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The role of knowledge, learning and mental models in public perceptions of climate change related risks[1].

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Introduction:

In the past decade it has become clear that humanity is increasingly facing tremendous challenges of climatic change. Yet, little is understood about the way in which people's mental representation of the associated geo-physical risks has shaped response behaviours. Part of the problem relates to the kind of risk that climate change represents; a so-called *'un-situated'* risk (Hulme 2009). The term 'un-situated' means that in most people's immediate environment, the risks associated with climate change are often not directly observable. Since climate change is a slow, on-going, largely invisible process, this does not coincide with the traditional way in which humans perceive their external environment, making it difficult for people to accurately estimate climate-related risks. In addition, individuals' perception of how climate change is likely to impact them personally often seems to differ from their perception of how climate change is likely to affect society as a whole. It is therefore important to develop a better understanding of how individuals construct their knowledge, learn and ultimately make decisions about climate change.

There are two broad challenges to learning towards and maintaining a sustainable future. The first relates to attaining a detailed understanding of the effects of changes in Earth's systems, due to geophysical, biological, ecological, social, and economic causes. Second is the challenge of enabling effective mitigation and adaptation measures under such changing conditions. In this chapter, we address both challenges by looking at how individuals learn, perceive and construct mental representations of climate-related risks and critically review different theories and case studies that aid in understanding how these factors guide public attitudes and response behaviours. We recognize that addressing the complexities of climate change calls for an integrated approach. Consequently, we take an interdisciplinary perspective in the current chapter and aim to present a holistic overview of risk understanding on the individual level. In the last section (Section IV), we extend the discussion to address societal change towards climate change and sustainability more generally, and comment on associated policy implications for eliciting and maintaining effective mitigation and adaption responses.

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I. Knowledge, Mental Models and Public Understanding of Climate-Related Risks.

Cognitive scientists have often described the way individuals process and organize incoming information as an interrelated network of mental structures. According to *schema theory*, knowledge should therefore be seen as an elaborate network of abstract mental structures that represent an individual's understanding of the external world (Anderson 1977). More recently, the study of '*mental models*' has gained increased attention. A mental model is a person's internal, personalized, intuitive and contextual understanding of how something works (Kearney and Kaplan 1997). It is important to consider how individuals learn, understand, and form mental representations of climate change, as mental models have three major functions: (1) they serve as a framework into which people fit new information; (2) they define how individuals approach and solve problems; and perhaps most importantly (3) they help formulate actions and behaviour (Carey 1986; Morgan et al 2002). Particularly, because a sizable portion of the literature indicates that most people's mental model contains fundamental flaws and that a more substantial and meaningful understanding of the causes, consequences, and solutions to climate change is still lacking (APA 2010; Leiserowitz 2006; Steg and Vlek 2009). To highlight the importance of studying people's knowledge and mental models of risk factors, consider that some individuals erroneously perceive an increase in global mean temperature as something rather pleasant (Meinders 1998), being unaware of the large geophysical consequences potentially associated with such an increase. Indeed, incorrect mental models misguide people's understanding of the potential risks involved and thereby contribute to a 'wait and see' attitude (Xiang 2011).

One reason that explains why people hold such limited understanding is that the complexity of climate change often defies our intuitive understanding of concepts of stock and flow, as thinking about complex systems generally exceeds human cognitive capacity (Simon 1955). For example, in a set of experiments run by Sterman and Booth Sweeney (2002, 2007) and Sterman (2008) students deduced that a reduction in CO_2 emissions would be followed by an immediate reduction in global mean temperature. While such matching-heuristics are effective in daily experience with simple systems (where input and output are closely related in time and space), they are inappropriate for complex systems with multiple feedback loops and extended time delays such as climate change modeling (Xiang 2011).

One of the problems in trying to communicate and educate people about the potential consequences of climate change lies in the fact that people tend to process information in a manner that is consistent with their pre-existing beliefs. Selectively attending to evidence that confirms pre-existing beliefs and the negligence, re-interpretation and distortion of information to the contrary is generally referred to as '*confirmation bias'* (Lewicka 1998). Subsequently, much information that is retained in an individual's memory tends to be information that supports pre-existing thoughts, beliefs and attitudes.

Consider two relevant empirical studies that clearly illustrate these concepts: the first study assessed how concerned Democrat and Republican voters were about the risks associated with climate change. Increased levels of concern were indeed associated with increased knowledge levels among Democrats and individuals that expressed trust in the scientific

consensus on climate change. Yet, increased knowledge did not lead to more concern among individuals (e.g. Republicans) who were already sceptical about the occurrence of anthropogenic climate change from the outset (Malka, Krosnick and Langer 2009). A second example of the tendency to selectively retain information is illustrated by a case study on farmers in Illinois, USA. Farmers who believed that their region was undergoing climate change recalled temperatures and precipitation levels congruent with those beliefs. Yet, other farmers in the same region who believed in a constant climate recalled weather statistics congruent with those beliefs. In reality, both groups showed an equal amount of error in their recollection of weather statistics (Weber and Sonka 1994).

These cases studies serve to illustrate that the way in which we process information, learn and organize our knowledge, strongly influences how we view and interact with the external world. The purpose of the following section is to explain in more detail (a) how people construct perceptions of climate-related risks and (b) how individuals and societies currently perceive and respond to the potential risks associated with climate change.

II. Through the Looking-Glass: The Multi-Dimensional Nature of Risk Perception

While risk perception is an inherently complex process, at least five different dimensions have been identified that create, influence, and help shape perceptions of risk (Hillson and Murray-Webster 2009). These dimensions include: (1) *cognitive,* (2) *subconscious*, (3) *affective* (4) *socio-cultural* and (5*) individual factors*. From a purely cognitive and consequentialist perspective, the concept of 'risk' has two sub-components: (1) *uncertainty* – which relates to the probability or likelihood of a potential danger and (2) an *evaluation* of how much the threat 'matters', (i.e. an estimation of the *impact or severity* of the potential risk (Hillson and Murray-Webster 2009). Such mental 'likelihood/impact' risk assessments require individuals to employ analytical reasoning skills based on the information they have at hand. The main (economic) model under which risk is appraised in this manner is Expected Utility (EU) theory (Von Neumann and Morgenstern 1944). From an economist's viewpoint, a risk preference can be seen as a descriptive label for the shape of a utility function that is assumed to underlie an individual's choices (i.e. a measure of the desirability of a good or service to an individual). Individual utility functions are derived from a set of choices over 'risky alternatives'. The shape of a utility function denotes an individual's position on a risk continuum (e.g. risk averse, risk neutral or risk seeking). These attitudinal predispositions to risk are often thought to be representative of a general personality trait (Weber et al 2002). For example, economic frameworks of risk have been used to estimate individual willingness to pay for climate mitigation policies. This is typically done by presenting individuals with a hypothetical set of certain-versus-risky investment choices. Using this method, Cameron and Gerdes (2007) found that more risk-averse individuals and those who expect the cost of acting now to be preferable to the cost of acting in the future tend to express higher support for mitigation policies. Thus, in this context, risk is mainly addressed by formal logic, probability calculus and utility maximization (Weber 2006).

Yet, Kahneman and Tversky (1979) have argued that EU theory fails to predict actual behaviour in many decisions involving risk. In particular, lab experiments have pointed out that individuals are not consistently classified as risk averse or risk seeking across time and

situations (e.g. Shoemaker 1990) and a wide variety of behavioural phenomena show that people's actual preferences systematically violate the axioms of EU theory (e.g. see Ellsberg 1961; Slovic, Fischoff and Lichtenstein 1979). Simon (1955) suggested that the analytical demands of utility maximization generally exceed the cognitive capacity of the typical individual faced with complex decisions. Instead, actual decision-making behaviour, as opposed to a normative model of rational behaviour, involves simplified representations of complex problems and reliance on heuristics (rules-of-thumb). We take a heuristic to be an expression of fast, intuitive, unconscious information processing. Or in the words of Gigerenzer (2007): the "*adaptive intelligence of the unconscious.*" To this extent, alternative approaches to EU have been introduced in the field of behavioural economics, most notably 'Prospect Theory' (PT) (Kahneman and Tversky 1979) which recognizes judgment heuristics and biases. PT focuses heavily on the framing of risk questions and has identified a large range of heuristics and biases that humans employ when making decisions under uncertainty, including, but not limited to: *status quo bias, the availability heuristic, the endowment effect, the certainty effect, anchoring* and the *representativeness heuristic.* An interesting and relevant implication of prospect theory is that individuals tend to be risk-averse in what is known as the *'gain domain'* (i.e. when there is something to be gained) and risk-seeking in the '*loss-domain'* (i.e. people are willing to take larger risks if they already have to lose something from the outset). Therefore, if the consequences of climate change can be framed under the loss domain, this might help explain why individuals and societies are taking more risk (by not changing their behaviour) than what is generally advised by governments and scientists.

In addition, perhaps one of the most quoted biases in explaining risk-taking behaviour is '*optimism bias'*: a systematic tendency for individuals to underestimate potential negative outcomes (Weinstein 1980). In fact, in the context of climate change, individuals tend to display an unrealistic sense of optimism; as most people believe that climate change is likely to affect others (e.g. the third world), but not the individual in question (O'Neill and Nicholson-Cole 2009). More generally, the task environment of climate change is defined by high-level ambiguity: actors, whether scientists, policy makers, or the public often have to make decisions based on limited and uncertain information. Paired with cognitive constraints such as a low-level discernibility between numeric risks, individuals naturally tend towards heuristics to form a general view of climate change risks.

Traditionally, most theories that deal with risk and decision making under uncertainty have neglected the role of emotions in risk perception (Loewenstein et al. 2001). Yet, it has become increasingly apparent that individuals have a hard time relating to abstract risk messages (e.g. "climate change" versus "global warming" or "high probability of occurrence" versus "reasonable threat"). Given that the average member of the general public is not specifically trained to interpret statistical probability assessments, other research offers clues as to how humans construct their perceptions of risk. Mounting evidence from cognitive, social and clinical psychology has indicated that risk perceptions (across domains) are strongly influenced by emotion-driven processes (e.g. Chaiken and Trope 1999; Sloman 1996; Weber, 2006). Emotional reactions to risks often diverge from cognitive judgments and when such divergence occurs, emotional influences generally override cognitive deliberation (Loewenstein et al. 2001). Some researchers actually state that the public may not act upon

simple information about probabilities unless this information is given emotional significance (Slovic et al. 2004).

These findings are not entirely surprising. The human brain is fast and experienced in mapping cues from the environment (i.e. threats) into affective responses (Weber 2006). In fact, when responding to immediate environmental threats, instinctive emotions such as *fear* and *anxiety* arise in an evolutionarily older part of the brain known as the 'amygdala'(which is the center of the brain's limbic system) and plays a key role in emotional memory and processing (Davis 1992). It is important to note that different environmental risks can elicit different emotions (Böhm 2003). For example, industrial environmental risks (e.g. water pollution) tend to evoke *anger* and lead to the boycott of the polluter, while risks brought about by the activities of other individuals (e.g. car pollution) tend to invoke ethical emotions such as *guilt* and *shame.*

A more subtle form of emotion defined specifically as a positive (like) or negative (dislike) evaluative feeling towards external stimuli is known as '*affect*' (Slovic et al. 2004). An affective response is often a first reaction that guides information processing and judgment (Zajonc 1980). Particularly, people tend to rely on what is called an 'affective pool', which includes all the positive and negative affective associations that someone holds with regard to a risk representation, consciously and unconsciously (Breakwell 2010). In fact, in one US study negative affect and imagery toward climate change were identified as the strongest predictors of global warming risk perceptions (e.g. Leiserowitz 2006). Similar results were found in a Swedish study linking risk judgments of climate change to affective evaluations (Sundblad et al. 2007). These findings highlight the importance of emotions in the construction of environmental risk perceptions.

Cultural anthropologist Mary Douglas and political scientist Aaron Wildavsky have criticized existing theories of risk (including economic, cognitive and affective explanations) for neglecting the influence of social and cultural factors in the formation of individual risk perception. This criticism is reiterated by Dake (1991) :

"*An understanding of who fears what and why, requires serious attention to the political, historical, and social context in which risks are framed and debated…mental models of risk are not solely matters of individual cognition but also correspond to worldviews entailing deeply held beliefs and values regarding society, its functioning and its potential fate"* (p.62).

The cultural theory of risk (Douglas and Wildavsky 1982) suggests that individuals and groups deploy different perceptual lenses to arrive at their particular interpretation of the world and proposes that both economic and psychometric approaches 'depoliticize' risk and thereby do not accurately reflect an individual's commitments to competing cultural and political structures. Cultural theory makes a distinction between *social relations* (the interpersonal level) and worldviews (broadly shared values and beliefs). Based on years of anthropological research Douglas constructed a typology of risk culture, perhaps better known as the 'grid-group' system, where these broad (global) competing cultural types are delineated in more detail. These typologies are; '*egalitarianism'*, '*individualism'*, *'hierarchism'* and '*fatalism*'. Their relative position on the group-grid scale is determined by

the extent to which individuals feel bounded by feelings of belonging and solidarity (*group)* and the amount of control and structure that people maintain in their social roles *(grid)*.

Empirical research shows that such presuppositions about the nature of society lead people to perceive the same risks in different ways and as a result, cause a divergence in support of different public policies (e.g. Slovic et al. 1998; Steg and Stievers 2000). Cultural theory of risk, however, has been criticized for lacking empirical testing via recognized social science techniques (e.g. O'Riordan and Jordan 1999). Some of these criticisms have led to the creation of the '*culture-cognition'* project – an initiative that seeks to connect cognitivist and cultural theories. Cultural cognition of risk acknowledges that cognitions are shaped and influenced by group-grid worldviews. In fact, culture can condition the impact of social influences on risk perceptions (Kahan and Slovic 2006). Consider that young children are not in a position to sensibly evaluate the risks associated with climate change and thus rely on others to inform them about the potential risks involved. Significant referent individuals that youngsters rely on, unsurprisingly, tend to be people that share the same cultural worldview (Kahan and Slovic 2006).

The mass media as well as interpersonal interactions play a crucial role in circulating existing social representations of risk in a given culture. The Social Amplification of Risk Framework (SARF) highlights how risk perceptions are often amplified or attenuated depending on how they are communicated (Kasperson et al. 1988). Given that, for most people, the media is a prominent and integral source for acquiring information about climate change (e.g. Boykoff and Rajan 2007; Ungar 2000), it can significantly influence the public's perception (e.g. Sampei and Aoyagi-Usui 2009; Stamm et al. 2002). Steg and Sievers (2000) advise: '*risk communication should be in line with the cultural biases of the target group as people tend to have more trust in risk communication if the message is in line with their cultural biases*'. In short, researchers have clearly demonstrated the importance of cultural worldviews in perceptions of environmental risks more generally (Dake 1991) and also in the specific context of climate change (Leiserowitz 2006).

In addition to cognitive, subconscious, affective and socio-cultural considerations, clear individual differences in risk perception have also been noted. For example, research has indicated that there are significant differences in risk perception between men and women (e.g. Finucane et al. 1997). In addition, while some studies indicate systematic ethnic and socioeconomic differences in the perception of environmental risks (e.g. Flynn, Slovic and Mertz 1994), other recent research indicates that some variation in individual risk behaviour is likely to arise as a result of genetic predispositions (Kreek et al. 2005; Kuhnen and Chiao 2009). Furthermore, the psychological concept of '*self-efficacy'*, (i.e. an individual's perception of the capacity to bring about change through his or her own behaviour) (Bandura 1977) has been implicated in explaining variation in risk perception. As lower levels of self-efficacy would imply a decreased ability to protect oneself, this is likely to be associated with higher levels of perceived personal risk (Spence et al. 2011; Breakwell 2010). Finally, differences in the level of experience and familiarity that individuals hold with regard to certain risks also strongly influence perception (Song and Schwarz 2009;Whitmarsh 2008). This topic however, will be further explored in the following section (IV).

So far we have discussed five broad elements that construct and help shape an individual's perception of climate-related risks. In a reductionist approach, each of these elements can be considered independently. Yet, we want to stress the interconnected nature of all the aforementioned factors and highlight that environmental risk perception is the result of a complex set of interactions that encompasses cognitive, subconscious, emotional, socio-cultural and individual factors. In the next section we review existing perceptions of climate change related risks and how they may influence different behavioural responses in the general public.

III. Risk Perceptions of Climate Change and Public Responses

If a precondition of risk perception is that humans must be able to perceive a threat or danger in their direct environment, as some perceptual psychologists would argue (e.g. Gibson 1972), then climate change, as a broader concept, provides a unique challenge. This is so because direct experience is thought to strongly influence risk perception (Whitmarsh 2008), particularly because experiences can invoke strong memorable feelings, possibly making them more dominant in processing (Loewenstein et al. 2001).While the concept of climate change cannot directly be observed, consequences that are apparently correlated with climate change can be observed (i.e. increased severity and frequency of natural disasters). Yet, it remains questionable whether people actually attribute these consequences to climate change (Bickerstaff, 2004). In fact, some individuals may attribute natural disasters to higher powers, spiritual beliefs or other, unrelated factors. In addition, the response behaviours to climate-risks address mitigating the threat at hand (e.g. flooding) and not climate change as a broader concept. For example, a sensible response to flooding would be to move away from the danger zone, buy insurance or take other protective measures to ensure personal safety (i.e. *adaptation* responses). There is no obvious reason to assume that whenever a person's house floods, this provides an incentive for the individual to actively diminish his or her carbon footprint. For example, a recent study in the UK shows that flood victims did not particularly attribute the experienced flooding to climate change (Whitmarsh 2008); instead, they rather identified local observable causes (e.g. lack of water-course maintenance). Thus, this implies that, while direct (environmental) experience certainly influences risk perceptions and behaviours, a difference in perceptual attribution is likely to determine the nature of the response behaviour.

To illustrate, although familiarity with risks has been shown to lower risk perceptions (Weber 2006), evidence indicates that people living in low-lying coastal areas tend to have a heightened sense of personal risk (Brody, Zahran, Vedlitz and Grover 2008). Still, it has remained relatively unclear whether people living in places physically vulnerable to climate change or people that have had past experiences with the consequences of climate change also tend to show greater preparedness to take action (i.e. actually engage in *mitigation behaviours*). To this extent, a recent study by Spence et al. (2011), representative of the UK national population, found that past flooding experiences were significantly related to increased preparedness to reduce energy use (and therewith CO2 emissions). In particular, past flooding experiences mediated onto risk perception which in turn increased individual preparedness. Additionally, other research has also indicated that personal risk perceptions explain variance in behavioural intentions to address global warming (e.g. Bord, O'Connor

and Fisher 2000). These recent findings suggest that direct risk perceptions seem to be able to elicit both *adaptation* and *mitigation* behaviours.

The key take-away is that the effect of risk perception on behaviour is largely mediated by the extent to which individuals *attribute* their risk perceptions to a particular *source* (figure 1). Note that adaptation is likely to occur in both instances as (compared to mitigation) it is often non-optional (unless the aim is to stimulate preventive measures).

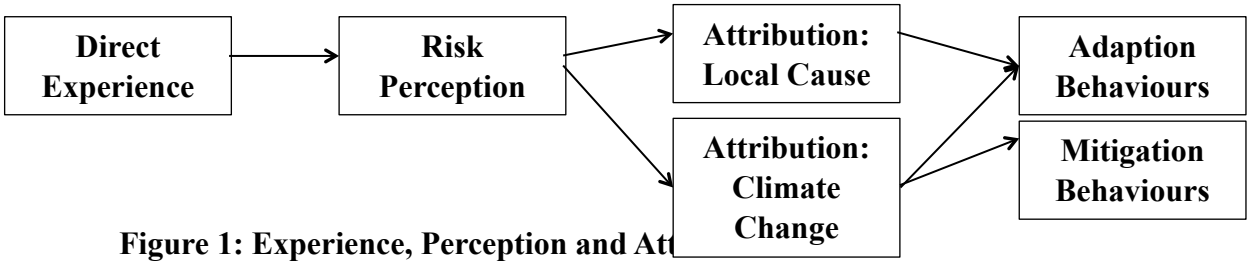

Figure 1: Experience, Perception and Att

So far we have discussed instances where people were able to *observe* some of the consequences potentially associated with climate change. But often there is a *disassociation* between the cognitive information that informs individuals that there is in fact a risk to be worried about and the inability for many people to observe or experience this risk in their direct environment (Weber 2006). Because there is no one coherent method of how an individual's 'risk perception' is measured, often risk perception represents an index of different constructs. For example, such measures may include 'societal risk factors' or a measure of 'general concern', 'perceived seriousness of a threat' (i.e. severity times likelihood estimations) or measures of 'personal worry' (c.f. Bord, O'Connor and Fisher 2000; Leiserowitz 2007; Staats et al. 1996). In particular, the terms '*concern'*, *worry*' and *'perceived seriousness*' are often used interchangeably. Yet, the literature often fails to note that these terms have slightly different meanings. For example, it is possible to have general concern for an issue without actively worrying about it. Worry is considered to be a much more active emotional state and a stronger predictor of behaviour than either "concern" or perceived "seriousness" (Leiserowitz 2007).

To illustrate the impact that such different definitions of 'risk perception' can have on outcome measurements, consider a study that was conducted by GlobeScan, covering 34 countries. The study found that the majority of people in each country believed that climate change was a *somewhat to very serious* problem (GlobeScan 2000). In 2006, GlobeScan repeated the study and found that the percentage of respondents that believed that climate change was a '*very serious threat*' increased significantly in most countries (GlobesScan 2006). In addition, a study done in the UK also indicated that 82% of the respondents reported to be *concerned* about the concept of climate change (Poortinga et al. 2006).While general concern seems to be well established, The Pew Global Attitude Survey (2006) found that, (while varying among countries) *personal* levels of worry about climate change are generally much lower

than either perceived seriousness or stated general concern. To this extent, criticism has been expressed with regard to the use of quantitative data in relation to measuring individual concern, particularly because concern is easily overstated, especially since the very structure of most climate change surveys serve to reinforce the perception that the environment is a serious issue that demands concern from any 'responsible' citizen (Bord et al. 1998).

It is also questionable whether stated concern reflects the perception that the problem of climate change is urgent or of high priority. For example, while many people are concerned about climate change, they rank it as less important as many other social issues such as terrorism, health care and the economy (Krosnik et al. 2006). This may explain why global climate change remains a relatively low priority compared to other issues of individual concern. Similar evidence is provided by Poortinga and Pidgeon (2003). Based on 1,547 face-to-face interviews, the researchers found that while there was some moderate concern for all risks mentioned in the study (e.g. radioactive waste, genetically modified food), climate change was ranked among the least important issues. Additionally, in a qualitative study conducted by Bedford et al. (2004), respondents reported feeling no immediate need for the implementation of any significant lifestyle changes. Finally, work by Lowe et al. (2006) also indicated that people did not think climate change would impact their day-to-day life directly. In sum, this evidence leads to the conclusion that although general concern is expressed, there is also a dominant belief that climate change is *a non-urgent and non-personal threat*, possibly hindering proactive behavioural responses (Lorenzoni and Langford 2001).

IV. Conclusion and Policy Implications

Perceptions of climate change hazards have been shown to interact with psychological, social, institutional, and cultural processes in ways that alter public responses to risk. In the current chapter we have illustrated that that there is still a significant gap in public understanding and that incorrect mental representations of climate change downplay the perceived risks and hinder public action. Moreover, individuals have significant difficulty understanding the connections between climate change-related events and the broader concept of climate change. Therefore, the creation of viable mitigation and adaptation strategies towards climate change risks requires greater public understanding of the nature and use of complex system modeling. In fact, O'Neill and Hulme (2009) argue that: "*cognitive engagement is imperative: if individuals do not have an adequate understanding of the issue, any mitigation policy risks being ineffective or even rejected".* Thus, a recurring policy question is how to develop a system that breaches this divide and encourages individuals to take ownership over adaptation and mitigation responses.

Research in applied psychology has shown the effectiveness of different ways and instruments to induce individual, group and larger scale behavioural change. Traditionally, a dominant approach has been to focus on changing individual beliefs and attitudes toward undesirable (i.e. unsustainable) behaviours through the reasoned action approach (Ajzen, 1991; Fishbein and Ajzen 1975). The environmental psychology literature has clearly pointed out a significant relationship between increased environmental knowledge and positive changes in measures of behavioural outcomes (for a review see Bamberg and Moser 2007;

Hines, Hungerford and Tomera 1986). Yet, as discussed in this chapter, cognitive knowledge plays just one part in explaining perceptions and behaviour, while other factors such as habits, emotions, social and cultural norms, given infrastructures and context conditions in which knowledge arises or is situated are in many cases equally relevant to understanding behaviour (e.g. van der Linden, 2011).

The research challenge is to understand changing perceptions vis-à-vis highly dynamic environments and how perceptions can be promoted that are more adequate to the problem dimensions and its characteristics. To this extent, we look ahead and identify two potential approaches that, in the face of accelerating change, can assist policy makers in stimulating the link between public engagement with climate change and learning for a more sustainable future.

In the realm of behavioural economics and public policy 'nudge' and 'think' strategies have become popularized (John et al. 2011; Thaler and Sunstein 2008). To start with the former, 'nudging' focuses on changing people's choice environment in an attempt to encourage them to act in ways that are more beneficial to both themselves and society as a whole. A good example of this phenomenon is illustrated in a recent nudge experiment that tried to encourage recycling behaviour. Realizing the limits of a top-down *'information-deficit'* approach, individuals were provided with a so-called *'social nudge'* (i.e. people in various British boroughs were informed about the positive recycling behaviour of their peers). Such a 'friendly social nudge' seems to encourage people to increase their own recycling behaviour (John et al. 2011).

The 'think' approach (John et al. 2011), on the other hand, assumes that individuals can step away from day-to-day life and reflect on a wide range of public policy choices. It assumes that people are '*knowledge hungry'*, *'learn to process new information'* and reach '*new heights of reflection' (p. 19)*. Think requires active deliberation and assumes that individuals would want to engage in debates about important issues with other members of society. Thus, while nudge focuses on manipulating people's choice environment and gently 'steering' citizens down the right path, think strategies stimulate group participation and encourages the design of democratic institutional platforms that support citizen-lead investigations. This view is very much in line with the concept of '*post-normal science'*, which encourages the idea of an '*extended peer community'*. When facts are uncertain, values in dispute, stakes are high and decisions urgent, all those that are affected by an issue (e.g. climate change) and prepared to enter into dialogue on it, are welcomed to share their (local) knowledge and understanding (Funtowicz and Ravetz 1991, p. 349).

In conclusion, in the realm of complex risks like climate change, policies should aim to foster the link between learning, knowledge acquisition and mitigation and adaptation responses. As discussed throughout this chapter, this essentially implies co-production of knowledge and applying the understanding and use of that knowledge in eliciting more sustainable behavioural and societal changes.

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