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Embodied uncertainty: living with complexity and natural hazards

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In this paper, we examine the concept of embodied uncertainty by exploring multiple dimensions of uncertainty in the context of risks associated with extreme natural hazards. We highlight a need for greater recognition, particularly by disaster management and response agencies, of uncertainty as a subjective experience for those living at risk. Embodied uncertainty is distinguished from objective uncertainty by the nature of its internalisation at the individual level, where it is subjective, felt and directly experienced. This approach provides a conceptual pathway that sharpens knowledge of the processes that shape how individuals and communities interpret and contextualise risk. The ways in which individual characteristics, social identities and lived experiences shape interpretations of risk are explored by considering embodied uncertainty in four contexts: social identities and trauma, the co-production of knowledge, institutional structures and policy and long-term lived experiences. We conclude by outlining the opportunities that this approach presents, and provide recommendations for further research on how the concept of embodied uncertainty can aid decision-making and the management of risks in the context of extreme natural hazards.

Keywords: disaster; embodied uncertainty; emergency management; knowledge co-production; risk interpretation

1. Introduction

To examine the concept of embodied uncertainty, this paper explores multiple dimensions of uncertainty in the context of living with extreme natural hazards. These dimensions are overlapping and may co-exist in any particular context, given that uncertainty and risk are prevailing conditions of everyday life. In this paper, risk is defined as 'a function of the characteristics and frequency of hazards experienced in a specified location, the nature of the elements at risk, and their inherent degree of vulnerability or resilience' (Benson et al. 2007, 16). Individuals, organisations,

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institutions and societies constantly deal with and embody risk, for example, in the form of the multiple layers of uncertainty associated with the threat of natural hazards, such as wildfire and flooding. The exact time, location, intensity and frequency of potential wildfire or flooding are constant unknowns, which make estimations of likelihood, vulnerability, severity, resource needs and the adequacy of disaster relief packages uncertain (Morrice 2012; Eriksen 2014; Simon 2014). Furthermore, such uncertainty is not universally observed, known and measured, but is subjectively interpreted by those who live at-risk, and those who attempt to manage it. Such individual and collective interpretations of risks lead to decisions about why and how we live in landscapes of uncertainty (Thompson and Warburton 1985; Macnaghten 2003; Robbins and Moore 2013).

Uncertainty tends to be categorised as *epistemic* – derived from incomplete knowledge, or *aleatory* – a product of intrinsic natural variability (sometimes called 'natural stochastic uncertainty', or 'variability uncertainty') (Walker et al. 2003; Patt and Dessai 2005; van Asselt and Vos 2006). In the climate change literature, aleatory uncertainty is part of a category of 'unknowable knowledge', which includes the 'human reflexive uncertainty' in response to climatic change and the uncertain outcomes of such actions. This category of uncertainty is considered to be irreducible for predictive purposes (Dessai and Hulme 2004), due to the fact that humans are part of the problem, system and potential solutions (Patt and Dessai 2005).

The uncertainty discourse in risk studies focuses mostly on scientific uncertainty as it relates to absent and/or conflicting knowledge, and how that uncertainty contributes to difficulties in assessing probabilities and consequences (Renn, Klinke, and van Asselt 2011). Scientific enquiry is considered to be a pathway to reducing epistemic uncertainty over time (Taddei 2012). However, uncertainty is not simply an absence of knowledge. Indeed, it may prevail where substantial information is available, particularly when new knowledge reveals new uncertainties, information is interpreted in very different ways, and/or there are diverse understandings of how best to characterise the uncertainty (van Asselt and Rotmans 2002; Walker et al. 2003; Dessai and Hulme 2004; Adler and Hirsch Hadorn 2014). Thus, risk can arise from both certainty and uncertainty, while uncertainty propagates through assessments of risk (Jones 2000).

Uncertainty often exists around both the likelihood of an event and the value of its consequences (Eiser et al. 2012). The value of an event may involve an objective calculation of the monetary costs, or a subjective interpretation of the (un)desired outcomes. Different actors perceive values differently: one actor's loss may be another's gain, and the consequences are typically distributed unevenly across time and space. Eiser et al. (2012), therefore, call for further research to understand how past experiences, feelings, values, beliefs, social norms and characteristics may shape risk interpretation and decision-making under uncertain conditions. In this paper, we build on this call by examining how uncertainty in the context of extreme natural hazards lies not only in cause and effect, but also within processes. We demonstrate how uncertainty is experienced, internalised and becomes embedded within decision-making and social norms over time. These processes are often non-linear, indeterminate and complex.

To enhance understanding among the disaster management and risk reduction communities of uncertainty as multifaceted and prevailing in different forms, and at different levels and time scales, we explore how uncertainty is framed and communicated, decisions made, and risks embodied. Uncertainty may involve objective

entities, or subjective realities; it may be widely observed, sensed and collectively shared, or completely internal to the individual. Influences on uncertainty may also be reducible or irreducible, and known or unknown. We draw from many disciplines and fields of research (including geography, disaster studies, sociology, psychology, earth sciences, public policy and political science) to provide a broad review of how uncertainty is treated in a range of literatures. We argue that there is a need for greater recognition, particularly by disaster management and response agencies, of uncertainty as a subjective experience for those living in areas exposed to natural hazards. The concept of embodied uncertainty provides a conceptual pathway to initiate discourse around experiential and lived uncertainty. We discuss this concept in the context of disasters and risk, particularly extreme natural hazards, and present questions, challenges and opportunities for moving forward in uncertainty thinking.

2. Problematising uncertainty

2.1. Scientific framing of uncertainty

Early definitions of uncertainty differentiate between two types of uncertainty: measurable uncertainty (defined as 'risk' proper) and immeasurable uncertainty (Knight 1921). Scientific framings view scientific knowledge (often technological) as the key to measuring and reducing uncertainty (Wynne 1992). The conventional approach to managing uncertainty has been to reduce unknowns to measurable 'risk' (Stirling 2008, 2010). However, reducing uncertainty may lead to ignorance, as possibilities are necessarily removed from consideration in order to proceed with structured investigation (Wynne 1992). For example, a study of NASA's decision-making prior to the Columbia space shuttle disaster in 2003 found that, leading up to the disaster, there was overconfidence in quantitative data and marginalisation of non-quantifiable information, which created insensitivity to the uncertainty involved and loss of institutional memory (Feldman 2004).

Uncertainty is a wide-ranging concept and a spectrum of typologies exists. For example, in the model-based decision support literature, three dimensions of uncertainty are defined: location (where uncertainty manifests), level (amount of knowledge) and nature (epistemic or aleatory). Within these dimensions, the level of uncertainty has been described on a five-level spectrum from 'determinism' (complete knowledge) to 'total ignorance' (Walker et al. 2003). Bammer, Smithson, and The Goolabri Group (2008) employ a 'taxonomy of unknowns', which starts with ignorance as an overarching term that branches into two fundamental types: error (incomplete knowledge) and irrelevance (deliberately ignored). The former leads to a state of incompleteness, and then to uncertainty as the taxonomy narrows. In this taxonomy, uncertainty itself is then comprised of vagueness, probability and ambiguity. Yet another typology defines quadrants of uncertainty – risk, ambiguity, uncertainty and ignorance – based on axes that chart the level of knowledge of probabilities and the level of knowledge of possibilities (Stirling 2010).

The non-linear and dynamic nature of many complex social and environmental systems leaves uncertainty irreducible in many cases. There is a growing acceptance – particularly among those from science and technology studies – that further knowledge will not necessarily provide solutions. Instead, learning to manage ignorance is necessary (Dovers and Handmer 1992; Stirling 2010; Adler and Hirsch Hadorn 2014). For example, in the context of a changing environment, acceptance

of irreducible or 'deep uncertainties' (Haasnoot et al. 2013) may offer planners a pathway for adapting solutions over time to address changing circumstances. Such approaches accept uncertainty and account for it by committing to short-term actions (e.g. mitigation), and establishing a framework of adaptive pathways for future actions that incorporate experiences and learning over time (Haasnoot et al. 2013; Walker, Haasnoot, and Kwakkel 2013). Rather than trying to reduce uncertainty and risk by oversimplifying a situation (wilful ignorance), we argue that accepting uncertainty as complex and non-linear promotes innovative ways of thinking, and opens up new approaches for addressing uncertain situations.

This is not without its challenges, particularly as the inherent complexity in addressing these uncertain situations demands approaches and structures that facilitate and accommodate this complexity. Characterising this complexity entails three distinct types of information: (1) fundamental understandings of components and dynamics within and between systems (*systems knowledge*); (2) knowledge that helps clarify and prioritise the desired and valued outcomes by society when dealing with impacts and drivers of disasters (*target knowledge*); and (3) knowledge on how to transform the system by, for example, enacting policies that address and mitigate the effects and impacts of disasters in society (*transformation knowledge*). Reconciling systems, target and transformation knowledge calls for transdisciplinary approaches that are sensitive to the specific socio-economic context where disasters manifest (Hirsch Hadorn et al. 2008).

Transdisciplinary approaches are characterised by their problem-oriented focus and, increasingly, the co-production of transformation knowledge (i.e. knowledge for problem solving) that effectively bridges the gap between the problematic status quo and the desired goal (Hirsch Hadorn et al. 2008). These approaches account for complexity by incorporating both the everyday world and theoretical constructions of problems, and thus have been adopted by many communities of practice, including: future studies (Tapio and Hietanen 2002), sustainability science (Cash et al. 2003), systemic learning (Blackmore et al. 2011), action research (Greenwood and Levin 1998), transition management (Loorbach, Frantzeskaki, and Thissen 2011), participatory research (Bidwell 2009; Kasemir et al. 2003), policy sciences (Ascher 2007) and post-normal science (Funtowicz and Ravetz 1993). Under conditions of high risk and high uncertainty, Funtowicz and Ravetz (1993, 753) recommend scientific research should consider 'extended facts', which include community values, history, personal experiences and other 'non-traditional' science information. Stirling (2010) recommends that where knowledge of probabilities and possibilities become less well known (outside the 'risk' space), the realms of ambiguity, uncertainty and ignorance require participatory deliberation, scenario methods and adaptive and resilient approaches to inform decision-making. Such approaches embrace multiple interpretations and options, which inform policy-makers about the alternatives, and thereby make decision-making more democratically accountable (Stirling 2010). This acceptance of uncertainty may lead to a better understanding of how uncertainty is embodied within co-produced knowledge and within institutional settings, structures and policy.

2.2. Uncertainty and decision-making

In the disaster risk reduction community, much research on uncertainty has focused on either decision-making under uncertainty or the communication of uncertainty

(Cutter et al. 2015). In the decision-making literature many studies focus on rational choice models (Becker 1978; Tversky and Kahneman 1986), which consider decision-making to be a series of analytical stages: identify the problem, generate and evaluate a set of options, implement the preferred option (Flin 1996; Saaty 2008). However, many decisions are made based on intuition, in a faster, almost automatic way often termed naturalistic decision-making (Lipshitz et al. 2001). Naturalistic settings are characterised by ill-structured problems, uncertain environments, shifting ill-defined goals, action/feedback loops, time–stress, high stakes and multiple players (Zsambok and Klein 2014). Decision-making processes under these naturalistic conditions can be defined as the way people use their experience to make decisions in real-world settings (Crego and Spinks 1997; Pascual and Henderson 1997; Crichton and Flin 2002; Klein 2008).

Much discussion has centred on the case for two 'modes' of thinking that drive information processing and decision-making. These have been termed the analytical and affective processing systems, or 'type 2' and 'type 1' decision-making (Epstein 1994; Sloman 1996; Chaiken and Trope 1999; Slovic et al. 2004). The analytic (type 2) approach involves slower computational cognitive processes, and is a learnt process that consciously and deliberately applies rules and procedures (e.g. formal logic, utility maximisation) to the analysis of data to find the optimal solution or outcome. The analytic system uses algorithms, normative rules and logic, and does not operate automatically. It is also oriented towards delayed action, and decisions made often require 'justification via logic and evidence' (Epstein 1994). The affective (type 1) approach is often termed the experiential system, and involves rapid, unconscious affective processes oriented towards immediate action. It is a holistic approach that reconciles behaviour with past experience (Epstein 1994), and is an evolutionary adaptation that automatically converts uncertain and adverse aspects of experience into affective responses (e.g. fear, dread, anxiety). It thus results in people interpreting risk as an affective or emotional state or feeling (Loewenstein et al. 2001; Slovic et al. 2004). Even if individuals adopt an analytical process for their decision, if the outputs from the two processing systems disagree, the affective system usually prevails (Loewenstein et al. 2001).

Recent debate has questioned if these dual-processing systems are actually distinct, and whether a unified theoretical approach is more appropriate to explain both intuitive and deliberative judgements, and the spectrum between them (Evans and Stanovich 2013a, 2013b; Keren 2013; Osman 2013; Thompson 2013). Either way, most of the models of decision-making assume a 'rational' model of managing uncertainty, and do not account for the more affective ways of thinking based on emotions and experience (Slovic et al. 2004). The current dominant approach to 'managing' uncertainty thus underrepresents, and thereby downplays, the role of emotions and experience. However, by adopting an alternative approach that acknowledges the embodiment of uncertainty, the affective mode can be better represented in models of decision-making under uncertainty.

2.3. *Communication of uncertainty*

Research into the communication of uncertainty in various fields associated with natural hazards, and environmental risks more broadly, typically focuses on the communication of uncertain scientific advice (Löfstedt and Perri 6 2008; Spiegelhalter, Pearson, and Short 2011). The advice communicated may be subject to many levels

of uncertainty, including epistemic and aleatory uncertainty (van Asselt 2000; Patt and Dessai 2005). Much of the research focuses on the most effective methods for science communications, examining questions like: whether revealing the uncertainty associated with a risk assessment will strengthen or decrease trust and credibility (Johnson and Slovic 1995; Smithson 1999; Miles and Frewer 2003; Wiedemann, Börner, and Schütz 2008); whether the inclusion of uncertainty will result in misuse of the information, and a consequent attenuation or amplification of a risk to meet pre-existing attitudes, beliefs and to justify a political agenda (Kuhn 2000); and how the format of probabilities (which encompass the uncertainty) influence decision-making behaviour and interact with existing beliefs related to career, knowledge, experience and values (Doyle, McClure, Johnston, et al. 2014; Doyle, McClure, Paton, et al. 2014).

Recent research has also explored the political uses of uncertainty, as it relates to, for example, climate change in Brazil, and found that uncertainty is socially and politically distributed in specific ways (Taddei 2012). Further studies are required to understand how uncertainty is dealt with in different social and cultural contexts, and the ways in which uncertain information and outcomes are both distributed across society and politically manipulated. This would move towards a better understanding of how uncertainty may be managed, filtered and contextualised – i.e. embodied within each unique context.

2.4. Embodied risk

'Embodied risk' has been explored in the public health literature in order to better understand how individuals make sense of health risks (Kavanagh and Broom 1998; Mol and Law 2004). Risks may be differentiated as environmental, lifestyle or corporeal (embodied). Environmental risk is delineated as *what happens*, lifestyle risk as *what we do* and embodied risk as an indication of *who we are* (Kavanagh and Broom 1998). Embodied risk relates to the ways in which people interpret and make personal meaning out of diagnoses that place them 'at risk'. One study explores experiences of hypoglycaemia from the perspectives of nurse and patient, drawing on the dualistic nature of the body as an object and as a subject (Mol and Law 2004). The study finds that the body enacts hypoglycaemia, and argues that medical treatment should therefore account for interventions into lived bodies and into people's lives. Such studies distinguish the concept of embodied risk from objective risk, and explore the importance and role of this enactment in shaping the individual responses and integration of the threat into people's daily lives.

Under conditions of infrequent and unpredictable hazard events there is a large amount of uncertainty and ambiguity in deciding whether and how to respond to risk (Solberg, Rossetto, and Joffe 2010). Social identities contribute to how we see ourselves and derive group membership. The categorisation of self and of others into common social identities is a strategy for enhancing cohesion with a given community (Fiske 2004; Joffe and Staerkle 2007). Social identities include social norms, which are rules for behaviour that are constructed within a group or culture, as people endorse or passively impose normative behaviours on their members (Solberg, Rossetto, and Joffe 2010). Social norms influence attitudes and behaviour (Terry, Hogg, and White 1999; White et al. 2009). Attributions of responsibility (who is responsible), and trust are also important mediators that underpin whether actions are taken to adjust to an identified risk (Terry, Hogg, and White 1999; Paton 2008).

Modelling with substantive data has been used to illustrate how social cohesion affects the decision to prepare for wildfire by facilitating the transfer of information that can influence the social construction of issues or problems (Eriksen and Prior 2011; Prior and Eriksen 2013). This raises the salience of risk issues relative to other everyday considerations among community members. It highlights how responses to risk derive from a suite of personal and interpersonal characteristics and relationships that affect how we individually and collectively embody uncertainty.

3. The concept of embodied uncertainty

The concept of embodied uncertainty incorporates both the conscious and subconscious lack of certainty. It is common to all, from individuals to societies (Figure 1). Embodied uncertainty is differentially internalised, depending on past experiences, social identities, beliefs, values, institutional structures, resources available and social norms. In a situation of high uncertainty, internalised characteristics influence how the multiple dimensions are individually or collectively experienced, interpreted and acted upon (Figure 2).

This broadened concept of uncertainty promotes a shift in thinking towards accepting (rather than reducing) uncertainty. By focusing on the lived experience within uncertain contexts, it accepts uncertainty as a persistent condition of daily life in many forms, scales and levels of conscious and unconscious decision-making. It lies on a continuum from (often decontextualised) epistemic knowledge to everyday practice guided by instinct. Embodied uncertainty is thus distinguished from objective (*disembodied)* uncertainty by being both consciously and subconsciously internalised and subjectively interpreted by individuals. This influences the ways in which personal meaning emerges from uncertainty related to risk (Kavanagh and Broom 1998; Mol and Law 2004). The embodiment of uncertainty gives tangible or visible form to the feeling of a lack of certainty.

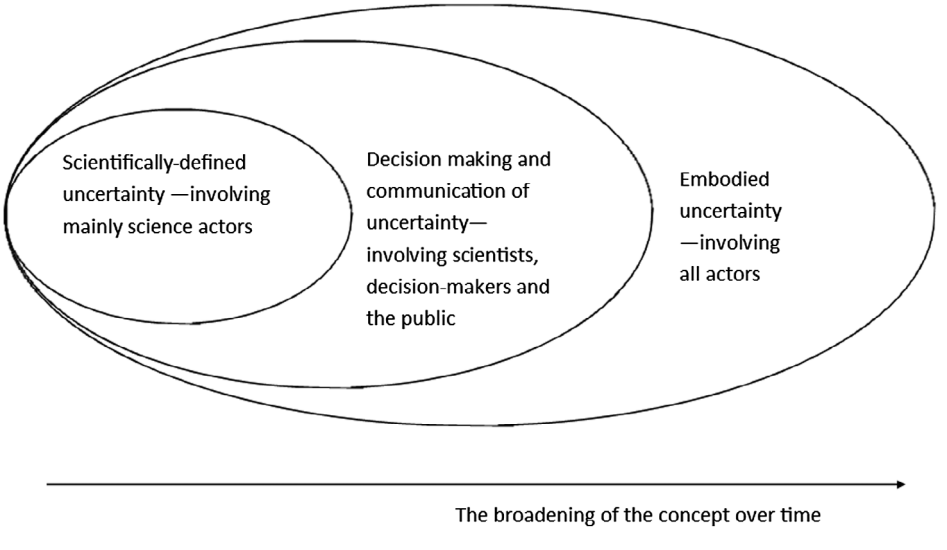

Figure 1. The progressive broadening of the scientific concept of uncertainty.

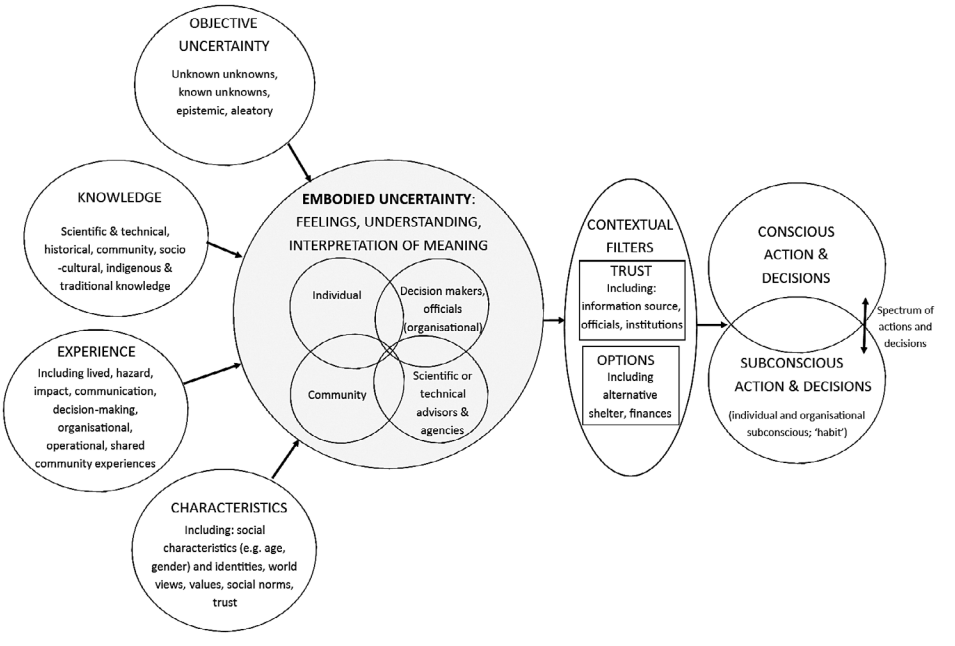

Figure 2. The concept of embodied uncertainty.

We frame the concept of embodied uncertainty as a verb not a noun because it is constantly contextualised and enacted. It is the lived experience of both known and unknown uncertainty. This uncertainty can exist at the level of the individual, family, community, organisation and/or institution in different cultural contexts. It may be positive or negative, providing opportunities to catalyse change or presenting challenges to overcome. By accepting the complexity of uncertainty, and the multiple ways in which it is understood, internalised and enacted, we move towards exploring the pluralistic nature of the concept and what this means for everyday life. The following four contextualised examples explore the concept of embodied uncertainty and exemplify different dimensions of uncertainty. Each of these requires further study, and we present them here to promote dialogue on the complex and heterogeneous nature of uncertainty itself, and to highlight the opportunities that lie within alternative discourses of uncertainty in the context of extreme natural hazards.

3.1. Embodied uncertainty, social identities and trauma

As individuals and as a people, whether community or nation state, we have embodied characteristics that we carry with us in daily life. No matter the situation, risky or not, our actions are born out of our social identities, our socially constructed and lived experiences of the world, and how social characteristics intersect in everyday life, such as education, class, age, gender, sexuality, ethnicity and (dis)abilities (Krüger et al. 2015). These characteristics influence how we process potential risk, providing us the ability to assess it *in situ*. Together, these parts create an embodied uncertainty about the world in general, and risk in particular.

Moving beyond visible or tangible social inequalities that impact both environmental and social vulnerabilities and capacities, embodied uncertainty attempts to 'make visible' the subliminal differences that underpin people's decision-making, ability and willingness to reduce risk. The stratification of societies has created both privilege and oppression based on identities such as race, class, gender, sexuality, religion, language and citizenship (Pease 2010). These identities, and social expectations associated with each identity, impact each individual's sense of self-efficacy (Merton 1948). Differential social identities then shape the decision-making process, not only through the rational choice model, but also through the subconscious identities we embody.

There are many different ways of responding to uncertainty: to some people uncertainty generates anxiety, to others it is enabling and empowering (Lindell and Perry 2000). Both of these responses may affect decision-making and life chances. As some social identities are fluid, so are the embodied uncertainty that may be beneficial or detrimental in different contexts. A businesswoman in the United States of America and a Quechua woman in Peru may have particular uncertainties in their respective locations. Have them switch places, and new sets of uncertainties are born. Further, experiences of trauma and secondary trauma may contextualise how individuals interpret and act towards risk (Erikson 1976; Gill 2007). For example, in San Salvador in 2009, tropical storm Ida devastated much of the peri-urban areas. As a consequence, small rainfall events that followed this disaster invoked widespread fear among residents that a landslide would destroy their communities (Tellman 2011).

3.2. Embodied uncertainty and the co-production of knowledge

Uncertainty is embodied in the production of knowledge, as we give preference (consciously or subconsciously) to certain types of information. Scientific and technical information can play an important role, but no system of knowledge and decision-making is completely objective, as psychological, contextual and institutional factors provide important variables (Bea et al. 2009). Decision-makers assess and make choices in response to risks using both objective criteria that have external validity and scientific legitimacy, as well as criteria that emerge within unique social contexts (Fearnley 2013). The, often tacit, knowledge that groups and individuals use to frame dimensions of uncertainty are fluid products of ongoing decision-making, shared experiences and assumptions and broader mental models. Community-based disaster risk management and other participatory approaches provide mechanisms by which to incorporate this plurality of perspectives into the co-production of knowledge (Williams and Dunn 2003; Cronin et al. 2004; Gaillard 2006; Cadag and Gaillard 2014). Similarly, joint fact-finding techniques can be employed to help groups work through science-intensive policy and planning disputes to create a shared vision and inform collective decision-making, even in situations with high degrees of uncertainty (Karl, Susskind, and Wallace 2007; Schenk 2016). In uncertain situations, robust environmental knowledge can be created in continual dialogue with societies exposed to natural hazards through both fact finding and meaning-making (Jasanoff 2010).

Shared mental models of a situation or perceived risk can be improved through training, effective team-based simulations, as well as shared scenario-based planning (Cannon-Bowers and Bell 1997; Crego and Spinks 1997; Paton, Smith, and Violanti

2000; Pliske, McCloskey, and Klein 2001; Borodzicz and van Haperen 2002; Keough and Shanahan 2008; Moats, Chermack, and Dooley 2008). By building a shared mental model of the situation and issue, a more mutual understanding of the role of uncertainty can be established, as well as shared recognition of the different ways this uncertainty can be mitigated, managed or embraced. This knowledge cannot be codified and transferred easily, as it accumulates organically among stakeholders with shared histories. That is, it does not exist independently from the actors that use it, but as an *embodied* interpretation of the world and how it is shaped. The meaning and value of situational knowledge does not come from standardisation and universal acceptance, but from the potency such models have on the ways in which stakeholders evaluate situations and make decisions in practice. Such co-produced knowledge is often contested, as stakeholders vie for influence over the shaping of the knowledge that is used to interpret risks and make decisions (Adler and Hirsch Hadorn 2014). Decision-making is also set within the social and political context of the situation. Power dynamics that were previously maintained may or may not be challenged, leading to altered outcomes and associated consequences. The fluidity of power to influence others in disaster situations therefore necessitates further investigation.

3.3. Embodied uncertainty, social and institutional structures and policy

The embodiment of uncertainty is also tied to broader social issues. Through the socialisation process, embedded social norms become embodied subconsciously by individuals over time. As individuals internalise these norms, they also reproduce them through their behaviours. Embodied uncertainty, through this reproduction process, becomes embedded into broader social processes (Berger 1991; Alaniz 2015). The same process occurs for institutions, organisations and communities. The way that an institution, organisation or community embodies uncertainty can become embedded within its policies and practices. This influences the ways in which its members think and act, although they may not be aware of this priming. Instead, certain framings of risk are implicitly embodied into their everyday activities through the repetition of certain practices, favouring of particular approaches and deference to certain narratives. Some individuals or institutions may be more or less risk adverse, resulting in many different attitudes and responses. Choices are furthermore unevenly distributed across society, and may be constrained when an organisation chooses to operate in high-risk locations, which affects the ability of staff to reduce their individual risk.

The ways that barrier island communities along the east coast of the United States of America assess the risks posed by climate change and evaluate potential responses provides an example of how uncertainty is embodied within institutions, and subsequently reflected in their policies (Kettle et al. 2014). Confronted with significant threats, yet determined to maintain their properties and way of life, communities – both formal municipal organisations, and residents and others stakeholders – are looking for ways to adapt *in situ*. Confronted with scientific evidence that the risks are getting worse under climate change and the suggestion that retreat may be necessary (Gutierrez, Williams, and Thieler 2009), uncertainty is used as a way to downplay and to challenge the extent and nature of the threats (Zucchino 2012). Even if residents ultimately accept the risks, they feel able and willing to manage them via their status quo approaches, including evacuating in advance of storms,

beach nourishment to maintain shorelines and protect infrastructure and elevating homes on stilts. The federal and state governments further mitigate the risks by subsidising insurance and providing post-disaster aid to enable re-building. The perception that extreme weather events can be prepared for and the effects mitigated lends a sense of security to barrier island residents. Strong interests (financial, cultural and otherwise), community characteristics, past experiences and the ability to evacuate when necessary, have resulted in low perceptions of risk and a resistance to change (Peach 2014). Residents downplay the risks to avoid stricter regulations and strongly resist the notion of retreating or restricting rebuilding. Conscious of the risk, lifestyle is prioritised and residents choose to remain 'at risk' while seeking support to mitigate those risks. Their embodied uncertainty may encompass climate and weather risks, but it also reflects concerns over property rights and how the state may respond.

3.4. Embodied uncertainty as long-term lived experiences

Uncertainty is lived and experienced, and may be influenced by both known and unknown factors, past experiences and future possibilities. There may also be timescales of consciousness, where it is possible to move between conscious and subconscious awareness of uncertainty, depending on a variety of influencing factors, such as decision demands and priorities, attention to other contesting issues, social contexts and influences, time and level of exposure. Uncertainty manifests over long time periods, where past experiences may create a sense of uncertainty about the future, particularly in locations that are considered to be 'at risk'. This becomes embodied into thought and action. This embodiment may be at both individual and institutional levels, affecting behaviour and decisions that are short-term in response to specific hazards, and long-term choices about investment for the future. Such manifestations of lived uncertainty may influence patterns of vulnerability and development over time.

This is observed in the island of Montserrat, West Indies, where the eruption of the Soufrière Hills Volcano has been ongoing since 1995 (Sword-Daniels et al. 2014). The volcanic eruption prompted a large-scale relocation further from the volcano in 1996, and the enforcement of an exclusion zone, although its geographic coverage shifted throughout 1996–1997 (Aspinall et al. 2002). The small village of Salem and its surrounds were placed within the exclusion zone in September 1997. The hazard map was later re-drawn in 1998, allowing the re-occupation of Salem from October 1998 onwards (Kokelaar 2002). This village is one of the closest to the exclusion zone, and has higher risk than other occupied areas further from the volcano. The sense of impermanence resulting from the one-time evacuation lingers still, and this embodied uncertainty surrounding the location of Salem has created reluctance among individuals and infrastructure providers to invest in the area. This has shaped the development of Salem such that people with lower socio-economic status, and immigrants from the wider Caribbean region, have higher representation in this 'less desirable' location, where rents are cheaper. Overall, this embodied uncertainty surrounding the location of Salem has altered vulnerability characteristics, creating a community of renters (rather than property owners), a greater proportion of immigrants with less experience with volcanic hazards and language issues in risk communication and stalled development with degrading infrastructure over time because of a lack of investment (Sword-Daniels et al. 2014). Embodied

uncertainty is exemplified as a long-term process in Montserrat where uncertainty that is embodied becomes embedded in community demographics and structures.

3.5. Discussion: bringing the themes together

The four contextualised examples discussed above highlight both the relevance and potential contributions the concept of embodied uncertainty can provide. They also promote exploration of methodologies and frameworks to develop the idea further. Together they characterise four different yet intricately related aspects of embodied uncertainty in the context of extreme natural hazards.

First, social identities and lived trauma are powerful determinants that underpin people's patterns of decision-making, ability and willingness to reduce risk. They constitute key factors for accommodating and coping with uncertainty, rather than seeking to reduce it. Second, given how uncertainty is also embodied in the process of knowledge production, transdisciplinary approaches to the co-production of knowledge enable a more cognisant and transparent means of dealing with the inherent epistemic power dynamics that accompany many approaches to risk reduction. Third, the embodiment of uncertainty is tied to broader social issues, which can present challenges regarding how to methodologically structure and account for this broader context. Finally, uncertainty is lived and experienced, and may be influenced by both known and unknown factors, past experiences and future possibilities. This, in turn, may influence patterns of vulnerability and development over time.

These elements of identity, knowledge (co)production, context and experience, offer innovative, sensitive and practical insights into the complex ways uncertainty becomes embodied, as people negotiate uncertainties associated with extreme natural hazards in the context of everyday life.

4. Conclusion

To examine the concept of embodied uncertainty, we have in this paper explored multiple dimensions of uncertainty and risk in the context of extreme natural hazards. These dimensions are overlapping and may co-exist in any particular context. In so doing, we hope to promote further dialogue on the complex and heterogeneous nature of uncertainty itself. Our premise lies on the acceptance (rather than the dogmatic reduction) of uncertainty. Embracing complexity, as well as the pluralism of subjective and inter-subjective uncertainty, is central to this concept. Understanding the embodiment of uncertainty at the individual, collective, organisational and institutional levels, at multiple scales and through processes over time, allows a pathway for multiple meanings to be understood, and new understandings to be constructed. This opens-up ways of thinking, and approaches for addressing, uncertain situations. These approaches promote the co-production of knowledge, and embrace multiple interpretations and solutions. Further, embodied uncertainty shapes interpretation and action in the context of risk, and can become embedded with time, thus further shaping decision-making and action. Improved understanding of uncertainty as a lived experience, rather than solely as an objective entity, establishes a fruitful field of study that has the potential to increase our understanding of the behaviours and decisions of actors in uncertain and dynamic situations.

We raise a number of questions through our analysis, which could be taken forward by researchers and disaster management and response personnel to further develop the concept of embodied uncertainty. These include:

- How does embodied uncertainty affect agency, ways of life and decision-making processes?
- How does embodied uncertainty manifest through time?
- How do social identities affect the embodiment of uncertainty?
- How does the spectrum of embodied uncertainty that exists within and between different groups manifest in decision-making?
- How can stakeholders collaboratively explore and account for embodied uncertainty to improve decision-making and effectively manage risks?

Further studies (conceptual and empirical) are required in order to fully explore the tools and approaches needed for the practical application of, or reconciliation with, the concept. There is much work to be done to advance our understanding of how risks can be effectively managed, given the embodied nature of uncertainty. Case studies that explore how uncertainty is embodied before, during, and after disaster events would be instructive in further exploring this concept. The concept of embodied uncertainty has potential for far wider applicability than the extreme natural hazards context that grounds our research. Embodied uncertainty is prevalent in multiple everyday aspects of life that could be meaningfully explored through many different epistemological research perspectives.

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