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Chapter 21

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

Jennifer Helgeson, Sander van der Linden and Ilan Chabay

Abstract

Climate change represents a complex set of challenges, in part because it is marked by risks that are not easily observed and identified – risks that humans have significant difficulty estimating. A large body of research has shown that the construction of human risk perception is a complex, multi-faceted process. Determining viable mitigation and adaptation strategies toward climate change risks therefore necessitates models that appropriately reflect human knowledge systems and learning processes. In learning for a sustainable future, we must look beyond traditional measures of risk variables and obtain a more comprehensive and holistic understanding of risk behaviour. In this chapter, we aim to provide such an interdisciplinary overview. Using practical examples we outline five fundamental processes that help form, shape and guide human perceptions of climate-related risks, namely: (1) cognitive; (2) subconscious; (3) affective; (4) socio-cultural and (5) individual factors. We subsequently critically review techniques for measuring risk perception, discuss (existing) public perceptions of climate change related risks and illuminate the different mechanisms by which risk perception can influence public action. A major conclusion is that eliciting effective adaptation and mitigation responses requires greater public understanding of and multi-level engagement with climate change and to this extent, we provide several recommendations for public policy.

Introduction

As the scientific consensus on the existence of anthropogenic climate change has become unequivocal (IPCC 2007), humanity is increasingly faced with the prospect of vastly changing environmental conditions. In light of this fact, there are two broad challenges in 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 aim to address the latter challenge by illuminating the crucial role of risk perception in driving and

shaping public responses to climate change. The apparent disconnect between risk perceptions of climate change and public action is undoubtedly linked to the kind of risk that climate change represents; a so-called 'un-situated' risk (Hulme 2009). The term 'un-situated' implies that in most people's immediate environment, the risks associated with climate change are often not directly observable. Since climate change is a slow, cumulative and largely invisible process, it does not coincide with the traditional way in which humans perceive threats in their direct environment, thus, making it difficult for people to accurately estimate climate-related risks. Moreover, 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.

We recognize that 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 first section we address the multi-dimensional nature of human risk perception and explain, using practical examples, how perceptions of climate related risks are constructed. The purpose of the second section is to look at ways of measuring risk perception and to critically discuss how (existing) climate change risk perceptions guide the formation of public responses to climate change. In the last section, we address societal change towards climate change and sustainability more generally and provide several public policy recommendations for eliciting and maintaining effective mitigation and adaptation responses.

Through the looking-glass: the multi-dimensional nature of risk perception

While risk perception is an inherently complex process, an extensive review of the literature allows for the identification of at least five different dimensions that underlie, influence and help shape human perceptions of risk[18]. These dimensions include: (1) *cognitive;* (2) *subconscious*; (3) *affective;* (4) *socio-cultural;* and (5*) individual factors*.

Reasoning about risk

Cognitive scientists have often described the way individuals process and organize incoming information as an interrelated network of mental structures. According

[18] These five dimensions are essentially an extension of the 'triple stand' model proposed by Hillson and Murray-Webster (2009).

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). Unfortunately, a sizable portion of the literature indicates that most people's mental model of climate change 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 (Meijnders 1998), being unaware of the large geophysical consequences potentially associated with such an increase. Indeed, incorrect mental models misguide (i.e. downplay) people's understanding of the potential risks involved and thereby contribute to 'wait and see' attitudes (Xiang 2011).

One reason why people hold such limited understanding of climate change is because its complexity 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), MIT students deduced that a reduction in CO_2 emissions would be followed immediately by a reduction in global mean temperature. While such matching heuristics are effective in daily experiences with simple system dynamics (where inputs and outputs 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).

Another problem that occurs when trying to communicate and educate people about the potential consequences of climate change stems from 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). In fact, much information that is retained in an individual's memory tends to be information that supports pre-existing thoughts and beliefs.

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 *et al.* 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 case studies serve to illustrate that the way in which we learn, process information and organize our knowledge strongly influences how we perceive and interact with the external world.

However, the idea that human risk perception is predominantly influenced by the organization of information and knowledge is a fairly cognitivist point of view. In fact, 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 2005). 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 then denotes an individual's position on a risk continuum (i.e. 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).

In practice, such economic frameworks of risk have been used to estimate individual willingness to pay for public mitigation policies. This is typically done by presenting individuals with a hypothetical set of certain-versus-risky investment choices. For example, 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 climate mitigation

policies. Thus, from this point of view, risk is mainly addressed with rational thought, logic, probability calculus and utility maximization (Weber 2006).

Conversations with the unconscious

Kahneman and Tversky (1979) have long 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; Fischoff *et al.* 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).

Prospect theory focuses heavily on the framing of risk questions and has identified a large range of heuristics and unconscious 'biases' that humans employ when making decisions under uncertainty. Without discussing all of these mechanisms in extensive detail, a particularly 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). Particularly 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).

In sum, the task environment of climate change is defined by high-level ambiguity, where scientists, policy makers and 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.

Feeling at risk

Traditionally, most theories of decision making under uncertainty have completely neglected the role of emotions in risk perception (Loewenstein *et al.* 2001). Yet, it has become increasingly apparent that individuals have a hard time forming risk judgments, when the relevant risk is represented purely as a statistical probability. Mounting evidence from cognitive, social and clinical psychology has indicated that risk perceptions (across domains) are strongly influenced by affective and 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 go as far as stating 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). The amygdala plays a key role in emotional memory and processing (Davis 1992). It is also important to note that different environmental risks can elicit different emotions (Böhm 2003). For example, general controllable risks (e.g. industrial pollution) tend to evoke anger and lead to the boycott of the inflicting agent while risks brought about by the activities of other individuals (e.g. car pollution) tend to invoke ethical emotions such as guilt and shame. The most intense emotions associated with environmental risks however, are so-called *prospective consequence based emotions*, such as fear and worry (Böhm 2003).

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). For example, 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 affective and emotion-driven processes in the construction of environmental risk perceptions.

A culture of risk?

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 perceptions.

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). While traditionally, the cultural theory of risk has been criticized for lacking empirical testing via recognized social science techniques (e.g. O'Riordan and Jordan 1999), recent empirical research shows that such presuppositions about the nature of society do 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 Sievers 2000). For example, egalitarian worldviews are likely to show most concern for the environment whereas individualist worldviews tend to show least concern (e.g. Leiserowitz 2006). A likely explanation is that while egalitarians generally perceive nature and the environment as fragile and at

risk, most western capitalist societies have propagated an individualist worldview, disconnecting humans from nature by objectifying it as a commodity that can be bought and sold (Doyle 2011). Another recent initiative is the 'culture-cognition' project – a combined effort that seeks to connect cognitivist and cultural theories. Cultural cognition of risk acknowledges that cognitions are shaped and influenced by group-grid worldviews.

In addition, 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 also clearly demonstrated the importance of social representations and cultural worldviews in the construction of environmental risk perceptions (e.g. Dake 1991; Leiserowitz 2006).

The risky individual

Finally, 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.* 2000). In addition, while some studies indicate systematic ethnic and socioeconomic differences in the perception of environmental risks (e.g. Flynn *et al.* 1994), other recent research indicates that substantial 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 imply a decreased ability to protect oneself, this is likely to be associated with higher levels of perceived personal risk (Breakwell 2010, Spence *et al.* 2011). 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).

So far we have discussed five fundamental 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. Having discussed the fundamental principles of risk perception, we turn to reviewing current perceptions of climate change related-risks and discuss how these perceptions are likely to influence public mitigation and adaptation responses.

Mind the gap: risk perceptions of climate change and public action

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). Yet, 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 provides a unique challenge. This is so because climate change is an intangible process that cannot be directly observed. Yet, the consequences that are likely to be associated with climate change can be observed (e.g. increased severity and frequency of natural disasters). Nonetheless, 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, 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. To illustrate, a recent study in the UK showed 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, differences in perceptual attribution are 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 *et al.* 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 CO_2 emissions). In particular, past flooding experiences mediated onto risk perception which in turn increased individual preparedness. Other research has also indicated that personal risk perceptions explain variance in behavioural intentions towards addressing global warming (e.g. Bord *et al.* 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 (compared to mitigation), as it is often non-optional (unless the aim is to stimulate preventive measures). A major implication is that if the goal is to stimulate mitigation responses, effort must be geared towards creating a strong(er) link between the occurrence of environmental changes and anthropogenic climate change.

Thus 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 about which to worry and the inability for many people to observe or experience this risk in their direct environment (Weber 2006). Many studies have tried to get a sense of how individuals perceive such seemingly 'unsituated' risks. 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' (cf. Bord *et al.* 2000,

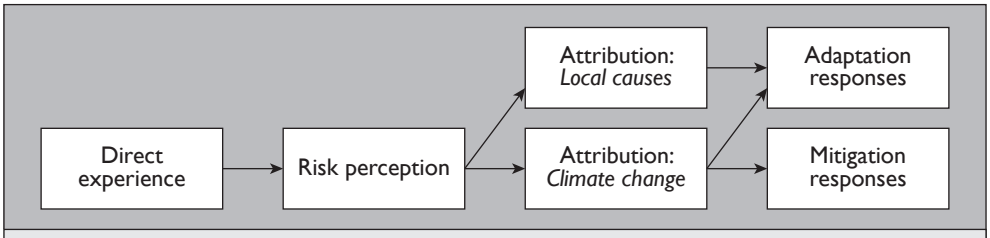

Figure 1. Experience, perception and attribution of risk.

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, we 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). Thus, general concern seems to be well established. Yet, 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 of the issue or general stated concern. To this extent, criticism has been expressed towards 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 (Krosnick *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).

Conclusion and policy implications

The aim of the current chapter has been to facilitate learning for a sustainable future by shedding light on the role of risk perception in the development of public responses to climate change. We have illustrated that perceptions of climate related risks are formed by five fundamental, interacting mechanisms, including cognitive, subconscious, affective, socio-cultural and individual processes.

A major conclusion is that a lack of public understanding is perpetuating incorrect mental representations of climate change. Existing (flawed) mental models downplay the perceived risks and as a result, hinder public action. The creation of viable mitigation and adaptation strategies towards climate change risks therefore requires greater public understanding of the nature and use of complex system modeling as well as a more holistic understanding of the climate change problem. 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'.

Yet, as discussed throughout this chapter, cognitive knowledge plays just one part in explaining perceptions and behaviour, while other factors such as heuristics, 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. For example, while it is known that (affective) experiences with climate-related risks can inspire mitigation behaviours through heightened risk perceptions, this is most likely to occur under the condition that individuals actually (consciously) attribute their perceptual experience of the environmental risk to anthropogenic climate change. 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. 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 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 minimizing the cost of behavioural change by altering 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. The 'think' approach 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' (John *et al.* 2011, p. 19). Thus, think strategies stimulate group participation and

encourages the design of democratic institutional platforms that support citizen-led investigations. This view is very much in line with the concept of 'post-normal science', which supports the idea of an 'extended peer community', where 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).

While both nudge and think strategies can be thought of as independent instruments, it is likely that an integrative approach will more effectively encourage the adoption of mitigation and adaption behaviours. Such an integrative approach should explore not only traditional but also new, interactive and experiential ways of providing people with information, knowledge and learning opportunities. For example, a number of recent policy-oriented studies on household energy use are highlighting that combining traditional modes of conveying information (e.g. energy statements) with non-traditional methods, such as providing people with 'smart readers' (i.e. experiential learning) and / or informing them about the positive energy-saving behaviour of their peers (i.e. 'social nudging') stands a greater chance of successfully promoting sustainable behaviours than either strategy alone (e.g. Dolan and Metcalfe 2011, UK Cabinet Office 2011).

In sum, in the realm of complex risks like climate change, policies should aim to foster the link between individual and social learning, knowledge acquisition and the implementation of 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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