reviewed below to illustrate the point in the context of climate information to support adaptation.

HEURISTICS AND BIASES
Psychological research on judgment and decision-making under uncertainty stimulated debate about the nature of rationality, and the extent to which human beings act rationally or irrationally. Proponents of the view that human beings are irrational fall into the “heuristics and biases” perspective, based upon Tversky & Kahneman’s (1974) classical work on prospect theory. This perspective notes that people’s mental shortcuts to reasoning (heuristics, or rules-of-thumbs, that afford useful proxies most of the time) cause them to fall prey to irrational tendencies (biases). The “bounded rationality” perspective, on the other hand, views human judgment as rational under the constraints of limited time and cognitive capacity. This perspective sees heuristics as a necessary means for allowing people to cope with time and capacity constraints when making a decision. Moreover, some proponents of this camp claim that many so-called heuristics actually are adaptive; in other words, they are not only fast and frugal, but also sufficiently accurate in realistic environments to be effective or adaptive (Smithson, 2008).

Regardless of the underlying perspective of rationality considered, a number of heuristics and biases have been shown to play a role in decision-making under uncertainty. Some of the most prominent (and perhaps most insightful given the task at hand) are reviewed below for illustrative purposes. While heuristics are believed to play a role in determining risk perceptions in the context of climate change (e.g., Rachlinski, 2000; Sunstein, 2006; Weber, 2006; Marx & Weber, 2012), relatively little empirical research has been done in the climate change field.

Availability Heuristic
Availability is a heuristic that leads people to make judgments about the likelihood of an event based on how easily an example, instance, or case comes to mind. In other words, people 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 an 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, 1974). For example, investors may judge the quality of an investment based on information that was recently in the news, ignoring other relevant facts (Tversky & Kahneman, 1974). Alternatively, it has been shown that individuals with a greater ability to recall antidepressant advertising estimate the prevalence of depression to be higher than those with low recall (An, 2008). Much research in the fields of judgment and decision-making, cognitive psychology, and social cognitive psychology refers to availability when explaining the overestimation of salient risks, and egocentric overestimations of one’s own contributions (Fiedler & von Sydow, 2015).

Retrievability of an instance (cognitive “availability” of the instance) is critical for this type of heuristic, and is favored by personal experience with, and the salience and vividness of, the instance itself (Tversky & Kahneman, 1974; Sunstein, 2006; compare with section 2.1.2). Marx & Weber (2012) highlight that while the availability heuristic can play a large role in judging the probabilities of extreme climate events (because people can typically recall unusual events), the situation is different vis-à-vis for long-term climate change. As highlighted by Marx & Weber (2012), many people have not yet experienced risks that can be attributed to climate change because by their very nature, climate change risks are not likely to cause serious harm to most in the near future (Sunstein, 2006). Thus, it is difficult for people to bring examples of such risks to mind. In this manner, the availability heuristic also helps to explain individuals’ propensity to delay or simply deny action against risks that will only be realized a long time into the future, even though the harmful effects of these risks may be large (Sunstein, 2006; refer to section 2.1.3 for discounting).

These authors write from a developed world context, however. The role of the availability heuristic would be particularly interesting to explore in the developing world context, such as the African continent, where arguably countries are increasingly feeling the effects of climate change in the present. While little experimental evidence exists on the availability heuristic in the climate change field, in experimental studies assessing farmers’ perceptions of climate change-related risks and the use of heuristics, Diggs (1991) and Menapace et al. (2012) show that farmers rely on the availability heuristic in forming their perceptions of future climate change risks. For example, if they recently experienced a drought they may ascribe a higher likelihood to a repeat drought event in the future. However, Diggs (1991) points out that the availability heuristic may lead farmers to implement appropriate adaptation practices to climate change impacts, but that more work is needed to ascertain whether these climate perceptions are strong enough to influence adaptation planning and practices, or whether they are only nonoperational perceptions on which farmers seldom act.

It is important to note that while common events are easier to remember than uncommon ones, not all easily recalled events are equally likely to occur. Some events are more available because they have taken place more recently, not because they are more frequent (recency effect, refer to section 2.1.2.2). Some are more available because they have been distorted by the media, which favors the reporting of catastrophic risks over chronic risks. And some are more available because they are associated with strong emotions (affect heuristic, section 2.1.1.3) (Marx & Weber, 2012). It must be noted that untangling the availability heuristic from confirmation bias (refer to section 2.1.1.5) can be difficult. Confirmation bias (paying more
attention or giving more weight to information or events that confirm rather than challenge one’s beliefs) is likely to impact an individual's availability heuristic, since a person who already believes that climate change is happening is probably more likely to associate individual weather events with climate change, whether such attribution is correct or not (Mase et al., 2015: 168).

Representativeness Heuristic

The representativeness heuristic is the tendency to judge the frequency or likelihood of an event by the extent to which it resembles the “typical” case; i.e., the most relevant or typical example of a particular event or object (Kahneman & Tversky, 1972). However, when decisions are based on representativeness, people may be likely to make more errors and be more likely to overestimate the likelihood that something will occur. But just because an event or object is representative does not mean that it is more likely to occur. For example, in a series of 10 coin tosses, most people judge the series HHTHTHTHTH to be more likely than the series HHHHHHHHHH (where H is heads and T is tails), even though both series are equally likely. The reason is that the first series looks more random than the second series. It “represents” our idea of what a random series should look like (Baumeister & Bushman, 2010). For another example, Tversky & Kahneman (1974) consider how people would assess the probability that an individual (Steve) is engaged in a specific occupation from a list of possibilities (e.g., farmer, salesman, airline pilot, or librarian). Steve is described to people as shy, meek, withdrawn, helpful, but with little interest in people or reality, and as having a need for order and structure and a passion for detail. Tversky & Kahneman suggest that in the representativeness heuristic, people would judge the probability that Steve is a librarian on the basis of how representative he is of, or similar to, the stereotype of a librarian.

Two features of the representativeness heuristic are base-rate neglect and insensitivity to sample size (Fiedler & von Sydow, 2015). Much research in judgment and decision-making, and in both cognitive psychology and social cognitive psychology, refers to representativeness when explaining stereotypes and causal attributions (Fiedler & von Sydow, 2015).

In the climate change field, representativeness would manifest, for example, in people evaluating the likelihood of an event affecting a particular person or group based on how representative the person or group is of ones that are affected by this particular risk. To consider an example given by Patt & Schröter (2008: 460), “one might judge it more likely that a homeowner in California will suffer a loss due to an earthquake than a landslide, because California is very representative of the kind of place that suffers earthquakes, and less so of the kind of place that suffers landslides, while ignoring evidence that landslides occur more frequently than earthquakes.” In terms of experimental evidence, both Diggs (1991) and Menapace et al. (2012) provide support for farmers using the representativeness heuristic in their perceptions of climate change. For instance, Menapace et al. (2012) consider the specific case of the potential use of the representative heuristic among farmers as follows: farmers judge the effects of climate change on future crop losses by the degree of similarity to the effects of short-run, personally observed hail precipitation trends on past crop losses. The authors show that having observed a positive hail trend increases long-run hail risk perceptions of climate change believers more than the perceptions of nonbelievers.
Affect Heuristic

Affect is seen to serve as a cue for many important judgments, including probability judgments: the affect heuristic represents a reliance on good or bad feelings experienced in relation to a stimulus (e.g., Slovic et al., 2005). In simple terms, the way people feel (their affect) toward a particular stimulus will influence the decisions they make. Affect-based evaluations are quick, automatic, and rooted in experiential information processing (refer to section 2.1.2). Research that focuses on “risk as feelings” (as opposed to “risk as analysis”) argues that people rely more on affect and emotion than cognition when making risk judgments and decisions, and that affect is linked to risk perception in many ways (e.g., Slovic et al., 2005; Slovic & Peters, 2006; Finucane, 2008). Studies have found that the affect heuristic is strongly associated with risk perceptions and policy support for different risk issues (e.g., Slovic et al., 2004; Siegrist et al., 2006), including climate change (e.g., Leiserowitz, 2006). Marx & Weber (2012) note that because the effects of climate change are perceived as delayed by many people, climate change is not yet viewed with feelings of dread by many people. The time-delayed and abstract nature of climate change risks do not evoke strong visceral reactions, and therefore inhibit people from taking action to mediate such risks.

It must be noted, however, that a growing – though far from comprehensive – literature shows a link between people’s personal experience with extreme weather events and their risk perceptions of climate change (see van der Linden, 2015, and references cited within that). Van der Linden (2015) highlights that the role of personal experience with extreme weather (and how it influences risk perceptions) deserves more attention in future research. In this context, this report suggests it is critical that research focus upon developing countries as well – the small body of literature on personal experience with extreme weather and risk perceptions has all been conducted within developed countries, where a greater number of people are likely to be more "insulated" or "removed" from the impacts of climate change than in developing countries. Such research needs also focus on people’s personal experience of climate change impacts beyond those related to extreme weather. Preliminary, exploratory work currently being written up by the Climate System Analysis Group (CSAG) suggests that in developing countries, people attribute a variety of hazards to climate change because of personal experience, and that these direct experiences may elicit strong emotions.

Framing Heuristic/Effects

All information is “framed” by the context in which it appears. Framing involves emphasizing certain dimensions of an issue over others, setting the context for perception and discussion around specific causes, risks, policy actions, and costs/benefits that might result from these actions (Myers et al., 2012: 1106). For example, suggesting that a treatment has a 20 percent chance of death emphasizes a negative outcome, while suggesting that it has an 80 percent chance of survival highlights the chances of a positive outcome (Morton et al., 2011). Research has established that how an issue is framed can have significant impact on perceptions of, and prescriptions for, addressing those issues (e.g., Morton et al., 2011; Baumer et al., 2017). Thus, the framing effect is an example of cognitive bias, in which people react to a particular choice in different ways depending on how it is presented. Framing effects have been studied in a variety of areas. Research on framing and climate change has shown the importance that framing
choices can have on climate change perceptions and communication (e.g., Antilla, 2005; Myers et al., 2012; Scannell & Gifford, 2013). For example, framing a climate change message in terms of loss as opposed to gain, as outlined in section 3.2.1).

In terms of decision-making under uncertainty, prospect theory (section 3.2.1) states that people tend to avoid risk when a positive frame is presented but seek risk when a negative frame is presented (Tversky & Kahneman, 1981). If people are asked to choose between a safe and certain option versus a risky option associated with uncertainty, they will choose the former if the outcome of the choice is framed in terms of gains, and the latter if the outcome is framed in terms of losses. Gain versus loss framing has received much attention across various fields of literature. Morton et al. (2011) explore how uncertainty and framing might together affect individual responses (action) to communications about future climate change. Their results are broadly consistent with the tenets of prospect theory: higher uncertainty combined with a negative frame (highlighting possible losses) decreases individual intentions to act. However, higher uncertainty combined with a positive frame (highlighting the possibility of losses not materializing) produce stronger intentions to act. Their study is discussed again in section 3.2.1.

Reflections on Heuristics and Biases

Numerous other prominent, and less prominent, biases/heuristics that this review cannot examine for space and time reasons have been shown, experimentally or theoretically, to have relevance to the climate change field. Examples of these are the recognition heuristic, the anchoring-and-adjustment heuristic, the status quo bias, and the overconfidence bias. Confirmation bias appears to have particular relevance to the climate change domain, and describes the tendency of people to pay more attention or give more weight to information or events that confirm their beliefs, and ignore what challenges their beliefs; it is closely related to the processes of biased assimilation, cognitive dissonance, and motivated reasoning (e.g., see Sunstein, 2006; Whitmarsh, 2011).

It should be clear from the preceding discussion that heuristics and biases play a key role in people’s decision-making processes, and as such, their influence in decision-making in the climate change domain warrants far more empirical research than is currently available. We suggest that the following questions are of particular interest: what psychological biases play a role in climate change decision-making? How might these biases be correlated with each other? What role does each bias play in the decision-making process, what weight does it have, and are some biases thus more critical than others? In other words, what is the relative importance of each heuristic and how might their effects combine?

EXPERIENTIAL VERSUS ANALYTICAL DECISION-MAKING

Decades of research in social, cognitive, and clinical psychology show that the human brain relies on two different information processing systems (e.g., Sloman, 1996; Chaiken & Trope, 1999). One kind of information processing system is experimental: it is often described as intuitive, experiential, automatic, affective (emotional), and fast. The other kind is analytical: it is often described as deliberate, analytical, effortful, rational, and slow. While these two systems act together to guide judgment and decision-making, experiential thinking is more prevalent than analytical thinking (e.g., Slovic et al., 2005; Marx & Weber, 2012). How we intuitively feel about
a situation often has a strong influence on our decision-making. Climate change is studied in statistical terms (e.g., by analyzing long-term changes in temperature and precipitation patterns), and hence it is generally communicated and presented in relatively abstract and analytical language, especially to decision makers. This approach, however, relies on the assumption that people process uncertain information in a logical and analytical matter, an assumption that has been shown to be generally violated.

Physiological Processes Behind Experiential versus Analytical Decision-Making

Marx et al. (2012) identify physiological reasons why experiential decision-making seems to take preference over analytical decision-making. They draw on the brain's analytic processing system to explain that to process statistical summarized information the body uses the neo-cortex part of the brain. In terms of the evolutionary timeline, this structure of the brain is newer and only found in mammals and other advanced primates. To process analytical information, a formal logic needs to be employed, which is slow and requires conscious awareness and significant effort. On the other hand, experience-based decision-making uses a different part of the brain, one that is older in terms of the evolutionary process and is, therefore, hardwired and automatic. During experiential decision-making, the brain relates current decision-making situations to previous experiences and associated consequences of such decisions. Therefore, an emphasis is placed on decision outcomes that may or may not have strong feelings or emotions associated with them. Emotions are a powerful class of associations and may serve as an early warning system (Loewenstein et al., 2001). Strong emotions are memorable and therefore dominate the decision-making process (Slovic et al., 2002; Slovic et al., 2007; refer also to section 2.1.1.3).

While the two processing systems both interact and operate separately, the ultimate decision-making process is often dominated by the experiential system because it is faster and delivers output more vividly and earlier. However, Heath & Heath (2007) find that if, prior to making a decision, people are primed with analytical information and then asked to make an emotional decision, they are less likely to be swayed by emotional choices than if they are primed with emotional information. They find that essentially getting into an analytical frame of mind produces a different reaction when presented with emotional appeals.

Of relevance to the dissemination of climate information to policy makers, Marx & Weber (2012) find that technical experts and academics tend to rely more heavily on analytic processing when assessing risk, whereas policy makers, end-user stakeholders, and the general public tend to react by prioritizing the experiential/affective processing. This seems to fit with Heath & Heath’s (2007) finding because academics and technicians will likely be primed with analytical information on a day-to-day basis.

Most often, climate information is communicated in an analytical format. This is shown above to be counterintuitive to the physiological working of the brain and, hence, may go some way to explaining the communication difficulties across the science–society space when applying climate information in practice.
Recency Effect, Finite Pool of Worry, and Description–Experience Gap

Weber (2006) finds evidence that worry tends to drive risk management decisions. If people are not alarmed by a risk, they will not take precautionary measures to prevent it. Recent personal experience also strongly influences the weight the risk is assigned. This is referred to as the recency effect (Marx & Weber, 2012): experiential processing gives a lot of weight to recent observations. Since rare events generally have not occurred recently, they are underweighted, which may explain why, for example, flood control infrastructure might be neglected by a government. However, low probability events are assigned a higher nominal weighting and generate more concern or overreaction when the hazard has occurred recently. Thus, low-probability events generate more concern than they deserve in those instances where they do occur, and less concern than they deserve when they have not occurred in the recent past (Marx & Weber, 2012).

Shome et al. (2009) find that people have a limited capacity for worry. In academia, this phenomenon is referred to as the “finite pool of worry.” This phenomenon has three main components of relevance. As worry about one type of risk increases, worry about other risks decreases. Appeals to the emotional system (in an attempt to invoke worry) tend to capture the short-term attention but it is hard to maintain the level of interest long term. Appeals to the emotional system can, paradoxically, lead to emotional numbing.

Rakow & Newell (2001) describe the description–experience gap. This concept details that when decision makers are faced with essentially the same information in a different manner, their decisions will be different. For instance, people tend to prefer option (A) when presented with the following statistical information: (A) A 90 percent chance of $0 and a 10 percent chance of $10 or (B) $1 for sure. But when participants complete an exercise designed to allow them to experience winning and losing so that they experience a 90 percent chance of $0 and a 10 percent chance of $10, the preference reverses and participants tend to prefer option (B).

Provision of Experiential Impact Information versus Analytical Climate Information

Marx & Weber (2012) reflect on how scenarios (worst case, best case, most likely case scenarios) can be used to help people navigate making decisions using uncertain information. Although sometimes scenarios are criticized as not expounding the full range of uncertainties, they appeal to the experiential processing system. It is found that they are most effective if presented alongside contingency plans, especially for worst case scenarios. Winkler (2016) further recognizes that few stakeholders can directly use future projections of climate variables in their decision-making. Instead, they respond better to being presented with the change in the parameter that is being influenced by the altered climate (Tribbia & Moser, 2008; Prudhomme et al., 2010).

Similarly, Marxet al. (2007) and Harold et al. (2016) suggest that analytical information is best understood when it is tailored to the context of the decision maker’s situation. This tailoring is best achieved by translating information into images, emotions, or stories of relevance to the decision maker. Climate information that is tailored to the emotional experiences of the audience has more impact and can lead to more public attention. Scenarios, narratives, and analogies can help the audience to engage with climate information and envisage a future
where the potential consequences of climate change are played out. These influence both personal behavior as well as public policy and is more likely to result in contingency planning. Leiserowitz (2006) reiterates that communication about climate change should be tailored to the needs and predispositions of the target audience.

However, while it is beneficial to draw on experience-based decision-making in communication, experiential processing is beset with its own biases, such as the finite pool of worry and single action bias, which refers to the tendency of people, when responding to a threat, to rely on taking only one action, even when it provides only incremental risk reduction and may not be the most effective option (Leiserowitz, 2006; Shome et al., 2009). A recent trend in research discusses the need to find ways of communicating that can transcend audience segmentation; i.e., how does one communicate to appeal to a wide range of people, and active “self-transcendent” values across many different audiences, to overcome the very high costs of tailored communication approaches (e.g., Corner et al., 2014)?

Marxet et al. (2007) conclude by stating that both systems—analytic and experiential—should be considered in the format and communication of climate information. If experiential decision-making is not considered, many decision makers will not take into account climate information. The challenge remains on how to engage both analytic and experiential systems in the processes of both group and individual decision-making.

### Case Example of Climate Narratives

Narratives, or stories of change, are a new method being tested at CSAG as discussion starters to aid the communication of uncertain climate projections. Each narrative is set in a possible future, within the range of uncertainty, but is not to be a definitive future or as representing certainty about any particular future. For instance, a narrative may start “It is 2040 and Maputo continues to experience heat waves on a regular basis, which has increased the frequency of heat health-related problems…….”

The narratives represent speculative climate futures, together with their possible impacts, based on current evidence and scientific judgement. Each narrative is seen as equally likely. No probability or likelihood is associated with any narrative. Therefore, in considering decision making using these narratives, all the narratives should be considered. Lastly, narratives are provided in conjunction with the underlying evidence available as analytical/statistical information. They are never used as stand-alone evidence as they do not represent the entire range of possible futures.

### The Influence of Different Experiential Communication Approaches on Decision-Making in the Climate Change Field

**Visualization approaches within experiential climate change decision-making**

*Use of imagery.* O’Neill & Hulme (2009) investigate the use of icon imagery in communicating climate science to lay audiences. They find that icons developed by nonexperts are more engaging than expert icons (developed by those with expert knowledge on climate change). The most common reason participants are drawn to an icon is that they can personally relate to it; for instance, they mention that a picture of the Norfolk Broads National Park for those who live in Norfolk. Most participants are not drawn to expert icons such as the images depicting ocean acidification and thermohaline circulation, which are seen as being too difficult to understand and too “scientific.”
O’Neill & Smith (2014) reflect on the advantages and disadvantages of using images as a form of climate communication. Images have lots of qualities that assist in communicating information. They can capture the imagination of participants by providing emotional portrayals, they can assist in remembering information, and they can overcome language and geographical barriers. Images provide superior communication tools over text for three reasons. First, images are interpreted based on similarity, while words rely on social context. Second, images do not require precise syntactic devices to be understood. The risk of loose or imprecise syntax is thereby overcome. Last, images are direct representations of reality rather than a version of reality that can be conveyed through text (O’Neill & Smith, 2014). However, O’Neill & Smith (2014) also recognize that climate visuals may be disadvantageous because they require multiple composite images to convey the concept of time. Additionally, images (particularly photographs) are seen as perfect truth rather than representing a particular view of the world. Images can convey multiple meanings and, therefore, any one image may be subject to multiple understandings.

O’Neill et al. (2013) suggest that imagery plays a role in either increasing the sense of importance of climate change (saliency) or in encouraging feelings of being able to take action on climate change (efficacy), but very few images seem to encompass both. They find that when participants are shown images of climate impacts they demonstrate enhanced feelings of salience, but their feeling of self-efficacy decreases. On the other hand, images of energy futures (such as renewable versus nonrenewable energy sources) increase self-efficacy. Images of politicians and celebrities decrease salience and self-efficacy.

3D modeling. Another visual communication technique is that of 3D modelling – for example, 3D visualizations of forecasted snow conditions and existing ski runs in Switzerland under current conditions and after 50 years with climate change. O’Neill & Smith (2014) recognize that 3D landscape visualizations aid participants in immersing themselves into a future scenario with realistic landscapes and imagery. Sheppard (2005) goes further to describe 3D visualization as a conveyance mechanism that speaks to the way in which humans are genetically adapted. Sheppard (2005) describes 3D visualizations as offering additional advantages in the communication of climate change by making potential consequences of climate change real to people in a convincing manner. Preliminary results of engagement using 3D techniques suggest that participants find the technique engaging, find the scenarios sound, and find that their self-awareness of both climate change mitigation and adaptation increases (O’Neill & Smith, 2014). However, Sheppard recognizes that, like other communication techniques, ethical concerns arise in using an approach that deliberately uses visual imagery to engage emotions. Additionally, 3D imagery does not account for uncertainty and has inherent subjectivity and loaded value judgments about future emissions and potentially emotive imagery (Nicholson-Cole, 2005). 3D imagery is resource-intensive and impractical for widespread rollout, especially in developing country contexts.

Use of infographics. Another visual communication tool consists of infographics. Very limited academic literature seems to exist on the use of infographics for communication of climate information. Harold et al. (2016) investigate the effect of integrating text into a graphic and find that when the distance between text and graphic is reduced, users are less likely to treat the
text and graphic as two separate sources of information. Hence, the integration of text may increase comprehension of the graphic. Locoro et al. (2017) investigate the use of weather infographics (among others). Results show that static and interactive infographics vary in their use. Users express a clear preference for the use of an interactive infographic of weather forecasts such as those available through the wunderground website. However, this is strongly correlated to users’ age, gender, and educational background; moreover, the sample group for the study was drawn from university students and scholars, so was not a random sample. Somewhat conversely, Harold et al. (2016) find that, in some cases, animating graphics actually impairs comprehension.

In conclusion, with regard to further research on the use of visualizations in climate change communication, O’Neill & Smith (2014) state that research to date has predominantly focused on the western, English-speaking nations. Therefore, research potential exists to widen the academic literature outside of this context.

**Gaming approaches within experiential climate change decision-making**

For the purposes of this review, 3D visualizations of future landscapes are separated from simulation role-playing games, which may use thought-provoking scenario cases and, in some instances, 3D landscapes to represent these. Van Pelt et al. (2015) find that simulation games have potential as tools to communicate climate change uncertainty and bring together the abstract concepts conveyed in climate change science with the experiences of decision makers. The Red Cross Red Crescent Climate Centre and partners are forerunners in the development of climate change games; they have co-designed over 25 participatory games and delivered in excess of 150 game-based sessions in over 30 countries. Using simple props, the games aim to simulate decisions that will need to be made under a changing climate. The audiences for the games range from subsistence farmers to academics and policy makers. Organizations such as the World Food Programme, the United Nations, the World Bank, and Oxfam have also done extensive work in the field of digital gaming.

Games are recognized as effective tools for eliciting experiential knowledge for addressing complex world problems. They are able to simulate reality, which is advantageous in studying the process of decision-making. During training sessions, games are effective ways of testing plausible situations and decisions in a controlled environment without potential real-world consequences. If designed well, games can help to prepare people for critical decisions that need to be made to avoid the future consequences of climate change (de Suarez et al., 2012).

Although games are seen as childish by some, some evidence suggests that games play an important role in promoting dialogue and learning about some of the most difficult world problems. Some disadvantages of games include the significant investment of time required to both develop and play the games, as well as, often, the necessity for interactive (usually face-to-face) delivery, although online formats are becoming increasingly more common. Wu & Lee (2015) separate climate games into five categories: offline facilitated experiences, card/board games, computer games, mobile games (apps), and pervasive games (combination of offline and online activities). Table 2 provides the pros and cons of each.
Table 2. A Summary and Comparison of Formats of Climate Change Games

<table>
<thead>
<tr>
<th>Game format</th>
<th>Key features</th>
<th>Pros and cons</th>
<th>Examples</th>
<th>Goals and outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offline facilitated</td>
<td>Facilitated activities, often involving teams or role</td>
<td>Flexible and adaptable, but facilitation requirement a potential barrier</td>
<td>Climate Diplomat; SMARTIC</td>
<td>Facilitated learning with debriefing; qualitative assessment</td>
</tr>
<tr>
<td>experience</td>
<td>play</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Card-/board-game</td>
<td>Short gameplay session, usually involving a small number of players</td>
<td>Typically low in cost and technological requirements, but may be harder to scale</td>
<td>Arctic Saga; EcoChains: Arctic Crisis; Keep Cool</td>
<td>Facilitated learning with debriefing; qualitative assessment</td>
</tr>
<tr>
<td>Computer game</td>
<td>Computer-based role play, simulation, or management games</td>
<td>Consistent and scalable experience, but requires computer hardware</td>
<td>Anno 2070; Climate Challenge; Fate of the World</td>
<td>In-game assessment</td>
</tr>
<tr>
<td>Mobile game</td>
<td>Highly graphical with short, on-the-go play sessions</td>
<td>Able to provide portable, location-based games, but requires smartphone technology</td>
<td>Climate Mission 3D; WB Climate</td>
<td>In-game assessment</td>
</tr>
<tr>
<td>Pervasive game</td>
<td>May include a combination of online and offline activities</td>
<td>New experiences with multiple entry points, but may be less intuitive to learn</td>
<td>FutureCoast; Greenify; Love Letters to the Future</td>
<td>In-game assessment; concrete behavior and actions</td>
</tr>
</tbody>
</table>


Reflections on Experiential versus Analytical Decision-Making

While experiential communication techniques hold promise in narrowing the usability gap of climate information, the caveats associated with concepts such as the finite pool of worry, the recency effect, and the ethics of appealing to emotions need to be taken into account. However, it is important to acknowledge that every form of communication, whether it be experiential or analytical, contains value-laden information. This is true even for analytical graphs of climate information. A particular message is always being communicated through any visualization and hence no visualization is value-neutral.
DELAY AND PROBABILITY DISCOUNTING

In the context of decision theory, discounting refers to how much the value of a reward (or punishment) is decreased when its occurrence is either delayed or uncertain (Richards et al., 1999: 121). As an old saying goes “A bird in the hand is worth two in the bush,” and thus people tend to prefer 1) what they in hand now versus having more in the future, and 2) what is certain over what is uncertain (Jones & Oaksford, 2011). Individuals have been found to prefer a small reward sooner over a large reward later, and it is generally assumed that this relates to the subjective value of a delayed reward being discounted while an immediate reward is not (Myerson et al., 2011). Responses to probabilistic rewards have been found to elicit similar effects, in that individuals would opt for a smaller certain reward over a larger probabilistic reward, and it is generally assumed that this relates to the value of a probabilistic reward being discounted while a certain reward would not (Myerson et al., 2011).

Various studies look at probability and delay discounting (also called temporal discounting) in parallel, or at the parallels between the two, highlighting similarities but also emphasizing the need to distinguish between them. Richards et al. (1999) assess human impulsivity in the context of drug abuse by measuring delay and probability discounting. Their results indicate that a positive correlation exists between delay and probability discounting within subjects, meaning that an individual that displays steep delay discounting also displays steep probability discounting. While not contradicting such correlation, a key finding by Myerson et al. (2011) is the need to distinguish between delay and probability discounting, as they reflect different underlying mechanisms despite their functions having similar mathematical form.

To summarize, delay discounting predicts that people will be risk-averse for delayed gains and risk-seeking for delayed losses (delay discounting is discussed in greater detail below). Empirical evidence for this effect parallels findings of similar effects on risk-orientation due to probabilistic uncertainty, as in Kahneman & Tversky’s (1979) prospect theory, the most prominent decision theory in economics (Fiedler & von Sydow, 2015). Given the importance of prospect theory, this review considers probability discounting through a prospect theory lens, discussed in further detail in section 3.2.1.

As defined by Odum, “Delay discounting is the decline in present value of a reward with delay to its receipt” (2011: 427). Values have been found to decline hyperbolically with delay, with value degraded systematically as the reward becomes more remote. This has been found to be the case across different species and populations, as well as across different reward types (Odum, 2011). Costs and benefits accrued in the present are typically considered to be worth more than costs and benefits accrued in the future. A central part of delay-discounting procedures tends to be the identification of the indifference point, the point at which the value of two rewards, one delayed and one relatively immediate, is more or less the same. In research trials with humans, people are generally asked to make a series of choices from hypothetical options. For example, Rachlin et al. (1991) gave college students the choice between $1000 immediately and $1000 in a month, adjusting the immediate reward downward to see at which point participants would swap to the future reward. They also adjusted the immediate reward back up to $1000 to see at which point the participant would switch back to the immediate option. The average amount at which a participant switches preference between the immediate and future reward is deemed to be the indifference point.
Kaplan et al. (2014), in their study on the discounting of an environmental loss, look at how the delay in an impact influences someone’s concern about the impact and his/her willingness to act on this impact. More specifically, participants are given a short narrative that places them as the owner of a farm exposed to groundwater pollution. Prompted by the time it would take for this impact to materialize, to the point that their vegetables would not be edible, they are then asked to respond to questions about their level of concern about the effects of the pollution, as well as the time they are willing to spend to solve the groundwater pollution challenge. This is repeated for a number of temporal delays, with the time at which the impact would materialize starting at one month, increasing to six months, one year, three years, five years, and ten years. Interestingly, they find that with every delay, people discount on the willingness to spend time to solve the challenge at a higher rate than they discount on the level of concern.

While climate change projections are increasingly focusing on near-term time scales, to the extent that a climate change signal is evident in the near term, the strongest messages around projected change tend to appear in the medium term (mid-century) and distant future (end of the century). Discourse among scientists, the media, and policy makers has mostly considered the future consequences of climate change over varying time scales (e.g., 50 to 150 years). Research has found that many people view climate change as a psychologically distant, future threat (Leiserowitz, 2005; Spence et al., 2012), which inhibits action. The role of temporal delays in influencing decision-making related to prioritization and implementation of climate change adaptation provides an interesting area of research to which the delay (temporal) discounting lens could be applied. In this regard, Frydman & Camerer (2016) note, in the context of decision-making under uncertainty in the financial field, that thinking about future rewards that are timed to personally important events, increases people’s patience, likely because such events make the future more salient.

VALUES

Social values and worldviews are also argued to play an important role in risk perception and behavior and in decision-making. As Dietz (2013: 14081) notes, “[V]alues underpin more specific preferences for one course of action over another. Our preferences depend on what we believe about how actions will affect things we value.” Decision-making is not value-neutral. Studies have shown, for example, that values and worldviews strongly condition the way people think about the risk of climate change, and policy options to mitigate it: people with biospheric and altruistic values are more likely to report concern about the risks and consequences of climate change, are less likely to be skeptical about the reality or seriousness of the problem, and are more willing to accept policy measures aimed at mitigating climate change (e.g., Nilsson et al., 2004; Leiserowitz, 2006; Corner et al., 2011; Poortinga et al., 2011). Whitmarsh (2011) also demonstrates that people’s beliefs about climate change are fundamentally linked to their existing values and worldviews. Beyond this, her findings demonstrate that perceptions of the credibility and meaning of evidence, and of the trustworthiness of communicators of climate change information, are determined by people’s values and worldviews. As Corner et al. (2014: 415) note, the results from these and other studies “... appear to provide strong evidence in favor of the “interpretative” effects of values on climate engagement: the values we hold influence how we interpret the information we are exposed to about climate change in ways that lead us to either accept or reject the need for greater engagement and action.”
Currently, two major implications of research on values and worldviews to the climate change decision-making space are recognized (e.g., Whitmarsh, 2011; Dietz, 2013; Corner et al., 2014). First, attitudes and beliefs about climate change are relatively entrenched and information about the issue will be evaluated and used on the basis of individuals’ different values and worldviews. Thus, to stimulate uptake information needs to be carefully framed according to the values and worldviews of the intended audience. Second, more deliberative engagement techniques will be necessary to find common societal goals around climate change, not only between decision makers and the broader public, but between decision makers as well (as decision makers are also likely to exhibit diversity in values).

**REFLECTIONS ON DELAY AND PROBABILITY DISCOUNTING**

It is not possible within the scope of this review to examine all relevant categories of human factors that influence individuals in their decision-making. The purpose of the review was to showcase some of these factors and relate them back to the climate change field. It is important to bear in mind that many other influential human factors exist. For instance, a range of psychological perspectives (often from the field of health psychology) suggest that one key determinant of action is the feeling of efficacy (e.g., Morton et al., 2011): situations of threat and uncertainty can lead to action when people feel as though they have the capacity to act. In the absence of feelings of efficacy, additional uncertainty is more likely to lead to denial.

Because climate change is a global problem with global consequences, people’s sense of personal efficacy (i.e., the belief that individual actions can make a difference) is often very low. It therefore seems important to ensure that people feel empowered to take effective action in response to climate change (e.g., Grothmann & Patt, 2005). For another example, this review has touched only briefly on the potential role of emotion (reviewed here mostly in terms of affect, i.e., feelings of good or bad, the “faint whisper of emotion” following Slovic et al., 2005), but in recent years the literature on decision-making has increasingly considered and demonstrated the important and varied role of emotion in guiding judgments and decisions (e.g., Smithson, 2008; Lerner et al., 2015). For instance, many studies demonstrate that good moods result in optimistic judgments and choices (i.e., activities are seen as having high benefits and low risks), with the opposite true for bad moods. For example, Frydman & Camerer (2016) note in the context of the financial sector that when investors are in a good mood, they may be more prone to taking risk, and more risk-averse when in a bad mood.

An important consideration for the decision-making field is that people are social beings who respond to group norms. Norms are broadly defined as “expectations of how people are supposed to act, think or feel in specific situations” (Popenoe, 1983: 598). They are the informal understandings that govern individuals’ behavior in society. For example, in many countries, it is a norm that people shake hands when they are formally introduced. Social norms and contexts can play an important influencing role in people’s decision-making and their behavior (for the classic study in the environmental domain, see Cialdini et al., 1990). For instance, IOM (2013) notes that in the context of the passing and implementation of smoking bans, acceptance of health-protective policies shifts over time, leading to new societal norms. In the climate change domain, van der Linden (2015) shows that the more a person hears his/her family and friends talk about the risk of climate change, and the more climate change is viewed within that
person’s social network as a risk that requires action, the more that person’s own risk perception and intentions to act are strengthened. The implications are that appealing to the norms and social context in which people make decisions can be an effective strategy (e.g., van der Linden et al., 2015).

In addition to probability and temporal discounting, people have been shown to discount risks “spatially”: in other words, climate change is more likely to happen to other people in other, more distant places (e.g., Spence et al., 2012). This spatial discounting may be less relevant in developing nations where climate change impacts are arguably already happening. Other factors that can affect humans’ decision-making when confronted with uncertain information include people’s degree of risk aversion, or personality and individual differences. Multiple other aspects may affect decision-making, such as age, ethnic background/culture, experience, and educational level. As stated, space and time constraints do not allow for unpacking of all these aspects, but a short commentary from the meta-analysis literature on the effects of gender is provided below, given that gender is a focal area for USAID.

Byrnes et al. (1999) undertook a meta-analysis of 150 studies to assess the preferences for risk taking across male and female participants. Studies were coded according to the categories of: type of task (e.g., self-reported behaviors versus observed behaviors); task content (e.g., smoking versus sex); and five age levels. Results show that, in general, men take greater risks than women. However, certain topics elicit larger gender differences than others; these include intellectual risk taking and physical skills. Additionally, it is found that the size of the gender gap varies significantly across age levels and appears to be becoming smaller over time. In a later study, Powell & Ansic (2007) again find that women are less risk seeking than men irrespective of familiarity and framing, costs, and ambiguity.

GROUP DECISION-MAKING CONTEXT

Decision-making in society is not only a function of the individual but is often performed in groups. Group decision-making has often been prioritized in critical areas of society, for example in the realm of politics or the judiciary. However, whether group decision-making is more effective than individual decision-making is not a simple question to answer, for many reasons. For instance, laboratory studies of group decision-making generally provide group members with more information than they would typically have in the real world (Johnson & Johnson, 2012), so the results of such studies cannot necessarily be generalized. Some broad conclusions can be drawn, however, regarding the circumstances and the reasons when and why group decision-making may or may not outperform individual decision-making.

Group decision-making can show several process gains over individual decision-making. One important factor that helps groups to outperform individuals on decision-making tasks is the type of cooperation: in general, cooperative groups tend to make better decisions than both competitive groups and individuals, particularly in complex tasks (Johnson & Johnson, 2012). Another advantage of group decision-making is that when group members interact they can come up with new ideas and solutions that they would not have generated individually (Watson, 1931).
In a related vein, when members of a group share information that is unique to them, they increase the total amount of information that the group has available to make a decision (Johnson & Johnson, 2012). Other advantages of groups are that they are more likely than individuals to notice mistakes in the decision-making process (Ziller, 1957), and have better collective and transactive memory (the latter occurs when group interactions facilitate the recall of important information; Forsyth, 2010). However, the literature suggests that various factors affect decision-making in the group context, leading groups to sometimes make less optimal decisions than individuals. Some of these are reviewed below.

BIASES

Decision-making biases can occur in the group decision-making context, and these constraints may result in failed group decisions. Some examples are examined below.

Groupthink

Groupthink occurs when members of highly cohesive in-groups try to minimize conflict and reach consensus without critically testing, analyzing, and evaluating ideas. In these situations, the need for reaching consensus is more important than the quality of the process by which consensus is achieved (Jones & Roolofsma, 2000). Groupthink is defined by Janis (1972: 9) as “a mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when members’ striving for unanimity overrides their motivation to realistically appraise alternative courses of action.” Groupthink arises from certain antecedent conditions and leads to particular symptoms in use (Janis, 1972; Stangor et al., 2014). Antecedent conditions are:

- high group cohesiveness
- insulation of the group (isolation from other sources of information)
- lack of impartial leadership (directive, authoritative leadership)
- homogeneity of members’ social backgrounds
- high stress and time pressures
- difficult decision-making task

In situations of group decision-making under uncertainty in the climate change sphere, it is arguable that at least the last two antecedent conditions (high stress and difficult decision-making tasks) will be present in many cases.

The symptoms of groupthink are:

- illusions of invulnerability, creating excessive optimism and encouraging risk taking
- illusions of unanimity
- in-group favoritism
- belief in morality of the group
- rationalizing warnings that might challenge the group’s assumptions
- stereotyping those who are opposed to the group as weak, spiteful, or stupid
- pressure to conform placed on any member who questions the group, couched in terms of “disloyalty”
- self-censorship of ideas that deviate from the apparent group consensus
As a result of these symptoms, the decision-making process uses suboptimal practices, leading to faulty decisions. Examples of these suboptimal practices are:

- incomplete survey of alternatives and objectives
- failure to examine risks of preferred choice
- poor information search
- failure to work out contingency plans

Groups suffering from groupthink are unwilling to search for or discuss discrepant or unsettling information relevant to the decision context, or to bring in outsiders with different information. Group members are also afraid or unwilling to express ideas or opinions that contradict those of the leader. Groupthink is more likely to occur in groups in which members feel a strong social identity, for example when there is a powerful leader who creates a positive group feeling, or in times of stress and crisis when the group needs to “rise to the occasion” and take important decisions (Stangor et al., 2014). In the climate change domain, these situations might be expected to occur frequently in the arena of disaster management, particularly in the context of reactive disaster management, which still prevails over disaster risk management. The reasoning behind this suggestion is that disaster management is by definition associated with “disasters,” i.e., situations of stress and crisis, in which rapid decisions, which can be vast in scope depending on the nature of the disaster, must be made. Further, disaster management typically occurs under a “command-and-control” philosophy, with strong hierarchical set-ups and leaders placed in powerful positions.

In general, the way in which consensus is reached in climate change decision-making groups needs to be studied to investigate the possible vulnerability of this decision-making sphere to groupthink and its consequences. Groupthink has received practically no examination in the climate change scholarly literature, apart from sporadic mention of its possible applicability to different climate change contexts (e.g., Nicholls, 1999; Pelling et al., 2008; Jasanoff, 2010), with no experimental or even detailed theoretical discussion.

As a final note, the literature does highlight some tactics that can be used to minimize the risk of running into the groupthink phenomenon (e.g., Marold et al., 2012; Stangor et al., 2014), the review of which falls outside the scope of this literature review.

**Group Polarization**

Group polarization occurs when, after discussion, the attitudes held by individual group members become more extreme than they were before the group began discussing the topic (Myers, 1982; Brauer et al., 2006). This may appear a surprising result, given the assumption that group decision-making will tend to lead to consensus and reaching the “middle ground.” However, group decision-making may lead to more extreme decisions being taken than individuals would have taken alone. Group polarization was first noted in the context of decisions that involve risk. Groups had to recommend how a person should choose between a very positive but risky outcome, and a less desirable but certain outcome (Stoner, 1968). The group recommendation was riskier than the average of individual group members’ initial recommendations. Group polarization has since been shown to extend to more decisions than those that involve risk.
For instance, in an experiment by Myers & Bishop (1970), groups of college students who had initially racist attitudes were found to become more racist after group discussion, whereas groups of college students who had initially antiracist attitudes became less racist after group discussion. Similar findings have been found for groups discussing a wide variety of topics and across many different cultures (Stangor et al., 2014).

Group polarization does not occur in all groups and in all settings but tends to happen most often when two conditions are present:

- Group members must have an initial leaning toward a given opinion or decision. If group members generally support liberal policies, their opinions are likely to become even more liberal after discussion. But if the group is made up equally of both liberals and conservatives, group polarization would not be expected.
- Group polarization is strengthened by discussion of the topic. In addition, group polarization effects are stronger when group members have high social identity (e.g., Abrams et al., 1990).

Group polarization has also been observed in important real-world contexts, including financial decision-making in corporate boardrooms (e.g., Zhu, 2010). It has also been argued that the recent polarization in political attitudes in many countries (for example in the United States between the “blue” Democratic states versus the “red” Republican states) is occurring in large part because each group spends time communicating with other like-minded group members, leading to more extreme opinions on each side (Stangor et al., 2014). And some have argued that terrorist groups develop their extreme positions and engage in violent behaviors as a result of the group polarization that occurs in their everyday interactions (e.g., Drummond, 2002). As group members, all of whom initially have some radical beliefs, meet and discuss their concerns and desires, their opinions polarize, allowing them to become progressively more extreme.

While polarization of public opinions on climate change has been noted (e.g., McCright & Dunlap, 2011), little research appears to exist on the effects of group polarization in the context of decision-making on climate change, particularly in the policy domains. It is not unconceivable, however, that polarization could be observed in decision-making groups – for example, of policy makers – on climate change. For instance, while outright denialism (i.e., a person's choice to deny reality) may not be expected to be as likely to occur among policy makers as among the general public, policy makers could reasonably be hypothesized to divide into those believing that climate change action should take place now or in the near future and those believing that climate change action should be postponed to the long-term or indefinitely. Group polarization could thus reasonably be hypothesized to enhance both sets of attitudes when policy makers work in groups.

**Shared Information Bias**

While group discussion can, in some cases, improve the quality of a group’s decisions, this only occurs if the group discusses the information that is most useful to the decision that needs to be made. Groups, however, tend to discuss some types of information more than others. Aside from pressure to focus on information that comes from leaders and that is consistent with group norms (Stangor et al., 2014), discussion is influenced by the way the relevant information is
originally shared among group members. Group members tend to discuss information they all have access to (i.e., shared information) while ignoring equally important information that is available to only a few members (i.e., unshared information), a tendency known as the shared information bias (Faulmüller et al., 2010; Reimer et al., 2010).

Although the tendency to share information poorly seems to occur quite frequently, at least in experimentally created groups (Stangor et al., 2014), it does not occur equally under all conditions. For instance, groups have been found to better share information when group members believe that there is a correct answer that can be found if there is sufficient discussion (Stasser & Stewart, 1992), and if they are forced to continue their discussion even after they believe that they have discussed all the relevant information (Larson et al., 1994). These findings suggest that an important job of the group leader is to continue group discussion until he or she is convinced that all the relevant information has been addressed (Stangor et al., 2014). The structure of the group will also influence information sharing (Stasser & Taylor, 1991). Groups in which the members are more physically separated and thus have difficulty communicating with each other may find that they need to reorganize themselves to improve communication. And the status of group members can also be important. Group members with lower status may have less confidence and thus be unlikely to express their opinions. Wittenbaum (1998) found that group members with higher status were more likely to share new information. However, those with higher status may sometimes dominate the discussion, even if the information they have is not more valid or important (Hinsz, 1990). Groups are also likely to share unique information when group members do not initially know the alternatives that need to be determined or the preferences of other group members (Reimer et al., 2010). Little research appears to exist on the effects of the shared information bias in the context of decision-making on climate change, particularly in the policy domains.

INEFFECTIVE GROUP DECISION-MAKING PROCESSES: BRAINSTORMING

One very widely used technique that aims to produce creative decisions in working groups is known as brainstorming, first developed by Osborn (1953). Despite the widespread use of brainstorming, research that has tested the effectiveness of brainstorming provides very little evidence to suggest that it works. The overwhelming majority of individual studies and meta-analyses of those studies find that brainstorming groups: 1) do not generate as many ideas as one would expect, and 2) the ideas that they do generate are usually of lesser quality than those generated by an equal number of individuals working alone, who then share their results (Stangor et al., 2014). Brainstorming therefore represents an example of a case in which a group process loss occurs (instead of the widely assumed process gain).

Different explanations have been put forward for the failure of brainstorming. One problem is social loafing by group members, the tendency of people to exert less effort to achieve a goal when they work in a group than when they work alone (Paulus & Dzindolet, 1993). Another is social apprehension – a person’s fear that that he/she will be negatively evaluated by other group members (Stangor et al., 2014): when individuals are told that other group members are more knowledgeable than they are, they reduce their own contributions (Collaros & Anderson, 1969). The flip side is that when individuals are convinced that they themselves are experts, their contributions increase (Diehl & Stroebe, 1987).
The most important difficulty that reduces the effectiveness of brainstorming in face-to-face groups is that being with others in a group hinders opportunities for idea production and expression. In a group, only one person can speak at a time, and this can cause people to forget their ideas because they are listening to others, or to miss what others are saying because they are thinking of their own ideas, a problem known as production blocking (Stangor et al., 2014). Production blocking occurs because individuals working alone can spend the entire available time generating ideas, while participants in face-to-face groups must perform other tasks as well, and this reduces their creativity (e.g., Diehl & Stroebe, 1987, 1991).

Ways to make brainstorming more effective include, for example, the nominal group technique (Delbecq et al., 1975) or the Delphi technique (e.g., Clayton, 1997) (see box below). A number of research programs have found that electronic brainstorming is more effective than face-to-face brainstorming, for a variety of reasons (e.g., Connolly et al., 1993; Gallupe et al., 1994; Mesmer-Magnus et al., 2011), although in large part it is more effective because it reduces the production blocking that occurs in face-to-face groups. Hence, techniques that make use of initial individual thought followed later by group discussion represent the best approaches to brainstorming and group creativity. A group that needs to make a decision can effectively make use of these insights by asking members to spend some time thinking about and writing down their own ideas before the group begins its discussion (Stangor et al., 2014).

Of relevance to the climate change domain is the fact that while brainstorming is used or recommended in the scholarly literature on climate change decision-making (e.g., Cornish, 2004, van de Kerkhof, 2004), the above issues regarding its effectiveness do not appear to have been taken into consideration.

### The Nominal Group Technique and the Delphi Technique

The nominal group technique is a structured variation of a small-group discussion to reach consensus. The basic process for conducting this technique starts with a moderator presenting a question or problem to the group. Each person is asked to generate ideas, working in silence and independently, and write them down. The ideas are collected by sharing them in round-robin fashion (one response per person each time), until all ideas have been recorded. Each recorded idea is discussed to determine clarity and importance. Each person is then asked to individually and anonymously vote to prioritize the ideas. The votes are tallied to identify the ideas rated highest by the group as a whole.

The Delphi technique’s original purpose was to obtain the consensus among a group of experts. A valid Delphi process would consist of at least three rounds of a questionnaire survey (though the decision about the number of rounds is largely pragmatic). The initial questionnaire round serves to identify broad issues related to the problem at hand; a questionnaire consisting of open-ended questions is circulated to a panel of experts. The responses are analyzed and used to construct the second questionnaire. The second and subsequent rounds are more specific, with the questionnaire seeking the rating or ranking of various items in terms of their significance. As the iteration progresses, there tends to be a convergence to consensus. Some of the key features of the Delphi technique are anonymous responses, and feedback on responses after each round.
REFLECTIONS ON DECISION-MAKING IN A GROUP CONTEXT

For space and time constraints, not all factors affecting group decision-making can be examined (nor within the section on biases were all biases that affect group decision-making reviewed). The above discussion intended to make clear how group decision-making can be distorted, focusing particularly on different biases that lead to imperfect or failed decisions, and on brainstorming, a widely adopted process technique for group decision-making. Marold et al. (2012), for instance, highlight that social context, social interactions, and group dynamics can all influence decision-making under uncertainty. Therefore, the widespread belief that group-based approaches may enhance, or correct for, errors in individual judgment and decision-making is challenged.

It is important to highlight, again, that very little research has examined the effect of group decision-making biases and other factors in the context of the climate change field; there is, however, little reason to believe that such biases and factors would not affect decision-making in this domain as they do in others.
3. STRATEGIES TO DEAL WITH UNCERTAINTY

Having unpacked the factors that affect decision-making under uncertainty, the attention is now turned to documented strategies to deal with this uncertainty to provide insight on how people attempt to compensate for uncertainty when making decisions.

ADAPTIVE RISK-MANAGEMENT STRATEGIES

Uncertainty affects decision-making and action by leading to effects such as hesitancy, indecisiveness, and procrastination (Marold et al., 2012). Individuals and groups need to find ways to handle uncertainty. Lipshitz & Strauss (1997) suggest three broad classes of strategies used to cope with uncertainty: suppression, reduction, and acknowledgment.

Strategies of suppression consist of the denial of uncertainty, such as ignoring uncertainty, relying on intuition, or taking a gamble. Using traditional decision-making approaches in the climate change field can be considered a form of suppression, as traditional approaches are mostly based on past experiences, which may not be applicable in the future or reach the desired outcomes when the context of uncertainty applies.

Strategies of reduction involve trying to increase information or predictability. Some examples of such tactics consist of collecting more information, asking for advice, or delaying action until more information is available, a common reaction to the receipt of uncertain climate information. Two relevant considerations pertain to tactics of reduction. First, as highlighted in IOM (2013), while some analysis and description of uncertainty is always important, how many and what types of uncertainty analyses are carried out should depend on the specific decision problem at hand. The effort invested in collecting data on and analyzing specific uncertainties should be guided by the extent to which the results of the analyses are likely to affect the decision. For example, would perfect information change the decision? In the simplest case, if a decision would stay the same for all states of information and analysis results, then it would not be worth conducting the analysis. To consider an example in the climate change context, rainfall projections for southern Africa have much higher uncertainty than temperature projections (IPCC, 2015). Delaying decisions that are affected by rainfall parameters until uncertainty is minimized would make more sense than delaying decisions that are affected by temperature parameters. In the latter example, the losses from delaying decisions are likely to be higher than the gains, given there is relative certainty that temperatures will increase. “Value of information” methods now seek to weigh the value of seeking more information and analysis against the costs of further delay (Kasperson, 2008).

The second relevant consideration to tactics of reduction consists of one of the characteristics of deep uncertainty briefly mentioned in section 1.1: its uncertainty is not likely to be reduced by additional research within the time period in which a decision must be made. Given that the climate change domain is characterized by deep uncertainty, tactics of reduction are likely to
prove of limited benefit in the context of climate change decisions. Apart from the uncertainty associated with climate change models, decision makers and scientists are unlikely to achieve a reduction in the uncertainty around climate change (i.e., a reduction in the number of feasible future scenarios) in the near future because no global consensus exists among politicians about a climate target or one or more pathways to achieve the maximum 2°C target of the Paris Agreement.

Hence, the climate change literature outlined a few different approaches that decision makers could use to decide upon a wide range of decision alternatives. Some of these are briefly outlined below. However, it is important to note that these all fall under the third broad set of tactics used to cope with uncertainty, called strategies of acknowledgement. Lipshitz & Strauss (1997) describe these as tactics that take uncertainty into account in selecting a course of action or preparing to avoid possible risks. Examples are: avoiding irreversible action; weighing pros and cons; preempting (generating specific responses to possible negative outcomes); and improving readiness (developing a general capability to respond to unanticipated negative developments).

In the context of the climate change risk management field, some of the main approaches and strategies that essentially consist of tactics of acknowledgment are: robust decision-making, portfolio management, using the precautionary principle, no-regret strategies, reversible/flexible strategies, safety margin strategies, and strategies that reduce decision-making time horizons (e.g., Hallegatte, 2009). Portfolio management, to discuss one example, is a simple strategy that relies on building a portfolio of adaptation strategies and measures; in other words, it is a diversification of management strategies (e.g., Yousefpour & Hanewinkel, 2016). In forestry, for example, it would consist of planting a variety of tree species. Portfolio management rests on the idea that integrating sufficient flexibility to switch from one strategy to another in a dynamic decision-making process can provide the basis for staying, at least partly, adapted and taking advantage of potential opportunities in the future (Yousefpour & Hanewinkel, 2016: 146). No-regret options, to discuss another example, are strategies that yield benefits even in the absence of climate change. For example, land use policies that aim to limit development in areas that are flood-prone under past and current climate conditions would not only reduce disaster losses in the present climate, but may be even more advantageous under climate change (Hallegatte, 2009).

The strategies and approaches discussed above have the ultimate goal of resulting in decisions that are robust to the uncertainty of climate change and its impacts (i.e., that perform satisfactorily under all climate change scenarios). However, this robustness is likely to be achieved at the cost of optimality; e.g., moving away from maximum production and benefit (e.g., Hallegatte, 2009; Yousefpour & Hanewinkel, 2016). The strategies and approaches discussed above can be considered to fall under a more general philosophy called adaptive risk management (also called adaptive management, adaptive co-management, or adaptive risk governance), which has grown as a response to the uncertainty challenges faced when dealing with the environment, sustainability, and technology (Dietz, 2013). At the core of adaptive risk management is that decisions should take explicit account of uncertainty, facilitate social learning, maintain some flexibility, and revisit the decision periodically (e.g., Dietz, 2013).
CHOOSING AMONG ACTIONS WITH UNCERTAIN OUTCOMES: NORMATIVE MODELS VERSUS DESCRIPTIVE MODELS/REALITY

Normative models of decision-making, which explore how people should make decisions (section 1.1.) assume that each decision is made up of four components: 1) a set of possible actions; 2) a set of possible future states of the world; 3) information on the probability of different future states of the world; and 4) information about the outcomes of possible actions under future states of the world (Marx & Weber, 2012). Normative models offer many advantages (Marx & Weber, 2012). First, if we know how a “rational” decision maker should behave, we have a benchmark against which to compare actual behavior. In this regard, prescriptive interventions can be implemented to help decision makers to more nearly satisfy the normative ideal (Lipshitz & Cohen, 2005). Second, their clear analytic basis can be easily updated. And third, the costs versus the benefits of acquiring more information can be relatively easily assessed.

Normative models also bring a set of weaknesses to the table (Marx & Weber, 2012). For instance, they cannot explain why or how observed decisions are made (i.e., when an observed decision departs from the norm, these models cannot provide an explanation). These models further expect decision makers to be fully rational as well as fully informed about the key components of the decision problem (they also often assume that there is sufficient knowledge about the outcomes available), assumptions that are consistently violated in the real world. Normative models often only consider one decision maker and not groups and the processes of group decision-making. These models have other weaknesses too, covered in Marx & Weber (2012). What is of interest here is that the shortcomings of normative models gave rise to descriptive models that attempt to explain how and why people actually make decisions.

One of the most commonly used normative models to predict decision-making under uncertainty is expected utility theory (EUT). Normative-based EUT states that in the face of 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) (Marx & Weber, 2012). Thus, decision makers should behave as if they were maximizing the expected utility of choice options. Given that, in reality, people behave differently than they ought to under EUT, a psychologically more realistic alternative to EUT was offered by Kahneman & Tversky (1979). These authors 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). This descriptive variation of EUT is called prospect theory.

Prospect theory is an account of probabilistic decision-making in economics. Created by Daniel Kahneman and Amos Tversky in 1979, prospect theory departs from the normative theories, which assume the rationality of economic agents; heuristically biased assessments of probability and utility had a strong impact on the theory (Kahneman & Tversky, 1979). Developed as a means to explain decisions under uncertainty, prospect theory is grounded in the notion that “decision framing influences the way individuals perceive a problem which then leads to different actions” (Elijido-Ten, 2017: 958). In the most basic sense, if considering gains and losses of equal amount, prospect theory assumes that the threat of a loss is generally given
more weight than the opportunity to gain (Elijido-Ten, 2017). For just one example of the empirical support for prospect theory, Barberies et al. (2001) note that investors are more sensitive to reductions in financial wealth than to increases.

In some of their initial work on prospect theory, Tversky & Kahneman (1981) provided experiment participants with a choice between two competing disease treatment programs, one treatment representing risk and uncertainty and the other representing safety and certainty. These were presented through the lens of how many lives that could be saved or how many lives that could be lost, yet with the same absolute outcome. The study found that when framed in terms of the lives gained people went for the more certain option, while when framed in terms of lives lost people’s choice leaned toward the more uncertain. Prospect theory thus considers people to be more inclined to take risks to avoid losses than they are to take risks when considering gains (Spence & Pidgeon, 2010).

Prospect theory emphasizes decision weights over subjective probabilities, in that people are seen as giving more weight to the amount of a possible gain than to the odds of that gain (Myerson et al., 2011). For example, people may be very aware of the odds of winning when buying a lottery ticket, but they give more weight to the amount of the possible win. In a similar vein, Botzen & van den Bergh (2012) note that people tend to either neglect or overweight low-probability risks, and that the way in which such risks are communicated, as well as personal perceptions of flood risks, play a large role in shaping the subsequent action or inaction.

In the context of climate decision-making under uncertainty, two of the major implications for how prospect theory may be applied by ATLAS can be summarized as follows:

- **Certainty**: People have a strong preference for certainty, tending to overweigh options that are certain, and to be risk-averse for gains. Individuals would rather get an assured, lesser win than take the chance to win more (but also risk getting nothing) (note that the overall expected value, or outcome, of each choice is equal). Losses are treated in the opposite manner as gains. When aiming to avoid a loss, people become risk seekers and take the gamble over a sure loss in the hope of paying nothing. Again, both options have equal expected values. These effects could possibly explain why decision makers are reluctant to implement adaptation measures where the costs exceed the benefits in the present. For example, increasing the design standard of a road surface to cope with possible future increased rainfall intensity only has benefits if that road actually experiences storms of such magnitude in the future – this is an uncertain gain where predictions about future rainfall are uncertain. The costs, however, are incurred at present. Thus, if decision makers continue using current design standards, they face a sure gain (in the form of money saved) over an uncertain gain; whereas changing design standards represents a sure loss in return for a future uncertain gain.

- **Loss aversion**: People are loss-averse, and therefore tend to give losses more weight than gains; most people will act so that they minimize losses, even though the probability of those losses is tiny. Loss aversion, combined with the tendency to overweight small probabilities to guard against losses, means that even though the likelihood of a costly event may be tiny, people would rather agree to a smaller, sure loss than risk a large loss. This explains why people take out insurance, preferring to make a small (but regular and indefinite) payment to avoid a potentially large loss. People’s reactions to losses are more extreme than their reactions to gains.
Prospect theory is the most influential theory on decision-making under uncertainty (Botzen & van den Bergh, 2012), and provides one lens for further understanding decision-making in the context of climate change. Communication of climate science poses a great challenge in that details around time scales, extent, and consequences remain uncertain, a challenge given that in the public eye uncertainty is counter to perceived scientific authority.

A number of studies argue that a solution to the possible inaction resulting from uncertainties relating to various aspects of climate change communication may to some extent lie in the framing of uncertain messages (Bertolotti & Catellani, 2014; Botzen & van der Bergh, 2012; Kumarasiri & Gunasekarage, 2017; Morton et al., 2011; Spence & Pidgeon, 2010). Focusing on decision-making among executives in large Australian companies, Kumarasiri & Gunasekarage (2017) find that decision makers are threat-biased and thus more likely to act on carbon emission management when climate change is framed as a threat rather than as an opportunity. They further show that financial pressure, driven by regulations and reputational pressures, is the main underlying driver of action among the executives.

However, the nuances that emerge in studies vary, reflecting how losses versus gains framing is but one aspect that further interacts with other factors influencing communication. Bertolotti & Catellani (2014) argue for the usefulness of going beyond “simple” loss and gain framing, showing that other levels of message framing and the content of messages also factors in. They find that while attitudes toward policy messages focused on renewable energy sources are more persuasive when presented in terms of the positive outcomes of adopting the policy and with emphasis on growth as the main concern, policy messages focused on greenhouse gas emissions are more persuasive when presented in terms of negative outcomes that can be avoided through the adoption of the policy and emphasis on safety as the primary concern.

Further nuances are reflected in Spence & Pidgeon’s (2010) research on attitudes and action toward climate change mitigation, which goes beyond gains and losses framing, reflecting the role of both the amount of information remembered from communications and the role of fear. Van der Linden et al. (2015) highlight that climate solutions are often framed as an immediate, certain loss for society and individuals (e.g., higher taxes, reducing energy consumption), while climate change impacts are framed as potential (i.e., uncertain) losses in a distant future. Given that prospect theory predicts that people are more reluctant to take action when losses are paired with uncertainty, van der Linden et al. (2015) point out that these framings encourage people to maintain the status quo rather than take action on climate change. They suggest that policy conversations should move away from highlighting the potential future losses of not acting on climate change to emphasizing the gains of immediate actions.

More explicitly focused on the uncertainty in climate change predictions, Morton et al.’s (2011) research findings are very much consistent with the tenets of prospect theory. They find that the losses versus gains framing of a climate change message impacts the implications of communicating uncertainty in climate change predictions. Specifically, when the possibility of avoiding loss (i.e., predictions of what will not happen) is presented, increasing uncertainty results in increased intention to engage in climate change mitigation action. When the possible losses (i.e., predictions of what will happen) are presented, increasing uncertainty results in
decreased intention to engage in action. As Morton et al. (2011) argue, an important implication is that uncertainty need not be a climate change communication barrier, and that through subtle shifts in framing, uncertainty can actually be used as an asset that motivates people to be cautious.

Importantly, as emphasized by Tversky and Kahneman themselves in reflecting on prospect theory, “Theories of choice are at best approximate and incomplete” (1992: 317) and can as such provide partial insight into the climate change-related decision-making picture. As reflected in the type of studies outlined above, prospect theory as a means to better understand decision-making in the context of climate change has largely been applied in the context of climate change mitigation. No such research focusing explicitly on the losses versus gains framing of climate change projections and related uncertainties in the context of climate change adaptation was identified.
4. CONCLUSIONS AND WAY FORWARD

This literature review provides an entry point into the academic discourse of using uncertain climate information for decision-making. It draws on contributions from the field of psychology, summarizing how uncertainty affects decision-making, and describing application of uncertain information to decision-making in the fields where this research has been most prominent to date, such as finance and health.

The purpose of this literature review is to identify psychological concepts that are relevant to informing decisions that involve consideration of climate information. The information in this literature review informs an additional investigation to be presented in a forthcoming research study. Criteria for further investigation include: 1) the need for the psychological concept to hold potential for informing the framing and format of climate information, with the aim of stimulating greater uptake of climate information, and 2) the need for the psychological concept to have broad applicability for testing across a diverse group of decision makers, regardless of factors such as age, gender, culture, and experience. A subsequent research piece will focus on testing the concepts of experiential versus analytical information, prospect theory, and, to a lesser extent, delay discounting in a scenario-based survey and workshop.

The literature shows that experiential information takes precedence over analytical information in decision-making processes. Taking advantage of this finding may have significant positive implications for increasing the uptake of climate information in decision-making.

Prospect theory assumes that the threat of loss is given more weight than the opportunity to gain, and that people are more inclined to take risks (act on uncertain information) to avoid losses than they are to take risks when considering gains. If this is the case, then uncertain climate change projections framed in terms of possible losses are more likely to result in action than uncertain climate change projections framed in terms of possible gains.

Delay discounting deals with how the value of an award decreases with time and, hence, the further into the future the reward is set to materialize, the less valuable it is. Accordingly, with the climate change signal being most evident in the medium to distant future, and the subsequent focus on mid- to end century, the value of acting (adapting) now is potentially discounted if the reward is only expected to materialize in the distant future.

These concepts, for different reasons, appear to provide some of the greatest potential for testing in a scenario-based survey and workshop, and informing the academic discourse on the use of uncertain climate information. The results of scenario-based testing and further academic study should help foster more effective decision-making for climate change policy, planning, and action.
5. REFERENCES


