Received: 18 July 2019 | Revised: 5 February 2020 | Accepted: 6 February 2020

DOI: 10.1002/wat2.1418

OVERVIEW

WIREs WATER WILEY

The behavioral turn in flood risk management, its assumptions and potential implications

Christian Kuhlicke[1,2] | **Sebastian Seebauer**[3] | **Paul Hudson**[2] | **Chloe Begg**[1] | **Philip Bubeck**[2] | **Cordula Dittmer**[4] | **Torsten Grothmann**[5] | **Anna Heidenreich**[2] | **Heidi Kreibich**[6] | **Daniel F. Lorenz**[4] | **Torsten Masson**[7] | **Jessica Reiter**[4] | **Thomas Thaler**[8] | **Annegret H. Thieken**[2] | **Sebastian Bamberg**[9]

[1]Department Urban and Environmental Sociology, Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany

[2]Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany

[3]Joanneum Research Forschungsgesellschaft mbH, Graz, Austria

[4]Disaster Research Unit (DRU), Freie Universität Berlin, Berlin, Germany

[5]Department of Ecological Economics, Carl von Ossietzky Universität Oldenburg, Germany

[6]GFZ German Research Centre for Geosciences, Section Hydrology, Potsdam, Germany

[7]Institute of Psychology, University of Leipzig, Leipzig, Germany

[8]Institute of Mountain Risk Engineering, University of Natural Resources and Life Sciences, Vienna, Austria

[9]Department of Social Work, Bielefeld University of Applied Sciences, Bielefeld, Germany

Correspondence
Christian Kuhlicke, Department Urban and Environmental Sociology, Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany.
Email: christian.kuhlicke@ufz.de

Funding information
The work carried out by Sebastian Seebauer was supported by the Austrian Climate and Energy Fund and was carried out within the Austrian Climate Research Program;, Grant/Award Number: no. B670283; Austrian Climate and Energy Fund, Grant/Award Number: B670283

Abstract

Recent policy changes highlight the need for citizens to take adaptive actions to reduce flood-related impacts. Here, we argue that these changes represent a wider behavioral turn in flood risk management (FRM). The behavioral turn is based on three fundamental assumptions: first, that the motivations of citizens to take adaptive actions can be well understood so that these motivations can be targeted in the practice of FRM; second, that private adaptive measures and actions are effective in reducing flood risk; and third, that individuals have the capacities to implement such measures. We assess the extent to which the assumptions can be supported by empirical evidence. We do this by engaging with three intellectual catchments. We turn to research by psychologists and other behavioral scientists which focus on the sociopsychological factors which influence individual motivations (Assumption 1). We engage with economists, engineers, and quantitative risk analysts who explore the extent to which individuals can reduce flood related impacts by quantifying the effectiveness and efficiency of household-level adaptive measures (Assumption 2). We converse with human geographers and sociologists who explore the types of capacities households require to adapt to and cope with threatening events

(Assumption 3). We believe that an investigation of the behavioral turn is important because if the outlined assumptions do not hold, there is a risk of creating and strengthening inequalities in FRM. Therefore, we outline the current intellectual and empirical knowledge as well as future research needs. Generally, we argue that more collaboration across intellectual catchments is needed, that future research should be more theoretically grounded and become methodologically more rigorous and at the same time focus more explicitly on the normative underpinnings of the behavioral turn.

This article is categorized under:

Engineering Water > Planning Water

Human Water > Water Governance

Science of Water > Water Extremes

KEYWORDS

capacities, effectiveness, motivation, resources, risk governance, vulnerability

1 | INTRODUCTION

Flood risk management (FRM) has undergone considerable changes in recent years (e.g., Bubeck et al., 2017a; Thieken et al., 2016b). Particularly, the interest in the active involvement of citizens at risk in the management of floods has increased over the past decades. As structural measures, such as dikes and dams cannot offer comprehensive protection, exposed residents are expected to take private measures to mitigate flood risks (Begg, 2018; Bubeck, Kreibich, et al., 2017a; Mees et al., 2016). As a result, FRM is increasingly governed by policies and regulations which highlight the need for citizens to take adaptive actions to reduce flood-related impacts (Bubeck, Kreibich, et al., 2017a). Some policies are implicit with regard to defining and renegotiating the roles and responsibilities of citizens (e.g., "Making Space for Water" (United Kingdom) (DEFRA, 2005), while other regulations are more explicit (e.g., German Federal Water Act, §5 WHG 2009[1]).

We term this shift toward promoting behavior-related changes in flood prone areas as a *behavioral turn* in FRM. This shift in FRM is taking place in different intensity and is probably most pronounced in Europe (Begg, 2018) and North America (Sheaffer, 1960; Thistlethwaite, Henstra, Brown, & Scott, 2018). It mirrors a wider political agenda of individualizing responsibilities (Hutter, Leibenath, & Mattissek, 2014; Kuhlicke, 2019), which can also be observed in other domains of public policy, such as health care, retirement provision, or labor market policy (Bogliacino, Codagnone, & Veltri, 2016).

In our view, the behavioral turn is based on three fundamental assumptions: first, that the motivations of citizens to take adaptive actions can be well understood; second, that private adaptive measures and actions are effective in reducing flood risk; and third, that individuals have the capacities to implement such measures. We propose that if these assumptions do not hold, risk reduction cannot be adequately achieved by households and the behavioral turn would result in new and/or reinforce existing patterns of inequality.

Therefore, we—a group of human geographers, psychologists, sociologists, economists, engineers, and environmental scientists—argue that the behavioral turn and its implications should become a subject of more explicit investigation. To initiate this discussion, we draw and reflect upon specific "intellectual catchments," defined as: domains that scholars "declare to be their turf, in which they legitimately collect data, use methods, or refer to theoretical models" (Gross, 2004, p. 567). Each of these intellectual catchments represents one of the three assumptions mentioned earlier. Psychologists and other behavioral scientists focus on relevant sociopsychological factors when predicting the motivation for adaptive actions (Assumption 1). Economists, engineers, and quantitative risk analysts explore the extent to which flood-related impacts can be reduced. They do so by quantifying the effectiveness and efficiency of household-level adaptive measures (Assumption 2). Human geographers and sociologists explore whether individuals have the capacities to adapt to and to cope with flood related impacts (Assumption 3). Each of the intellectual catchments is shaped by different assumptions, sets of theories and methodologies (see Figure 1).

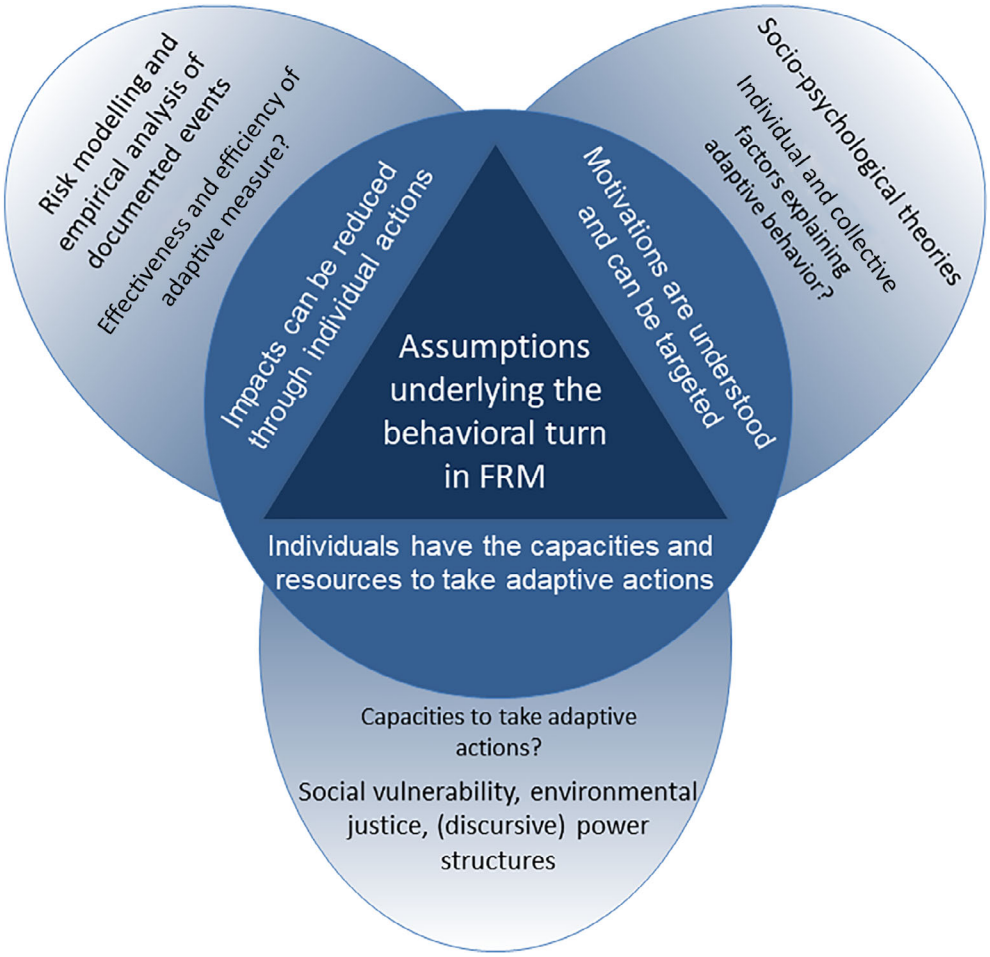

FIGURE 1 Intellectual catchments engaging with the assumptions of the behavioral turn in FRM. FRM, flood risk management

Within each of these three intellectual catchments, we assess the extent to which outlined assumptions are supported by empirical evidence. We focus therefore, above all, on empirically based studies and not on studies predominantly based on modeling (Bubeck, de Moel, Bouwer, & Aerts, 2011). We proceed with highlighting knowledge limitations and recommendations for future research within each of the intellectual catchments. In conclusion, we describe general principles future research could follow and provide suggestions for the way forward by building productive connections across intellectual catchments.

2 | WHAT MOTIVATES INDIVIDUAL ADAPTIVE BEHAVIOR?

This intellectual catchment focuses on identifying factors that shape the motivation of people to engage with adaptive behavior. We use the term "adaptive behavior" to refer to actions that aim at preventing or minimizing anticipated or negative consequences of flood events. Such actions can be taken before, during or after an event (Kreibich, Bubeck, Van Vliet, & De Moel, 2015). We focus here primarily on households as they are the most prominent target group of the behavioral turn and most related research focuses on them (for companies see: Bhattacharya-Mis et al., 2018; Gayan & Bingunath, 2012). This intellectual catchment is based on pioneering work in psychology (Slovic, Kunreuther, & White, 1974), sociology (Drabek, 1986, 1987), as well as geography (Burton, Kates, & White, 1993; Kates, 1962; White, 1974).

2.1 | Studies on individual adaptive behavior in FRM

Relevant factors for explaining adaptive behavior are, among others, experienced flood damage in the past (Grothmann & Reusswig, 2006; Harvatt, Petts, & Chilvers, 2011; Osberghaus, 2017; Zaalberg, Midden, Meijnders, &

McCalley, 2009), personal risk perception (Grothmann & Reusswig, 2006; Terpstra & Lindell, 2013), fear of being flooded in the future (Harries, 2012; Terpstra, 2011), and coping appraisal (including self-efficacy and response/outcome efficacy) (Bubeck, Botzen, Kreibich, & Aerts, 2013; Grothmann & Reusswig, 2006; Terpstra & Lindell, 2013). Some studies have also identified a positive influence of perceived social norms (Lo, 2013; Poussin, Botzen, & Aerts, 2014), local connectedness (Kim & Kang, 2010), and perceived incentives for adaptive behavior (Poussin et al., 2014).

Several theoretical strands were introduced in order to identify relevant explanatory variables for adaptive behavior (Kellens, Terpstra, & De Maeyer, 2013). Originating from Grothmann and Reusswig (2006), protection motivation theory (PMT; Rogers, 1983) is most prominent in recent FRM research. The PMT describes the cognitive process people undergo when facing risks: They appraise the threat of flooding (i.e., likelihood of being exposed to a flood, expected severity, and fear), and their ability to cope with it (i.e., self-efficacy, response efficacy, and response costs). When threat appraisal is low, individuals refrain from adaptive action. If high threat appraisal coincides with high coping appraisal, adaptive responses are triggered. If high threat appraisal meets low coping appraisal, people turn to non-protective responses, for example, denial of the risk (Rogers & Prentice-Dunn, 1997). Recent reviews and meta-analyses show that coping appraisal is more strongly correlated with adaptive behavior than threat appraisal (Bamberg, Masson, Brewitt, & Nemetschek, 2017; Bubeck, Botzen, & Aerts, 2012; van Valkengoed & Steg, 2019). Nevertheless, this does not mean that threat appraisal is less important than coping appraisal as undertaking adaptive actions can reduce perceived risks (van Valkengoed & Steg, 2019; Weinstein, Rothman, & Nicolich, 1998). Moreover, without a significant threat appraisal there is no subjective need to adapt.

Other social-cognitive models for explaining adaptive behavior regarding natural hazards combine PMT factors in different ways and/or feature additional concepts (for an overview of applicable models see Table 1). The person-relative-to-event model (Mulilis & Duval, 1995) conceptualizes the relation between perceived risks and the perceived opportunities to prevent harm from these risks as the main determinant of adaptive behavior. Hence, it basically combines threat appraisal and coping appraisal from PMT in one variable. The Protective Action Decision Model (PADM) (Lindell & Perry, 2012) includes stakeholder perceptions as a determinant for decisions about how to respond to an imminent or long-term threat, in addition to the PMT's threat appraisal (in PADM: threat perceptions) and coping appraisal (in PADM: protective action perceptions). Weinstein (1993) discusses the similarities and differences of important behavioral theories for explaining risk-reducing behavior, and how they relate to the PMT.

2.2 | Knowledge limitations

The application of specific theories in research on adaptive behavior has allowed researchers to conduct (meta-)analyses and to assess the robustness of empirical evidences. A fundamental knowledge limitation is grounded in the limited predictive power of the theories applied so far (Kellens et al., 2013). The first quantitative meta-analysis conducted by Bamberg et al. (2017) in this intellectual catchment found that threat and coping appraisal (together with negative flood-related emotions) on average explain only 13% of the variance in flood-adaptive behaviors/intentions. Selected studies expanded the PMT and achieved explained variances in flood-adaptive behavior of up to 45%, though. These studies included additional explanatory constructs such as flood experiences in the past, reliance on public flood protection, and non-protective responses (fatalism, denial, and wishful thinking; Babcicky & Seebauer, 2019; Grothmann & Reusswig, 2006) and perceived social environment (i.e., whether friends and neighbors implemented risk-reducing measures; Bubeck et al., 2013).

Another fundamental limitation is grounded in, what one might call, the dominant epistemology of this intellectual catchment: the focus on the individual. Collective action is hardly reflected upon in research within this intellectual catchment, although there is initial evidence that social networks and the social environment influence protection motivation and coping appraisal, respectively (Bubeck et al., 2013; Kim & Kang, 2018). Social-psychological research on flood risks mostly assumes a unidirectional relation between the individual and the community it lives in. Social influences on the individual are often seen as an exogenous factor that cannot be changed or negotiated by the individual. For example, subjective norms are taken into account as they are perceived by the individual (Poussin et al., 2014); or collective action is captured by identifying individuals' beliefs in and willingness to be part of a group (Thaler & Seebauer, 2019). We therefore propose that alternative theories focusing on collective factors (e.g., shared cognitions) should be applied more rigorously in order to better understand what motivates adaptive behavior (see Section 2.3 and Table 1).

Another knowledge limitation is grounded in the prevalent practice of cross-sectional sampling in standardized surveys (Bubeck & Botzen, 2013a; Siegrist, 2013, 2014); a practice hardly able to capture behavioral dynamics over time or

TABLE 1 Relevant sociopsychological theories on individual and collective behavior

Theory	Explanatory variables for behavior	Sources
Theories with an emphasis on individual behavior		
Protection motivation theory (PMT)	Threat appraisal and coping appraisal as independent explanatory variables for behavior	(e.g., Rogers, 1983; Rogers & Prentice-Dunn, 1997)
Person-relative-to-event (PrE)	Relationship between the level of appraised threat relative to perceived personal resources (similar to coping appraisal in PMT) and perceived responsibility	(e.g., Mulilis & Duval, 1995)
Theory of planned behavior (TPB)	Attitude toward behavior, subjective norms, and perceived behavioral control (similar to coping appraisal in PMT), together shape an individual's behavioral intentions and behaviors	(e.g., Ajzen, 1999)
Model of action phases (MAP); Motivation–intention–volition model (MIV); health action process approach (HAPA)	Decision sequence leading up to adaptive behavior. MAP, MIV, and HAPA distinguish three decision stages characterized by distinct cognitions and affects: (1) Motivation stage (mirrors threat appraisal in the PMT). (2) Intention stage (reflection on specific actions by comparing response efficacy, self-efficacy, and perceived effort/costs; similar to coping appraisal in PMT). (3) Volition stage translates intention into action if supported by situational factors (resources and barriers, social context) and self-control strategies.	(Gollwitzer, 1990; MAP) (Martens & Rost, 1998; MIV) (Schwarzer, 2008; HAPA)
Protective action decision model (PADM)	Decision sequence leading to behavioral response (1) Predecision processes: reception, attention, and comprehension of environmental and social cues, information sources, warning messages (2) Protective action decision making: dependent on three core perceptions—threat perceptions (similar to threat appraisal in PMT), protective action perceptions (similar to coping appraisal in PMT), and perceptions of social stakeholders (3) Behavioral response: information search, protective response or emotion-focused coping influenced by situational facilitators and impediments	(e.g., Lindell & Perry, 2012)
Theories with an emphasis on collective behavior		
Social identity model of collective action (SIMCA); Social identity model of pro-environmental action (SIMPEA)	How identification with a social group, beliefs about the effectiveness of a group to bring about change, or group-based anger, can motivate people to team up with others in order to improve the situation of the group as a whole. Results on earthquake and hurricane preparedness indicate that strong identification with a local community and perceptions of high collective efficacy may help to establish adaptive behavior-related strategies	(e.g., Van Zomeren, Postmes, & Spears, 2008; SIMCA) (e.g., Fritsche, Barth, Jugert, Masson, & Reese, 2018; SIMPEA)

to infer causality. Feedback effects (e.g., of adaptive behavior on threat appraisal) and recursive processes are mentioned in cross-sectional studies, but hardly empirically investigated. The limited availability of longitudinal studies as well as the lack of (quasi-) experimental studies implies that most causal relations claimed theoretically have not yet been confirmed empirically.

There are several additional limitations we would like to outline. Limitations arise from a wide diversity of how behaviors and behavioral intentions are operationalized and analyzed. While such diversity is constitutive for most scientific endeavors, it may also hamper comparability of results. Bamberg et al. (2017), for instance, found considerable heterogeneity in the operationalization of threat and coping appraisal, a problem also reported by van Valkengoed and Steg (2019). Furthermore, some studies aggregate different adaptive behaviors into a composite index (e.g., Richert, Erdlenbruch, & Figuières, 2017). However, composite indices can reduce explanatory power if different types of behavior with different explanatory variables are combined in one index (see Table 2).

The fact that human motivational processes cannot be measured directly also complicates research. The typical research practice of using self-reported data builds on the presupposition that individuals are not just aware of, but are also able to reflect about and accurately describe their cognitions, emotions, and motivations. Individual responses on the costs and effectiveness of specific flood-proofing measures are often taken at face value (Babcicky & Seebauer, 2019), although it seems more likely that many households did not (yet) deliberate about them. While this is a fundamental knowledge limitation characteristic for all research on motivational processes, it is recommendable to assess and thoroughly consider in which decision stage respondents are in (see Table 1: MAP, MIV, HAPA). For example, respondents in the motivation stage have not yet deliberated the efficacy of options for self-protective action. Hence, their self-reported efficacy estimates are rather guesses than expressions of stable beliefs.

Finally, common research practice with social-cognitive action theories is to treat such theories as value-expectancy models within a linear regression paradigm. By entering the factors identified as relevant into an additive linear function, it is assumed that all factors may directly compensate each other; for example, low expected threat severity accompanied by a high level of fear would result in the same threat appraisal as high perceived severity and low fear. Further, this research practice focuses on "main effects" (e.g., the effect of perceived severity after controlling for the effect of fear) while neglecting interaction effects (i.e., the interactive effect of perceived severity and fear), in particular if interaction effects are nonlinear. In some cases, there might be an inverted U-shaped effect of fear on adaptive behavior: fear may motivate protective action up to a certain point, but too much fear may backfire leading to paralysis and reduced action.

2.3 | Future research

We suggest advancing the discussion on the theoretical level by selecting and combining theories according to the type of adaptive behavior that is to be explained or predicted. When expanding a particular theory, additional explanatory constructs should be drawn from alternative social-cognitive models that apply to the same type of behavior. Table 2 provides a typology of adaptive options available to flood-prone households and illustrates each type with exemplary behaviors. The behavioral characteristics presented in Table 2 are drawn from sociopsychological research on pro-environmental behaviors and propose to distinguish three different characteristics of adaptive behavior. (a) Routine/repetitive versus investment/one-time behaviors: routine/repetitive behaviors need to be maintained continuously to avoid relapse into earlier non-protective patterns; however, repetition holds the risk of automaticity, if habits turn too rigid to be revised once the behavioral context changes (Klöckner & Verplanken, 2018). In contrast, as soon as they are implemented, one-time investment behaviors typically remain effective without or with only minimal additional effort. (b) Individual versus collective behavior: this dichotomy refers to individuals taking action autonomously only in their apartment, for instance, or as part of a local community group with a shared goal (see Section 2.2). (c) Low-cost versus high-cost behavior: this differentiation refers to the effort in time, money, dealing with nuisance, or other resources necessary for implementing a particular adaptive behavior (Diekmann & Preisendörfer, 1992). In practice these behavioral types are not as distinct and clear-cut as Table 2 may suggest; instead, they should be understood as a heuristic orientation for understanding differences between specific adaptive behaviors.

The different social-cognitive action theories listed in Table 1 are suited to explain different types of behaviors. Some theories address phases of the risk management cycle (i.e., rows in Table 2): PADM's inclusion of cognitions of hazard cues (including warning information) makes it particularly useful for analyzing preparation and response actions immediately before and during a flood. MAP, MIV, and HAPA theorize sequential implementation and may therefore help to understand adaptive behaviors that are gradually implemented across various phases of the risk management cycle, for example, setting up a flood store with emergency supplies and materials, acquiring the skills for effectively using those materials in regular training, and actively deploying these materials and skills when disaster strikes. Other theories apply to specific types of behavior (i.e., columns in Table 2): due to its inclusion of subjective norms theory of

TABLE 2 Types of adaptive behaviors

Phases of the risk management cycle	Characteristics of the behavior							
	Routine/repetitive				Investment/one-time			
	Individual		Collective		Individual		Collective	
	Low cost	High cost	Low cost	High cost	Low cost	High cost	Low cost	High cost
Prevention	• Storing keepsakes and documents on upper floors • Conducting maintenance checks on pumps and emergency materials	• Acting as flood warden for a city block • Selecting new furniture or appliances for light weight and easy breakdown	• Monitoring the implementation of public flood defenses	• Being politically active in a citizen initiative, for example, for keeping (infra-) structures outside of floodplains	• Installing a pump pit in the basement • Installing anti-backflow valves on pipes	• Constructing flood-proof windows and walls • Moving (permanently) upstairs or outside of the flood-prone area	• Signing a petition for improved public protection	• Participating in the design of structural defenses • Acquiring boats and high-capacity pumps
Preparation	• Accessing weather warnings • Replacing expired emergency supplies	• Organizing temporary accommodation	• Conducting joint flood drills with neighbors	• Removing foliage and debris from riversides	• Developing an emergency plan for all household members	• Storing emergency tools and materials	• Establishing a joint evacuation meeting point	• Setting up joint flood stores with tools and materials
Response	• Accessing flood updates and monitoring water depth	• Operating pumps • Erecting mobile protection devices	• Providing shelter and food	• Coordinated closing of flood doors over an entire city district	• Deploying sandbag barrier at own building • Bolting down firewood stacks and hay bales	• Contracting a moving company for evacuating belongings	• Deploying sandbag barrier at choke points	• Evacuating physically frail people, goods and livestock
Recovery	• Cleaning and drying the building	• Repairing the building • Replacing damaged items	• Offering psychosocial support in personal talks	• Helping in clean-up	• Re-installing hard-to-move or high-value furniture only in upper floors	• Building back better with tiled flooring, metal doorframes • Buying insurance (premium depends on context)	• Donating clothes or spare furniture	• Donating money

planned behavior (TPB) is particularly suited for explaining repetitive behavior since frequent behaviors often become normative in societies. SIMCA and SIMPEA are tailored to explain why flood-prone households team up in collective action with others. PMT, MAP, MIV, HAPA, and TPB present decision frameworks which include balancing of subjectively perceived costs and benefits from an investment.

3 | HOW EFFECTIVE ARE INDIVIDUAL ADAPTIVE ACTIONS?

Research has investigated the effectiveness of adaptive measures at the property level. This determines the role that these measures can play in overall FRM. Individual-level adaptation to flooding can be split into risk reduction and risk transfer. Risk reduction seeks to lower or prevent impacts. For example, actions that make properties more resistant to flood water to lower flood damage or actions that reduce the probability of suffering a negative health impact. Therefore, risk reduction measures can potentially limit both financial or monetary flood impacts as well as nonmonetary flood impacts. Risk transfer on the other hand seeks to limit the financial uncertainty of a potentially damaging event rather than the direct impact per se. For example, insurance is the primary example of risk transfer. Insurance acts to limit the financial uncertainty of an event because the large random monetary loss from a flood is replaced with a smaller fixed costs in the form of the insurance premium. This provides the individual in question with a greater sense of security, which can be welfare enhancing if the individual is risk averse (Mas-Colell, 1995). Of these two avenues of managing flooding at an individual level, we focus in this review upon risk reduction through risk reduction measures (for risk transfer see Surminski & Thieken, 2017; Botzen et al., 2019; or Linnerooth-Bayer, Surminski, Bouwer, Noy, & Mechler, 2019).

3.1 | Studies on the effectiveness of individual measures

Overall, private adaptation measures can be split (broadly) into wet and dry flood-proofing (Aerts, Botzen, & de Moel, 2013; Kreibich et al., 2015). Wet flood-proofing limits damage once water has entered a building. Dry-flood-proofing limits the likelihood of flood water entry. These actions can include both technical and nontechnical measures (Table 2). For instance, storing keepsakes and documents permanently upstairs can be considered as nontechnical wet flood-proofing. Relocation outside of flood-prone areas is an extreme example of nontechnical dry flood-proofing, which in effect reduces the risk of being flooded to an individual to zero. However, unless the property itself is removed another actor can purchase the property resulting in little change to overall risk. Systematic relocation programs can achieve an overall reduction in flood risk if buildings are removed and land-use changes occur. For example, Hudson and Botzen (2019) reveal that zoning polices are cost-effective but for the most part are out of scope for private households.

Kreibich et al. (2015) note that many different approaches, for example, empirical damage data or expert judgment, and different sets of data are employed to estimate the monetary damage reduction abilities of specific measures, resulting in a large range of estimates. For example, Hudson, Botzen, Kreibich, Bubeck, and Aerts (2014) estimate that "flood adapted use," (i.e., using living space in a low-value way), reduces the average monetary flood-damage by €14,000. Most costs of this action are opportunity costs of forgone activities, which are hard to measure in monetary terms because of their intangible or subjective nature. Still, the benefit-cost ratio of this measure is likely to be high.

In terms of technical measures, Kreibich et al. (2015) summarizes the benefits and costs (the monetary employment costs) from several flood-proofing measures. They find for wet flood-proofing, a reliable range of 35–50% of damage prevented at a cost of between €1000 and €8000. For dry flood-proofing (including elevation, a sub-set of dry flood-proofing) there is a reliable range of 22–65% with a cost range of €2000–€57000.

Aerts (2018) reviews cost estimates for property-level adaptation finding costs for average residential buildings. In order to present a range similar in context to Kreibich et al. (2015) the costs from Germany, United States, and United Kingdom are summarized. Aerts (2018) finds estimates for dry flood proofing at between US$9200 and US$24000 and wet flood-proofing at US$2400–US$23000.[2]

Besides the ability of a measure to effectively lower the damage during a flood, these measures are only efficient if their total benefits exceed their total costs (i.e., provides a net benefit). Cost-benefit studies that have been undertaken indicate that overall small investments (e.g., securing oil tanks [Kreibich, Christenberger, & Schwarze, 2011]) or flood adapted uses of a home (Hudson et al., 2014) are particularly efficient by this standard (see: Holub & Fuchs, 2008;

Hudson et al., 2014; Kreibich et al., 2011; Lamond, Rose, Bhattacharya-Mis, & Joseph, 2018; Poussin, Botzen, & Aerts, 2015). An additional aspect is that individual-level adaptation measures are most often found to be efficient when there is a 2–5% annual probability of being flooded (Hudson et al., 2014; Lamond et al., 2018; Poussin et al., 2015).

Additionally, early warning systems when combined with individual-level preparedness actions can reduce damage. However, empirical studies on this topic in relation to individual-level action are rare (Kreibich, Müller, Schröter, & Thieken, 2017). Generally, quantitative knowledge about non-technical adaptation measures appears to be less robust in comparison to the knowledge about technical measures, which reflects the focus of the scientific literature (see the differently focused reviews of: Kreibich et al. (2015), Lamond et al. (2018), and Aerts (2018).

Therefore, overall, this evidence base shows that while the measures can be potentially expensive for those at highest risk or in areas without high levels of flood protection, the use of property-level measures can still be cost-effective in the long-run. This is because they tend to reduce the expected direct monetary damage from a flood more than they cost to install. This in turn implies that the behavioral theories presented in Section 2 are important. This is because the outcomes of the decision process to employ adaptive measures will have significant consequences on overall flood outcomes and impacts.

3.2 | Knowledge limitations

While the effectiveness of large-scale engineering measures is relatively independent of human behavior, the effectiveness of private adaptation measures also depends on how individuals perceive and act upon flood risk information and upon the measures themselves. For instance May and Chatterton (2012) highlight that adaptation measures could display a probability of successful usage of 77–90% (depending on the degree of maintenance required). Therefore, the less capable a person is in using and maintaining their adaptation measures, the less likely these measures are to be effective in the event of a flood. Similarly, the success of early warning in terms of damage reduction is strongly determined by the behavior of recipients (Morss, Mulder, Lazo, & Demuth, 2016; Penning-Rowsell & Green, 2000; Sayers, Penning-Rowsell, & Horritt, 2018).

Furthermore, a core epistemological limitation with very practical implications results from the research being overwhelmingly focused on understanding the effectiveness of measures in monetary terms, for example, looking at the physical capabilities of the measures themselves. We know there are a range of intangible or nonmonetary flood impacts (Bubeck, Otto, & Weichselgartner, 2017b), like psychological or mental health impacts (Foudi, Osés-Eraso, & Galarraga, 2017) or well-being losses (Hudson, Pham, & Bubeck, 2019c). Thieken et al. (2016a) and Reiter, Wenzel, Dittmer, Lorenz, and Voss (2018) found that households can perceive psychological stress and recovery activities more seriously than financial losses. Additionally, Hudson, Botzen, Poussin, and Aerts (2019a) and Fernandez, Stoeckl, and Welters (2019) revealed that the welfare loss from the intangible impacts of flooding can be larger than the tangible welfare impacts. Sekulova and van den Bergh (2016) emphasize therefore that tangible impacts of flooding do not sufficiently capture all of a flood's consequences. Bubeck and Thieken (2018) argue that intangible effects can last considerably longer than repairing or replacing damaged economic assets (see also Reiter et al., 2018; Thieken, Bessel, et al., 2016a). Additionally, there is a nascent field investigating the intangible benefits of individual-level adaptation strategies (Lamond et al., 2018) resulting from preventing negative psychological impacts or by providing a greater sense of security (Hudson, Botzen, et al., 2019a; Joseph, Proverbs, & Lamond, 2015). There is thus an emerging debate aiming at determining if adaptive measures can also lower the damage suffered during a flood as a proxy for the welfare loss prevented.

Despite knowing the existence of these impacts and the existence of some methods to monetize them (Meyer et al., 2013), these intangible or nonmonetary losses tend to be neglected in the practice of risk assessments due to the difficulty of assigning monetary values to nonmonetary impacts (Prettenthaler et al., 2015).

A further related knowledge limitation regards how society as a whole approaches FRM decision making. While society as a whole plays an indirect role in FRM, social concerns, and beliefs in effect make the rules of the game, determine relative priorities (e.g., what is affordable, if responsibilities should be collective vs. individualized), and what are acceptable outcomes. These socially determined concerns indirectly influence how FRM decision makers assess and determine which actions to take. While there are a range of possible decision support frameworks such as multi-criteria analysis or robust decision making (Haasnoot, Kwakkel, Walker, & ter Maat, 2013; Kunreuther et al., 2012), the current focus on tangible or monetary flood impacts has led to the predominate decision making framework being based on cost-benefit analyses or cost-effectiveness at the policymaking level (Mechler et al., 2014). This is also appears to be the

case in models of individual adaptive behavior under various behavioral rules (Haer, Botzen, de Moel, & Aerts, 2017; Hudson, Botzen, Feyen, & Aerts, 2016). Such approaches typically do not focus on individual shares; they direct attention rather to the overall outcome (Gawel & Kuhlicke, 2017) and by doing so can find it difficult to account for social inequalities (Kind, Botzen, & Aerts, 2017) or different risk management objectives (Unterberger, Hudson, Botzen, Schroeer, & Steininger, 2019). This is a significant limitation moving forward as broader social and economic differences can lead to differences in vulnerability across society (Cutter, 2017; Kaufmann, Priest, & Leroy, 2018). The systematic exclusion of the full range of benefits and costs from adaptation strategies prevents us from understanding if these measures generate larger subjective perceived benefits than costs. Failing to account for such differences could lead to greater problems if the movement toward more socially inclusive risk management called for by the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) or the sustainable development goals is acted upon (UN, 2018; UNISDR, 2015).

3.3 | Future research

The current conceptualization of effectiveness is heavily based on comparing the degree of monetary damage and how it can be reduced through adaptive actions. However, floods not only inflict monetary impacts but also wider subjective well-being (Von Möllendorff & Hirschfeld, 2016) or mental health impacts (Waite et al., 2017). These are impacts that can be limited by adaptation. Therefore, we suggest to broaden the range of concepts that are used to assess if adaptive action is effective or not. This is because the dominant assessment approach has a welfare economics underpinning that assumes that estimates of effectiveness capture the full range of welfare impacts. However, the current focus on monetary assessments of direct tangible consequences only focuses on one sub-element of the changes in welfare. Therefore, the inclusion of more subjective, well-being focused indicators is relevant to move closer to a more complete welfare assessment. Although, an evolving literature is beginning to establish an empirical base (Hudson, Botzen, Poussin, & Aerts, 2019; Hudson, Pham, & Bubeck, 2019c; Sekulova & van den Bergh, 2016), this integration of monetary and nonmonetary impacts in the assessment of risk remains a task that requires more effort, including an expansion of the temporal timespan by considering long-term recovery processes and the cooperation across the boundaries of intellectual catchments.

We suggest linking both objective and subjective indicators of human well-being more systematically to assess the effects of individual adaptation. Subjective indicators can refer, above all, to the perception of people about their own well-being, how secure they feel, how they were impacted by a flood event or how quickly and well they recover. These additional subjective indicators are complements to the more objective measurements (e.g., damage prevented) that currently is in the focus. Such indicators need to be systematically linked with adaptive behavior to better understand the effect of adaptive behavior on human well-being.

4 | DO INDIVIDUALS HAVE THE CAPACITIES TO TAKE ADAPTIVE ACTIONS?

Research in this intellectual catchment contributes to better understanding the behavioral turn by investigating to what extent households actually have the capacities to take adaptive actions. As Kuhlicke, Steinführer, et al. (2011b) point out, the term capacity is widely used as an umbrella term for referring to a broad set of resources (including abilities, skills, competences, and social relations) of an individual or a social entity (such as a group, a community, or a society). These resources are either actually available or provide a potential, that is, something latent. This intellectual catchment is grounded on pioneering work focusing on social vulnerability (Blaikie, Cannon, Davis, & Wisner, 1994; Chambers, 1989; Watts & Bohle, 1993), rather applied research aiming at assessing and enhancing the capacities of individuals, groups and communities (Allen, 2006; Anderson & Woodrow, 1989; Davis, 2004), and also relates to more recent debates on climate change adaptation (i.e., adaptive capacity; Adger, Brooks, Bentham, Agnew, & Eriksen, 2004; Folke et al., 2002).

4.1 | Studies on social vulnerability in FRM

Empirical studies suggest, that the unequal exposure and distribution of adaptive/coping capacities can be explained by socio-demographic-economic indicators such as age, income, formal education, gender, ethnicity, and so forth (Douglas

et al., 2012; Fielding, 2007; Fielding, 2012, 2017; Maantay & Maroko, 2009; Montgomery & Chakraborty, 2015; Sayers et al., 2018; Tapsell, Penning-Rowsell, Tunstall, & Wilson, 2002; Walker & Burningham, 2011). An analysis of 67 flood disaster case studies published between 1997 and 2013 has identified demographic characteristics as well as the socio-economic status of a household as main drivers of social vulnerability (Rufat, Tate, Burton, & Maroof, 2015). Furthermore, it was found that deprived communities are most vulnerable as a result of limited capacities to prepare for, respond to and recover from flooding (Tapsell & Tunstall, 2008; Walker & Burningham, 2011).

At the same time, an emerging strand of research indicates that coping and adaptive capacities of individuals are shaped by a multitude of factors, most of them eluding from simple measurements by means of official statistical data (e.g., age, income, and gender) (Grothmann & Patt, 2005; Kuhlicke, Scolobig, Tapsell, Steinführer, & De Marchi, 2011a; Rufat et al., 2015). Koks, Jongman, Husby, & Botzen, 2015, for instance, study the overlap between flood hazard, exposure, and social vulnerability to better inform FRM strategies using the case-study of Rotterdam, the Netherlands. Their results show that a significant share of the population exposed to the risk of flooding can be defined as socially vulnerable, but in a very heterogeneous manner. Similarly, Kuhlicke, Scolobig, et al. (2011a) show that drivers of social vulnerability can vary considerable over time, as a demographic group (e.g., elderly) may be less vulnerable during the preparatory phase of a flood event but highly vulnerable during the recovery phase (for a similar finding: Reiter et al., 2018).

In addition, research showed that the availability of capacities can not only result from objective, sociodemographic factors, but also from other factors. For example, Dittmer, Lorenz, Reiter, and Wenzel (2016) showed that local discourses and narratives, (perceived) injustice and marginalization of certain actors or whole regions can influence adaptive behavior with regard to flood events. In the case of the river Elbe flood 2013, local discourses highlighting long-term deprivation of rural regions in the former GDR in the context of the German reunification shaped local perceptions of an (allegedly) poor FRM that resulted in fatalistic behavior in some communities, but also triggered individual and self-determined adaptive behavior in other communities.

Other studies have explored the relevance of networks, social capital and extended capital approaches. Pelling and High (2005) highlight the relevance of social capital in behavior-related adaptation processes. Research often focuses on the role of networks in recovery processes (Nakagawa & Shaw, 2004). However, Babcicky and Seebauer (2017) observe opposing effects: on the one hand, strong social ties can be effective during the response and recovery from a flood event; on the other hand, the expectation of social support can also reduce risk awareness, resulting in a situation where adaptive actions become less like to be taken by households. Furthermore, Wickes, Zahnow, Taylor, and Piquero (2015) study on the 2003 Brisbane flood indicates that social capital may have only limited effects on recovery processes.

Others have started to highlight the critical role of procedural aspects in decision-making processes in FRM (Johnson, Penning-Rowsell, & Parker, 2007; Scolobig & Pelling, 2016; Thaler, Fuchs, Priest, & Doorn, 2018; Thaler & Hartmann, 2016; Walker & Burningham, 2011). It is argued that the delegation of responsibility to the local (Begg, Walker, & Kuhlicke, 2015; Herbert, 2005) and/or individual level (Begg, Callsen, Kuhlicke, & Kelman, 2017) is often accompanied neither by an increasing right to participate nor with enhanced resources (Herbert, 2005). Therefore negative consequences of "hollowing out" of the public sphere are expected because of downscaling responsibilities to local actors without any further resources and power (Begg et al., 2015). The outcome is that individuals are hardly provided with the opportunity to co-decide upon what should constitute their individual space of responsibility (Begg et al., 2017).

4.2 | Knowledge limitations

While it is often acknowledged and emphasized that the capacities of households to take adaptive actions are influenced by a multitude of factors, including socio-demographic-economic factors, knowledge, and network related aspects as well as institutional aspects (Kuhlicke, Steinführer, et al., 2011b), the evidence base in this field of research is rather mixed. In contrast to the two preceding catchments (i.e., motivation and effectiveness), we were not able to derive to a comprehensive understanding of key factors shaping the capacities of households to take adaptive actions. While there is evidence that socio-demographic-economic indicators such as age, income, formal education, gender, and so forth have a strong influence on the capacities of households to adapt and cope with flood events, other studies highlight that capacities can be shaped by a set of heterogeneous factors and that the availably can vary considerably during different phases of a flood event. Furthermore, the availability of capacities is also influenced by less tangible

factors such as discourses and narratives. With respect to social networks the situation is somehow similar: while the importance of social capital is highlighted, the findings of studies we reviewed point again to mixed results, highlighting temporal and contextual aspects.

In contrast to the two preceding intellectual catchments, contextual factors play a decisive role in this catchment. While physical dry-flood-proofing measures function in the same way in different places and the social-cognitive factors that shape motivation to take adaptive actions can occur independently from contextual factors, capacities to take adaptive actions are enmeshed in specific contexts. For example, how embedded households are in their respective community, the culture of risk that exists in that community, or how material and immaterial resources are distributed in a society, all influence the capacity of households to take adaptive actions. There is thus a need to develop a more nuanced understanding of which contextual factors shape households capacities. However, to allow for comparison of empirical insights generated by studies conducted in different contextual settings, we argue that a stronger theoretical underpinning of research in this intellectual catchment is needed to be able to produce empirical evidences that are comparable across different contexts.

4.3 | Future research

We suggest advancing the discussion within this catchment by applying existing theoretical frameworks more often and systematically. There are five different sets of theories and concepts we consider as particularly relevant. Table 3 provides a systematic overview.

The first set of theories pursue a rather macro-oriented perspective, such as the Pressure and Release Model (PAR) (Blaikie et al., 1994; Wisner et al., 2005) or the Space of Vulnerability (Watts & Bohle, 1993). They focus on how societal processes outside of the influence of individuals "limit or enhance people's coping capacity" (van Dillen, 2002, p. 54). More specifically, they provide a theoretical frame that systematically scrutinizes how wider economic and/or political processes translate into specific patterns of how responsibility and financial resources are distributed in FRM, which then translate into specific vulnerable conditions (e.g., less protected settlements experience flooding more often than protected settlements).

The second set of theories focus on the interplay of society and individuals. These include so called practice theories, including different theoretical lenses developed by Bourdieu (2010), Giddens (1979, 1986), and Reckwitz (2002). These theories highlight that individual behavior is always embedded in social structures and associated power relations, which were formed in the past, but are also in constant flux and gradually modified in everyday social interactions and practices. Applying this to our field of research, FRM and its practices need to be seen as being embedded in larger sociopolitical structures (Lorenz & Dittmer, 2016). At the same time, they are constantly reproduced and/or gradually altered through individual practices. Such approaches can be used not just to systematically scrutinize how the respective societal context produces specific patterns of vulnerability with respect to flood events (De Marchi & Scolobig, 2012; Kuhlicke, 2015; Kuhlicke, Scolobig, et al., 2011a), but also how everyday precarious living conditions influence people's capacity to cope with and adapt to flood events (Gaillard, Walters, Rickerby, & Shi, 2019).

A third set of theories focus on social capital. We suggest to distinguish more clearly between different conceptualizations of social capital and apply them more rigorously to research on the behavioral turn. On the one hand, Bourdieu and Coleman conceptualize social capital as an individual capacity. It is, above all, the quality and quantity of the social relationships as well as economic and cultural capital which can be mobilized via individual networks that they put at the forefront of their analysis (Bourdieu, 1986, 2010; Coleman, 1988). Putnam (1993, 2000), on the other hand, emphasizes the role of social capital as a form of collective capacity. Social capital, in his understanding, relates to "features of social organization, such as trust, norms and networks that can improve the efficiency of society by facilitating coordinated actions" (1993, p. 167). The latter understanding is similar to the sociopsychological theories on collective behavior that we outline in Table 1.

A fourth area of relevance is the concept of affordability. Affordability is a normative concept (Saenz, 2009). It is commonly determined through the lens of what can people be expected to afford without it being an excessive financial burden (National Research Council, 2015) and still achieve a certain acceptable standard of living (Bundorf & Pauly, 2006). However, due to its subjective and normative nature, it is difficult to empirically study affordability due to the absence of an actionable theoretical baseline. While there have been attempts to study affordability in relation to insurance (Dixon et al., 2017; Hudson, 2018; Kousky & Kunreuther, 2014), there are few studies on the affordability of

TABLE 3 Relevant theories on capacities

Theoretical approach	Relevant aspects theories focus upon	Sources
Theories pursuing a macro-perspective		
Pressure and release model/ space of vulnerability	Root causes (e.g., economic and political processes that affect the allocation and distribution of resources) translate into dynamic pressures (e.g., a specific pattern of how responsibility and financial resources are distributed within FRM) that results in unsafe or particularly vulnerable conditions (e.g., less protected settlements experience flooding)	(Blaikie et al., 1994; Watts & Bohle, 1993; Wisner, Blaikie, & Cannon, 2005)
Theories focusing on the interplay of society and individual practices		
Practice theories	Borrowing from Ober and Sakdapolrak (2017, p. 3) the practice of adaptation can be captured by the following formula: "practice of adaptation = [(habitus) (capital)] + field" Habitus: refers to individual perceptions, attitudes and dispositions to take adaptive actions Capital: refers to the distribution of assets shaped by such factors as class, gender, education, age, and so forth Field: refers to a social space defined by specific internal logics, including established rules, forms of relevant capital, and so forth	(Bourdieu, 2010; Giddens, 1979, 1986; Ober & Sakdapolrak, 2017; Reckwitz, 2002; Sakdapolrak, 2007)
Network theories		
Social capital	Social capital as an individual capacity relates to the quality and quantity of the social relationships that can be mobilized via individual networks in order to cope with and adapt to the consequences of flood events Social capital as a form of collective capacity that is based on trust, norms and networks that help individuals and collective to cope with and adapt to the consequences of flood events	(Babcicky & Seebauer, 2017; Bourdieu, 1986; Ober & Sakdapolrak, 2017) (Mohan & Mohan, 2002; Putnam, 1993, 2000)
Affordability		
Concept of affordability	As a normative concept it asks what households can be expected to afford without facing an excessive financial burden in FRM	(Dixon et al., 2017; Hudson, 2018; Kousky & Kunreuther, 2014; Montgomery & Kunreuther, 2018)

property-level adaptive measures. An exception is Montgomery and Kunreuther (2018), who argue that loans might be a useful strategy to help lower income households afford adaptive measures.

We suggest linking the mentioned theories more systematically to an investigation of the behavioral turn. While theories such as the PAR and practice theory focus rather on the interplay of policies, distribution of various form of capital and power relations and specific conditions of individual and collective vulnerability, network theories and the concept of affordability rather focus on individual capacities (incl. network and resources), and how they might help to adapt to and cope with future flooding.

5 | CONCLUSION: BUILDING BRIDGES ACROSS INTELLECTUAL CATCHMENTS TO UNRAVEL THE POSSIBLE IMPLICATIONS OF THE BEHAVIORAL TURN

The previous sections showed that in recent years, research on the assumptions underlying the behavioral turn in FRM (Figure 1) has started to produce empirical evidences on their validity. However, they also underlined that current knowledge is limited with respect to some decisive areas.

While our suggestions for how to advance the understanding of the behavioral turn mostly remain within intellectual catchments, we are convinced that there is a need to produce a more sustained and more substantial dialogue across intellectual catchment boundaries. Although first attempts have already been made to cross disciplinary catchment boundaries (Aerts et al., 2018; Haer, Botzen, de Moel, & Aerts, 2017), we believe that the long-term consequences and implications of the behavioral turn in FRM should be explored by building more sustainable bridges across intellectual catchments. We therefore propose three overarching principles (Dolan & Metcalfe, 2012). Future research on the assumptions and implications of the behavioral turn should be (a) grounded more strongly in theories ideally spanning the different intellectual catchments, (b) empirical research should be conducted more systematically, particularly by taking a long-term perspective, and should (c) engage more openly with the normative assumptions of the behavioral turn. Each of these principles will be discussed below.

5.1 | More theoretically grounded research

Only through a stronger theoretical grounding, will we be able to generate more robust evidences for the assumptions and implications of the behavioral turn. This article found that what counts as a theory varies between intellectual catchments and theories can have very different purposes within and between intellectual catchments (Kwon & Silva, 2019). While theoretical frameworks from socio-psychology may help to generate robust evidences, conceptual frameworks such as the PAR (Blaikie et al., 1994; Wisner et al., 2005) or Space of Vulnerability (Watts & Bohle, 1993) are rather aiming at sensitizing researchers for societal processes and structures that might help explain specific patterns of vulnerability. However, there is a need to start developing conceptual bridges between catchments, ideally by relying on overarching concepts and theories. We believe that the concept of human well-being offers the potential for such a cross-catchment perspectives as it relates to and builds upon discussions taking place in different catchments.

5.2 | More methodologically rigorous research

There is a need to introduce and agree upon standards for measuring the key constructs, which underlie the behavioral turn. Standardization of measurements, in particular of survey instruments, may facilitate comparison of findings and may allow for future meta-analyses. This includes that in quantitative studies, researchers should report sufficient statistical data for calculating bivariate associations.

Applying multi-methods approaches more often may facilitate cross-catchment collaboration. Response rates in conventional self-report surveys have decreased over the last years (Couper, 2012). Therefore, automated data collection from user statistics in weather warning apps, insurance contracts, and so forth may provide more representative insights into individual behaviors. Multi-method designs combining, for instance, semi-structured interviews, expert observations from site visits and standardized surveys may allow triangulating and thus substantiating findings. Emerging collaborative data collection methods such as openbuildingmap.org (Dell'Acqua, Gamba, & Jaiswal, 2013; Pittore, Wieland, & Fleming, 2017) and newly emerging data sources (e.g., crowdsourcing) should be explored more systematically with regard to their potential for better understanding adaptive behavior over time.

We consider the establishment of a longitudinal perspective in FRM research as vital. The dominant practice of conducting cross-sectional surveys neglects the fact that adaptive behaviors develop and change over time. Without measuring the full range of flood impacts, how they are socially dealt with, their long-term repercussions and how they interact with individual-level adaptive behavior, knowledge about causal relations will remain fragmented.

Currently, very little experience with implementing longitudinal surveys exists in the natural hazards domain. This is due to distinct methodological challenges (Hudson, Thieken, & Bubeck, 2019b). For example, it is difficult to motivate people to participate in repeated surveys. In addition, respondents could leave the panel, which could negatively impact the quality of results (Bubeck & Botzen, 2013b; Hudson, Thieken, & Bubeck, 2019b). It also requires higher resource intensity compared to cross-sectional studies. Moreover, research project funding structures often do not allow for longitudinal studies. However, with more detailed data from before and after floods, more robust conclusions on effectiveness of adaptive measures could be drawn. A longitudinal perspective may enable, among other benefits, the design of behavioral change interventions. Investigating changes in quasi-experimental settings, and monitoring how flood risk policies and activities of private actors co-evolve over time, may provide results which

are more informative for practitioners and residents on the ground and more stimulating for the advancement of theory.

Streamlining methods, however, should not constrict the diversity of approaches necessary to advance FRM research. The integration of findings need not solely rely on meta-analysis and its requirements for standardized questionnaire formats and uniform operationalization of theoretical constructs. Comparative studies could contrast and validate findings for different adaptive actions or different contexts. This comparative approach, however, presupposes that researchers are explicit about what is being measured and what assumptions they build on.

5.3 | More research addressing the normative assumptions of the behavioral turn

There is a need for both researchers and stakeholders to engage more thoroughly with the policy and welfare implications of the behavioral turn in FRM. Encouraging citizens to become more active in the pursuit of individual and community resilience through the uptake of property-level adaptation measures can reduce financial damage. However, there is also a need for caution. While financial damage may be reduced, some individuals at risk of flooding continue to experience repeated and costly effects (both financially and psychologically) (Bubeck & Thieken, 2018; Kuhlicke et al., 2020). Furthermore, many households may simply not have the financial and/or personal capacities to implement household-level measures and to recover after a flood or they might be less motivated after they realized that individual adaptive behavior is not as effective as it was supposed to be.

Burden sharing in FRM thus does not simply boil down to efficiency or matters of individual motivations; it is also loaded with normative ideals of justice (Begg, 2018). Yet, the answer to the question of how just a specific distribution of responsibilities is, depends also on the philosophical traditions one is referring to: utilitarianism, for instance, aims to maximize utility, which may be understood as the aggregated happiness of individuals—, that is, FRM should offer the greatest gain for the society (Thaler & Hartmann, 2016) implying that it is fair to prioritize taxpayers' money to protect areas which represent the greatest value to society as a whole. Egalitarianism, on the other hand, highlights the importance of the equal distribution of resources across individuals implying that the least-advantaged, which in the context of FRM can be conceptualized as the most vulnerable individuals in society, should be prioritized when distributing resources for managing floods (Sayers et al., 2018). However, a theoretical discussion about the fairness of the distribution of responsibility between public and private actors often does not take place in policy or practice. It is thus often masked in controversies surrounding flood protection (e.g., acceptable levels of risks, distribution of public, and private responsibilities in FRM) (Kuhlicke, Callsen, & Begg, 2016; Otto, Hornberg, & Thieken, 2018). We therefore believe that it is vital to not just expand the evidence based on the assumptions underlying the behavioral turn, but to also critically reflect about the wider societal implications of this turn toward making individuals co-responsible for reducing flood risks by linking the discussion on the motivation and effectiveness of as well as capacities supporting adaptive behavior more comprehensively with different notions of social justice and what they imply for future decision-making in FRM.

ACKNOWLEDGMENTS

The article is based on the outcomes of the workshop “From data to resilience” which was jointly organized by the Helmholtz Centre for Environmental Research GmbH—UFZ and the University of Applied Science Bielefeld and which took place on May 16–18, 2018. The workshop was supported by the RISK_M project (Soziale Mobilisierung zur Optimierung eines Risikomanagements bei extremen Hochwasserereignissen). The work carried out by Sebastian Seebauer was supported by the Austrian Climate and Energy Fund and was carried out within the Austrian Climate Research Program; funding no. B670283.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Christian Kuhlicke: Conceptualization. **Sebastian Seebauer:** Conceptualization. **Paul Hudson:** Conceptualization. **Chloe Begg:** Conceptualization. **Phihlip Bubeck:** Conceptualization. **Cordula Dittmer:** Conceptualization. **Torsten Grothmann:** Conceptualization. **Anna Heidenreich:** Conceptualization. **Heidi Kreibich:** Conceptualization. **Daniel**

Lorenz: Conceptualization. **Torsten Masson:** Conceptualization. **Jessica Reiter:** Conceptualization. **Thomas Thaler:** Conceptualization. **Annegret Thieken:** Conceptualization. **Sebastian Bamberg:** Conceptualization; funding acquisition.

ORCID

Christian Kuhlicke https://orcid.org/0000-0002-1193-228X
Sebastian Seebauer https://orcid.org/0000-0003-4592-9529
Paul Hudson https://orcid.org/0000-0001-7877-7854
Chloe Begg https://orcid.org/0000-0003-3563-3214
Philip Bubeck https://orcid.org/0000-0001-5163-5290
Cordula Dittmer https://orcid.org/0000-0001-5371-8794
Torsten Grothmann https://orcid.org/0000-0001-9156-0158
Anna Heidenreich https://orcid.org/0000-0002-3477-2557
Heidi Kreibich https://orcid.org/0000-0001-6274-3625
Daniel F. Lorenz https://orcid.org/0000-0002-5690-6384
Torsten Masson https://orcid.org/0000-0001-9870-0846
Jessica Reiter https://orcid.org/0000-0001-8453-8462
Thomas Thaler https://orcid.org/0000-0003-3869-3722
Annegret H. Thieken https://orcid.org/0000-0001-7068-2615
Sebastian Bamberg https://orcid.org/0000-0003-1541-9616

ENDNOTES

[1] https://www.gesetze-im-internet.de/whg_2009/__5.html

[2] Approximately equal to €2100-€20200 and €8100-€21200 in 2019 euros respectively (March 2019).

RELATED WIREs ARTICLES

Integrating human behavior dynamics into drought risk assessment-A sociohydrologic, agent-based approach

FURTHER READING

Kreibich, H., van den Bergh, J. C. J. M., Bouwer, L. M., Bubeck, P., Ciavola, P., Green, C., ... Thieken, A. H. (2014). Costing natural hazards. *Nature Climate Change*, *4*, 303.

REFERENCES

Adger, W. N., Brooks, N., Bentham, G., Agnew, M., & Eriksen, S. (2004). *New indicators of vulnerability and adaptive capacity*. Technical Report Tyndall Centre for Climate Change Research.

Aerts, J. (2018). A review of cost estimates for flood adaptation. *Water*, *10*, 1646.

Aerts, J. C. J. H., Botzen, W. J., Clarke, K. C., Cutter, S. L., Hall, J. W., Merz, B., ... Kunreuther, H. (2018). Integrating human behaviour dynamics into flood disaster risk assessment. *Nature Climate Change*, *8*, 193–199.

Aerts, J. C. J. H., Botzen, W. J. W., & de Moel, H. (2013). Cost estimates for flood resilience and protection strategies in New York City. *Annals of the New York Academy of Science*, *1294*, 1–104.

Ajzen, I. (1999). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2).

Allen, K. (2006). Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. *Disasters*, *30*, 81–101.

Anderson, M., & Woodrow, P. (1989). *Rising from the ashes. Development strategies in times of disasters*. London: I: Intermediate Technology Publications.

Babcicky, P., & Seebauer, S. (2017). The two faces of social capital in private flood mitigation: opposing effects on risk perception, self-efficacy and coping capacity. *Journal of Risk Research*, *20*, 1017–1037.

Babcicky, P., & Seebauer, S. (2019). Unpacking protection motivation theory: Evidence for a separate protective and non-protective route in private flood mitigation behavior. *Journal of Risk Research*, *22*(12), 1017–1037.

Bamberg, S., Masson, T., Brewitt, K., & Nemetschek, N. (2017). Threat, coping and flood prevention – A meta-analysis. *Journal of Environmental Psychology*, *54*, 116–126.

Begg, C. (2018). Power, responsibility and justice: A review of local stakeholder participation in European flood risk management. *Local Environment*, *23*, 383–397.

Begg, C., Callsen, I., Kuhlicke, C., & Kelman, I. (2017). The role of local stakeholder participation in flood defence decisions in the United Kingdom and Germany. *Journal of Flood Risk Management*, *11*(2), 180–190.

Begg, C., Walker, G., & Kuhlicke, C. (2015). Localism and flood risk management in England: the creation of new inequalities? *Environment and Planning C: Government and Policy*, *33*, 685–702.

Bhattacharya-Mis, N., Lamond, J., Montz, B., Kreibich, H., Wilkinson, S., Chan, F., & Proverbs, D. (2018). Flood risk to commercial property: Training and education needs of built environment professionals. *International Journal of Disaster Resilience in the Built Environment*, *9*, 385–401.

Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (1994). *At risk: Natural hazards, people's vulnerability, and disaster*. London and New York: Routledge.

Bogliacino, F., Codagnone, C., & Veltri, G. A. (2016). An introduction to the special issue on "the behavioural turn in public policy: new evidence from experiments". *Economia Politica*, *33*, 323–332.

Botzen, Bouwer, L. M., Scussolini, P., Kuik, O., Haasnoot, M., Lawrence, J., & Aerts, J. C. J. H. (2019). Integrated Disaster risk management and adaptation. In R. Mechler, L. M. Bouwer, T. Schinko, S. Surminski, & J. Linnerooth-Bayer (Eds.), *Loss and damage from climate change: Concepts, methods and policy options* (pp. 287–315). Cham, Switzerland: Springer International Publishing.

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education* (pp. 241–258). New York: Greenwood Press.

Bourdieu, P. (2010). *Distinction*. London: Routledge.

Bubeck, P., & Botzen, W. J. W. (2013a). Response to "The Necessity for Longitudinal Studies in Risk Perception Research". *Risk Analysis*, *33*, 760–762.

Bubeck, P., & Botzen, W. J. W. (2013b). Response to the necessity for longitudinal studies in risk perception research. *Risk Analysis*, *33*, 760–762.

Bubeck, P., Botzen, W. J. W., & Aerts, J. C. J. H. (2012). A review of risk perceptions and other factors that influence flood mitigation behavior. *Risk Analysis*, *32*, 1481–1495.

Bubeck, P., Botzen, W. J. W., Kreibich, H., & Aerts, J. C. J. H. (2013). Detailed insights into the influence of flood-coping appraisals on mitigation behaviour. *Global Environmental Change*, *23*, 1327–1338.

Bubeck, P., de Moel, H., Bouwer, L. M., & Aerts, J. C. J. H. (2011). How reliable are projections of future flood damage? *Natural Hazards and Earth System Sciences*, *11*, 3293–3306.

Bubeck, P., Kreibich, H., Penning-Rowsell, E. C., Botzen, W. J. W., de Moel, H., & Klijn, F. (2017a). Explaining differences in flood management approaches in Europe and in the USA – A comparative analysis. *Journal of Flood Risk Management*, *10*, 436–445.

Bubeck, P., Otto, A., & Weichselgartner, J. (2017b). Societal impacts of flood hazards. Oxford Research Encyclopedia on Natural Hazards Science. Oxford: Oxford University Press.

Bubeck, P., & Thieken, A. H. (2018). What helps people recover from floods? Insights from a survey among flood-affected residents in Germany. *Regional Environmental Change*, *18*, 287–296.

Bundorf, M. K., & Pauly, M. V. (2006). Is health insurance affordable for the uninsured? *Journal of Health Economics*, *25*, 650–673.

Burton, I., Kates, R. W., & White, G. F. (1993). *The environment as hazard*. New York: Guilford Press.

Chambers, R. (1989). Editorial introduction: vulnerability, coping and policy. *IDS Bulletin*, *20*, 1–7.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology*, *94*, 95–S120.

Couper, M. P. (2012) Assessment of innovations in data collection technology for understanding society. Report to the Economic and Social Research Council.

Cutter, S. L. (2017). The forgotten casualties redux: Women, children, and disaster risk. *Global Environmental Change*, *42*, 117–121.

Davis, I. (2004). Progress in analysis of social vulnerability and capacity. In G. Bankoff, G. Frerks, & D. Hilhorst (Eds.), *Mapping vulnerability: Disasters, development and people* (pp. 128–144). London: Earthscan.

De Marchi, B., & Scolobig, A. (2012). The views of experts and residents on social vulnerability to flash floods in an Alpine region of Italy. *Disasters*, *36*, 316–337.

DEFRA. (2005) Making space for water: Developing a new Government strategy for flood and coastal erosion risk management in England, Government response. March 2005.

Dell'Acqua, F., Gamba, P., & Jaiswal, K. (2013). Spatial aspects of building and population exposure data and their implications for global earthquake exposure modeling. *Natural Hazards*, *68*, 1291–1309.

Diekmann, A., & Preisendörfer, P. (1992). Persönliches umweltverhalten: Diskrepanzen zwischen Anspruch und Wirklichkeit [Ecology in everyday life: Inconsistencies between environmental attitudes and behavior]. *Kölner Zeitschrift für Soziologie und Sozialpsychologie*, *44*, 226–251.

Dittmer, C., Lorenz, D. F., Reiter, J., & Wenzel, B. (2016). Drei Jahre nach dem Deichbruch – Über die Gegenwart einer nicht abgeschlossenen Katastrophe. *Notfallvorsorge*, *4*, 17–25.

Dixon, L., Clancy, N., Miller, B. M., Hoegberg, S., Lewis, M. M., Bender, B., … Choquette, S. R. (2017). *The cost and affordability of flood insurance in New York City*. Santa Monica, CA: Rand Corporation.

Dolan, P., & Metcalfe, R. (2012). Measuring subjective wellbeing: Recommendations on measures for use by national governments. *Journal of Social Policy*, *41*, 409–427.

Douglas, E. M., Kirshen, P. H., Paolisso, M., Watson, C., Wiggin, J., Enrici, A., & Ruth, M. (2012). Coastal flooding, climate change and environmental justice: Identifying obstacles and incentives for adaptation in two metropolitan Boston Massachusetts communities. *Mitigation and Adaptation Strategies for Global Change*, *17*, 537–562.

Drabek, T. E. (1986). *Human system response to disaster: An inventory of sociological findings*. New York: Springer Verlag.

Drabek, T.E., (1987) Emergent structures, Dynes, R.A., Marchide, B., Pelanda, C. (Eds.), *Sociology of disasters: Contribution of sociology to disaster research*. Franco Angeli Libri, Milano, Italy, pp. 259-290.

Fernandez, C. J., Stoeckl, N., & Welters, R. (2019). The cost of doing nothing in the face of climate change: a case study, using the life satisfaction approach to value the tangible and intangible costs of flooding in the Philippines. *Climate and Development*, *11*(9), 825–838.

Fielding, J. (2007). Environmental injustice or just the lie of the land: an investigation of the socio-economic class of those at risk from flooding in England and Wales. *Sociological Research Online*, *12*, 12–34.

Fielding, J. (2012). Inequalities in exposure and awareness of flood risk in England and Wales. *Disasters*, *36*, 477–494.

Fielding, J. (2017). The devil is in the detail: Who is actually at risk from flooding in England and Wales? *Journal of Flood Risk Management*, *10*, 267–276.

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: building adaptive capacity in a world of transformations. *AMBIO: A Journal of the Human Environment*, *31*, 437–440.

Foudi, S., Osés-Eraso, N., & Galarraga, I. (2017). The effect of flooding on mental health: Lessons learned for building resilience. *Water Resources Research*, *53*, 5831–5844.

Fritsche, I., Barth, M., Jugert, P., Masson, T., & Reese, G. (2018). A social identity model of pro-environmental action (SIMPEA). *Psychological Review*, *125*, 245–269.

Gaillard, J. C., Walters, V., Rickerby, M., & Shi, Y. (2019). Persistent precarity and the disaster of everyday life: Homeless people's experiences of natural and other hazards. *International Journal of Disaster Risk Science*, *10*, 332–342.

Gawel, E., & Kuhlicke, C. (2017). Efficiency-equity-trade-off as a challenge for shaping urban transformations. In S. Kabisch, F. Koch, E. Gawel, A. Haase, S. Knapp, K. Krellenberg, & A. Zehnsdorf (Eds.), *Urban transformations: Sustainable development through resource efficieny, qualits of life and resilience*. Cham: Springer.

Gayan, W., & Bingunath, I. (2012). Resilience and adaptation of small and medium-sized enterprises to flood risk. *Disaster Prevention and Management: An International Journal*, *21*, 474–488.

Giddens, A. (1979). *Central problems in social theory: Action, structure and cntradiction in social analysis*. Berkeley, CA: University of California Press.

Giddens, A. (1986). *The constitution of society: Outline of the theory of structuration*. Santa Barbara, CA: University of California Press.

Gollwitzer, P. M. (1990). Action phases and mind-sets. In E. T. Higgins & R. M. Sorrentino (Eds.), *Handbook of motivation and cognition: Foundations of social behavior* (pp. 53–92). New York: Guilford.

Gross, M. (2004). Human geography and ecological sociology: The unfolding of a human ecology. *Social Science History*, *28*, 575–605.

Grothmann, T., & Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change*, *15*, 199–213.

Grothmann, T., & Reusswig, F. (2006). People at risk of flooding: Why some residents take precautionary action while others do not. *Natural Hazards*, *38*, 101–120.

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, *23*, 485–498.

Haer, T., Botzen, W. J. W., de Moel, H., & Aerts, J. C. J. H. (2017). Integrating household risk mitigation behavior in flood risk analysis: An agent-based model approach. *Risk Analysis*, *37*, 1977–1992.

Harries, T. (2012). The anticipated emotional consequences of adaptive behaviour—Impacts on the take-up of household flood-protection measures. *Environment and Planning A: Economy and Space*, *44*, 649–668.

Harvatt, J., Petts, J., & Chilvers, J. (2011). Understanding householder responses to natural hazards: Flooding and sea-level rise comparisons. *Journal of Risk Research*, *14*, 63–83.

Herbert, S. (2005). The Trapdoor of Community. *Annals of the Association of American Geographers*, *95*, 850–865.

Holub, M., & Fuchs, S. (2008). Benefits of local structural protection to mitigate torrent-related hazards. In C. A. Brebbia & E. Beritatos (Eds.), *Risk analysis VI. WIT transactions on information and communication technologies* (pp. 401–411). WIT Press.

Hudson, P. (2018). A comparison of definitions of affordability for flood risk adaption measures: A case study of current and future risk-based flood insurance premiums in Europe. *Mitigation and Adaptation Strategies for Global Change*, *23*, 1019–1038.

Hudson, P., & Botzen, W. J. W. (2019). Cost–benefit analysis of flood-zoning policies: A review of current practice. *Wiley Interdisciplinary Reviews: Water*, *6*, e1387. https://doi.org/10.1002/wat2.1387

Hudson, P., Botzen, W. J. W., Feyen, L., & Aerts, J. C. J. H. (2016). Incentivising flood risk adaptation through risk based insurance premiums: trade-offs between affordability and risk reduction. *Ecological Economics*, *125*, 1–13.

Hudson, P., Botzen, W. J. W., Kreibich, H., Bubeck, P., & Aerts, J. C. J. H. (2014). Evaluating the effectiveness of flood damage risk reductions by the application of Propensity Score Matching. *Natural Hazards and Earth Schemes Science*, *14*, 1731–1747.

Hudson, P., Botzen, W. J. W., Poussin, J. K., & Aerts, J. C. J. H. (2019). The impacts of flooding and flood preparedness on happiness: A monetisation of the tangible and intangible subjective well-being impacts. *Journal of Happiness Studies*, *20*, 665–682. https://doi.org/10.1007/s10902-017-9916-4

Hudson, P., Botzen, W. J. W., Poussin, J. K., & Aerts, J. C. J. H. (2019a). The impacts of flooding and flood preparedness on happiness: A monetisation of the tangible and intangible subjective well-being impacts. *Journal of Happiness Studies*, *20*, 665–682.

Hudson, P., Pham, M., & Bubeck, P. (2019c). An evaluation and monetary assessment of the impact of flooding on subjective well-being across genders in Vietnam. *Climate and Development*, *11*, 632–637.

Hudson, P., Thieken, A. H., & Bubeck, P. (2019b). The challenges of longitudinal surveys in the flood risk domain. *Journal of Risk Research*, 1–22. https://doi.org/10.1080/13669877.2019.1617339

Hutter, G., Leibenath, M., & Mattissek, A. (2014). Governing through resilience? Exploring flood protection in Dresden, Germany. *Social Sciences*, *3*, 272.

Johnson, C., Penning-Rowsell, E., & Parker, D. (2007). Natural and imposed injustices: The challenges in implementing 'fair' flood risk management policy in England. *Geographical Journal*, *173*, 374–390.

Joseph, R., Proverbs, D., & Lamond, J. (2015). Assessing the value of intangible benefits of property level flood risk adaptation (PLFRA) measures. *Natural Hazards*, *79*, 1275–1297.

Kates, R. W. (1962). *Hazard and choice perception in flood plain management* (Research paper No. 78). Chicago, IL: Department of Geography, University of Chicago.

Kaufmann, M., Priest, S. J., & Leroy, P. (2018). The undebated issue of justice: Silent discourses in Dutch flood risk management. *Regional Environmental Change*, *18*, 325–337.

Kellens, W., Terpstra, T., & De Maeyer, P. (2013). Perception and communication of flood risks: A systematic review of empirical research. *Risk Analysis*, *33*, 24–49.

Kim, D., & Kang, J. E. (2018). Integrating climate change adaptation into community planning using a participatory process: The case of Saebat Maeul community in Busan, Korea. *Environment and Planning B-Urban Analytics and City Science*, *45*, 669–690.

Kim, Y.-C., & Kang, J. (2010). Communication, neighbourhood belonging and household hurricane preparedness. *Disasters*, *34*, 470–488.

Kind, J., Botzen, W. J. W., & Aerts, J. C. J. H. (2017). Accounting for risk aversion, income distribution and social welfare in cost-benefit analysis for flood risk management. *WIREs Clim Change*, *8*, e446. https://doi.org/10.1002/wcc.446

Klöckner, C. A., & Verplanken, B. (2018). Yesterday's habits preventing change for tomorrow? About the influence of automaticity on environmental behaviour. In S. Linda & J. I. M. de Groot (Eds.), *Environmental Psychology*. Hoboken, NJ: Wiley.

Koks, E., Jongman, B., Husby, T., & Botzen, W. (2015). Combining hazard, exposure and social vulnerability to provide lessons for flood risk management. *Environmental Science & Policy*, *47*, 42–45.

Kousky, C., & Kunreuther, H. (2014). Addressing affordability in the national flood insurance program. *Journal of Extreme Events*, *1*, 1450001.

Kreibich, H., Bubeck, P., Van Vliet, M., & De Moel, H. (2015). A review of damage-reducing measures to manage fluvial flood risks in a changing climate. *Mitigation and Adaptation Strategies for Global Change*, *20*, 967–989.

Kreibich, H., Christenberger, S., & Schwarze, R. (2011). Economic motivation of households to undertake private precautionary measures against floods. *Natural Hazards and Earth Schemes Science*, *11*, 309–321.

Kreibich, H., Müller, M., Schröter, K., & Thieken, A. H. (2017). New insights into flood warning reception and emergency response by affected parties. *Natural Hazards and Earth Schemes Science*, *17*, 2075–2092.

Kuhlicke, C. (2015). Vulnerability, ignorance and the experience of radical surprises. In M. Groß & L. McGoey (Eds.), *Routledge international handbook of ignorance studies* (pp. 239–246). Abingdon: Routledge.

Kuhlicke, C. (2019). *Risk and resilience in the management and governance of natural hazards*. Oxford: Oxford University Press.

Kuhlicke, C., Callsen, I., & Begg, C. (2016). Reputational risks and participation in flood risk management and the public debate about the 2013 flood in Germany. *Environmental Science & Policy*, *55*(Part 2), 318–325.

Kuhlicke, C., Masson, T., Kienzler, S., Sieg, T., Thieken, A. H., & Kreibich, H. (2020). Multiple flood experiences and social resilience: Findings from three surveys on households and companies exposed to the 2013 flood in Germany. *Weather, Climate, and Society*, *12*, 63–88.

Kuhlicke, C., Scolobig, A., Tapsell, S., Steinführer, A., & De Marchi, B. (2011a). Contextualizing social vulnerability: Findings from case studies across Europe. *Natural Hazards*, *58*, 789–810.

Kuhlicke, C., Steinführer, A., Begg, C., Bianchizza, C., Bründl, M., Buchecker, M., … Faulkner, H. (2011b). Perspectives on social capacity building for natural hazards: Outlining an emerging field of research and practice in Europe. *Environmental Science & Policy*, *14*, 804–814.

Kunreuther, H., Heal, G., Allen, M., Edenhofer, O., Field, C., & Yohe, G. (2012). Risk management and climate change. Cambridge: National Bureau of Economic Research.

Kwon, H. R., & Silva, E. A. (2019). Mapping the landscape of behavioral theories: Systematic literature review. *Journal of Planning Literature*, 0885412219881135.

Lamond, J., Rose, C., Bhattacharya-Mis, N., & Joseph, R. (2018) *Evidence review for property flood resilience phase 2 report*. Flood Re, UWE Bristol.

Lindell, M. K., & Perry, R. W. (2012). The Protective Action Decision Model: Theoretical modifications and additional evidence. *Risk Analysis*, *32*, 616–632.

Linnerooth-Bayer, J., Surminski, S., Bouwer, L. M., Noy, I., & Mechler, R. (2019). Insurance as a response to loss and damage? In R. Mechler, L. M. Bouwer, T. Schinko, S. Surminski, & J. Linnerooth-Bayer (Eds.), *Loss and damage from climate change: Concepts, methods and policy options* (pp. 483–512). Cham, Switzerland: Springer International Publishing.

Lo, A. Y. (2013). The role of social norms in climate adaptation: Mediating risk perception and flood insurance purchase. *Global Environmental Change*, *23*, 1249–1257.

Lorenz, D. F., & Dittmer, C. (2016). Catastrophes, disasters and emergencies. Socio-scientific perspectives. In A. Maurer (Ed.), *New perspectives on resilience in socio-economic spheres* (pp. 25–59). Heidelberg, Germany: Springer.

Maantay, J., & Maroko, A. (2009). Mapping urban risk: Flood hazards, race, & environmental justice in New York. *Applied Geography*, *29*, 111–124.

Martens, T., & Rost, J. (1998). Der Zusammenhang von wahrgenommener Bedrohung durch Umweltgefahren und der Ausbildung von Handlungsintentionen. *Zeitschrift für Experimentelle Psychologie.*, *45*, 345–364.

Mas-Colell, A. (1995). *Microeconomic theory*. New York: Oxford University Press.

May, P., & Chatterton, J. (2012). *Establishing the cost effectiveness of property flood protection* (FD2657 - Final Report). JBA Consulting, London: Defra.

Mechler, R., Bouwer, L. M., Linnerooth-Bayer, J., Hochrainer-Stigler, S., Aerts, J. C. J. H., Surminski, S., & Williges, K. (2014). Managing unnatural disaster risk from climate extremes. *Nature Climate Change*, *4*, 235–237.

Mees, H., Crabbé, A., Alexander, M., Kaufmann, M., Bruzzone, S., Lévy, L., & Lewandowski, J. (2016). Coproducing flood risk management through citizen involvement: insights from cross-country comparison in Europe. *Ecology and Society*, *21*(3).

Meyer, V., Becker, N., Markantonis, V., Schwarze, R., van den Bergh, J. C. J. M., Bouwer, L. M., ... Viavattene, C. (2013). Review article: Assessing the costs of natural hazards – state of the art and knowledge gaps. *Natural Hazards and Earth System Sciences*, *13*, 1351–1373.

Mohan, G., & Mohan, J. (2002). Placing social capital. *Progress in Human Geography*, *26*, 191–210.

Montgomery, M., & Kunreuther, H. (2018). Pricing storm surge risks in Florida: Implications for determining flood insurance premiums and evaluating mitigation measures. *Risk Analysis*, *38*, 2275–2299.

Montgomery, M. C., & Chakraborty, J. (2015). Assessing the environmental justice consequences of flood risk: A case study in Miami, Florida. *Environmental Research Letters*, *10*, 095010.

Morss, R. E., Mulder, K. J., Lazo, J. K., & Demuth, J. L. (2016). How do people perceive, understand, and anticipate responding to flash flood risks and warnings? Results from a public survey in Boulder, Colorado, USA. *Journal of Hydrology*, *541*(Part A), 649–664.

Mulilis, J.-P., & Duval, T. S. (1995). Negative threat appeals and earthquake preparedness: A person-relative-to-event (PrE) model of coping with threat 1. *Journal of Applied Social Psychology*, *25*, 1319–1339.

Nakagawa, Y., & Shaw, R. (2004). Social capital: a missing link to disaster recovery. *International Journal of Mass Emergencies and Disasters*, *22*, 5–34.

National Research Council. (2015). *Affordability of National Flood Insurance Program Premiums: Report 1*. Washington, DC: Author.

Ober, K., & Sakdapolrak, P. (2017). How do social practices shape policy? Analysing the field of 'migration as adaptation' with Bourdieu's 'Theory of Practice'. *Geographical Journal*, *183*, 359–369.

Osberghaus, D. (2017). The effect of flood experience on household mitigation-Evidence from longitudinal and insurance data. *Global Environmental Change-Human and Policy Dimensions*, *43*, 126–136.

Otto, A., Hornberg, A., & Thieken, A. (2018). Local controversies of flood risk reduction measures in Germany. An explorative overview and recent insights. *Journal of Flood Risk Management*, *11*, S382–S394.

Pelling, M., & High, C. (2005). Understanding adaptation: What can social capital offer assessments of adaptive capacity? *Global Environmental Change*, *15*, 308–319.

Penning-Rowsell, E. C., & Green, C. (2000). New insights into the appraisal of flood-alleviation benefits: (2) The broader context. *Water and Environment Journal*, *14*, 354–362.

Pittore, M., Wieland, M., & Fleming, K. (2017). Perspectives on global dynamic exposure modelling for geo-risk assessment. *Natural Hazards*, *86*, 7–30.

Poussin, J. K., Botzen, W. J. W., & Aerts, J. C. J. H. (2014). Factors of influence on flood damage mitigation behavior by households. *Environmental Science and Policy*, *40*, 69–77.

Poussin, J. K., Botzen, W. J. W., & Aerts, J. C. J. H. (2015). Effectiveness of flood damage mitigation measures: Empirical evidence from French flood disasters. *Global Environmental Change*, *31*, 74–84.

Prettenthaler, F., Kortschak, Hochrainer-Stigler, S., Mechler, R., Urban, H., & Steininger, K. W. (2015). Catastrophe Management: Riverine Flooding. In K. W. Steininger, M. Koning, B. Bednar-Friedl, L. Kranzl, W. Loibl, & F. Prettenthaler (Eds.), *Economic evaluation of climate change impacts* (pp. 349–366). Cham: Springer International Publishing.

Putnam, R. D. (1993). *Making democracy work. Civic traditions in modern Italy*. Princeton, NJ: Princeton University Press.

Putnam, R. D. (2000). *Bowling alone. The collapse and revival of American community*. New York: Simon & Schuster.

Reckwitz, A. (2002). Toward a theory of social practices. *European Journal of Social Theory*, *5*, 243–263.

Reiter, J., Wenzel, B., Dittmer, C., Lorenz, D. F., & Voss, M. (2018). *The 2013 flood in the community of Elbe-Havel-Land in the eyes of the population. Research report of the quantitative survey*. Berlin, Germany: KFS Working Paper KFS.

Richert, C., Erdlenbruch, K., & Figuières, C. (2017). The determinants of households' flood mitigation decisions in France - On the possibility of feedback effects from past investments. *Ecological Economics*, *131*, 342–352.

Rogers, R. W. (1983). Cognitive and physiological processes in fear appeals and attitude change: A revised theory of protection motivation. In J. Cacioppo & R. Petty (Eds.), *Social Psychophysiology*. New York: Guilford Press.

Rogers, R. W., & Prentice-Dunn, S. (1997). *Protection motivation theory, Handbook of health behavior research 1: Personal and social determinants* (pp. 113–132). New York, NY: Plenum Press.

Rufat, S., Tate, E., Burton, C. G., & Maroof, A. (2015). Social vulnerability to floods: Review of case studies and implications for measurement. *International Journal of Disaster Risk Reduction*, *14*, 470–486.

Saenz, C. (2009). What is affordable health insurance? The reasonable tradeoff account of affordability. *Kennedy Institute of Ethics Journal*, *19*, 401–414.

Sakdapolrak, P. (2007). Water related health risk, social vulnerability and Pierre Bourdieu. In K. Warner (Ed.), *Perspectives on social vulnerability* (pp. 51–59). Bonn, Bonn: UNU Institute for Environment and Human Security.

Sayers, P., Penning-Rowsell, E. C., & Horritt, M. (2018). Flood vulnerability, risk, and social disadvantage: current and future patterns in the UK. *Regional Environmental Change*, *18*, 339–352.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology*, *57*, 1–29.

Scolobig, A., & Pelling, M. (2016). The co-production of risk from a natural hazards perspective: science and policy interaction for landslide risk management in Italy. *Natural Hazards*, *81*, S7–S25.

Sekulova, F., & van den Bergh, J. C. J. M. (2016). Floods and happiness: Empirical evidence from Bulgaria. *Ecological Economics*, *126*, 51–57.

Sheaffer, J. R. (1960). *Flood proofing: An element in a flood damage reduction programme*. Chicago, IL: Department of Geography Research Paper, University of Chicago.

Siegrist, M. (2013). The necessity for longitudinal studies in risk perception research. *Risk Analysis*, *33*, 50–51.

Siegrist, M. (2014). Longitudinal studies on risk research. *Risk Analysis*, *34*, 1376–1377.

Slovic, P., Kunreuther, H., & White, G. F. (1974). Decision processes, rationality, and adjustment to natural hazards. In G. F. White (Ed.), *Natural hazards: Local, national, global* (pp. 187–205). New York: Oxford University Press.

Surminski, S., & Thieken, A. (2017). Promoting flood risk reduction: The role of insurance in Germany and England. *Earth's Future*, *5*, 979–1001.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). Vulnerability to flooding: Health and social dimensions. *Philosophical Transactions of the Royal Society of London Series A-Mathematical Physical and Engineering Sciences*, *360*, 1511–1525.

Tapsell, S. M., & Tunstall, S. M. (2008). "I wish I'd never heard of Banbury": The relationship between 'place' and the health impacts from flooding. *Health & Place*, *14*, 133–154.

Terpstra, T. (2011). Emotions, trust, and perceived risk: Affective and cognitive routes to flood preparedness behavior. *Risk Analysis*, *31*, 1658–1675.

Terpstra, T., & Lindell, M. K. (2013). Citizens' perceptions of flood hazard adjustments: An application of the protective action decision model. *Environment and Behavior*, *45*, 993–1018.

Thaler, T., Fuchs, S., Priest, S., & Doorn, N. (2018). Social justice in the context of adaptation to climate change—Reflecting on different policy approaches to distribute and allocate flood risk management. *Regional Environmental Change*, *18*, 305–309.

Thaler, T., & Hartmann, T. (2016). Justice and flood risk management: Reflecting on different approaches to distribute and allocate flood risk management in Europe. *Natural Hazards*, *83*, 129–147.

Thaler, T., & Seebauer, S. (2019). Bottom-up citizen initiatives in natural hazard management: Why they appear and what they can do? *Environmental Science & Policy*, *94*, 101–111.

Thieken, A. H., Bessel, T., Kienzler, S., Kreibich, H., Müller, M., Pisi, S., & Schröter, K. (2016a). The flood of June 2013 in Germany: How much do we know about its impacts? *Natural Hazards and Earth System Sciences*, *16*, 1519–1540.

Thieken, A. H., Kienzler, S., Kreibich, H., Kuhlicke, C., Kunz, M., Mühr, B., ... Schröter, K. (2016b). Review of the flood risk management system in Germany after the major flood in 2013. *Ecology and Society*, *21*(2), 51.

Thistlethwaite, J., Henstra, D., Brown, C., & Scott, D. (2018). How flood experience and risk perception influences protective actions and behaviours among Canadian homeowners. *Environmental Management*, *61*, 197–208.

United Nations. (2018). *The sustainable development goals report*. Geneva: Author.

UNISDR. (2015) Sendai Framework for Disaster Risk Reduction 2015-2030. United Nations, United Nations - Headquarters (UN).

Unterberger, C., Hudson, P., Botzen, W. J. W., Schroeer, K., & Steininger, K. W. (2019). Future public sector flood risk and risk sharing arrangements: An assessment for Austria. *Ecological Economics*, *156*, 153–163.

van Dillen, S. (2002). A measure of vulnerability. *Geographica Helvetica*, *57*, 64–77.

van Valkengoed, A. M., & Steg, L. (2019). Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change*, *9*, 158–163.

Van Zomeren, M., Postmes, T., & Spears, R. (2008). Toward an integrative social identity model of collective action: A quantitative research synthesis of three socio-psychological perspectives. *Psychological Bulletin*, *134*, 504–535.

Von Möllendorff, C., & Hirschfeld, J. (2016). Measuring impacts of extremeweather events using the life satisfaction approach. *Ecological Economics*, *121*, 108–116.

Waite, T. D., Chaintarli, K., Beck, C. R., Bone, A., Amlôt, R., Kovats, S., ... Oliver, I. (2017). The English national cohort study of flooding and health: Cross-sectional analysis of mental health outcomes at year one. *BMC Public Health*, *17*, 129.

Walker, G., & Burningham, K. (2011). Flood risk, vulnerability and environmental justice: Evidence and evaluation of inequality in a UK context. *Critical Social Policy*, *31*, 216–240.

Watts, M. J., & Bohle, H. G. (1993). The space of vulnerability: The causal structure of hunger and famine. *Progress in Human Geography*, *17*, 43–67.

Weinstein, N. D. (1993). Testing four competing theories of health-protective behavior. *Health psychology*, *12*(4), 324. https://doi.org/10.1037/0278-6133.12.4.324

Weinstein, N. D., Rothman, A. J., & Nicolich, M. (1998). Use of correlational data to examine the effects of risk perceptions on precautionary behavior. *Psychology & Health*, *13*, 479–501.

White, G. F. (1974). *Natural hazards: Local, national, global*. New York: Oxford University Press.

Wickes, R., Zahnow, R., Taylor, M., & Piquero, A. R. (2015). Neighborhood structure, social capital, and community resilience: Longitudinal evidence from the 2011 Brisbane flood disaster. *Social Science Quarterly*, *96*, 330–353.

Wisner, B., Blaikie, P., & Cannon, T. (2005). *At risk: Natural hazards, people's vulnerability, and disasters* (2nd ed.). London: Routledge.

Zaalberg, R., Midden, C., Meijnders, A., & McCalley, T. (2009). Prevention, adaptation, and threat denial: Flooding experiences in the Netherlands. *Risk Analysis*, *29*, 1759–1778.

How to cite this article: Kuhlicke C, Seebauer S, Hudson P, et al. The behavioral turn in flood risk management, its assumptions and potential implications. *WIREs Water*. 2020;7:e1418. https://doi.org/10.1002/wat2.1418