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A Review of Risk Perceptions and Other Factors that Influence Flood Mitigation Behavior

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In flood risk management, a shift can be observed toward more integrated approaches that increasingly address the role of private households in implementing flood damage mitigation measures. This has resulted in a growing number of studies into the supposed positive relationship between individual flood risk perceptions and mitigation behavior. Our literature review shows, however, that, actually, this relationship is hardly observed in empirical studies. Two arguments are provided as an explanation. First, on the basis of protection motivation theory, a theoretical framework is discussed suggesting that individuals' high-risk perceptions need to be accompanied by coping appraisal to result in a protective response. Second, it is pointed out that possible feedback from already-adopted mitigation measures on risk perceptions has hardly been considered by current studies. In addition, we also provide a review of factors that drive precautionary behavior other than risk perceptions. It is found that factors such as coping appraisal are consistently related to mitigation behavior. We conclude, therefore, that the current focus on risk perceptions as a means to explain and promote private flood mitigation behavior is not supported on either theoretical or empirical grounds.

KEY WORDS: Floods; mitigation; protection motivation theory (PMT); protective behavior; review; risk perception

1. INTRODUCTION

Storms and floods are the most frequent and costly weather-related disasters in Europe, and accounted for 77% of the economic losses caused by extreme weather events between 1980 and 2006.[1] There is evidence that several factors could increase future flood risk, such as global warming and ongoing socioeconomic development in flood-prone areas.[2–6]

Traditionally, the increasing risk of flooding was predominantly tackled by maintaining or reducing the probability of flood events by means of protection measures. Flood management policies thus focused on large-scale engineering of flood defense infrastructure, which was designed and implemented by governmental agencies.[7–9] In recent years, flood management in Europe has increasingly shifted to more integrated approaches that aim at both flood prevention and the alleviation of flood impacts.[8–11] This shifted focus toward the "risk" (that is, probability times the damage) of flooding has led to a growing interest in flood mitigation measures that serve to reduce potential damage, as well as in risk transfer instruments, such as insurance, which can be complementary to existing flood protection measures.[7,12] This development could significantly change the role of the involved stakeholders, and will require private households to take more flood mitigation measures, such as the use of flood protection devices, adapted building use, or the purchase of insurance.[13–16]

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Flood insurance is considered as a private mitigation measure in this article because it reduces the financial consequences for an individual once a flood occurs. It has been demonstrated that private flood mitigation measures can significantly reduce flood damage and, thereby, contribute to risk reduction.[7,15–18] However, practical experience also suggests that people who live in risk-prone areas rarely undertake mitigation measures voluntarily, which often results in a high vulnerability to disasters.[19]

Given the growing importance of private flood mitigation in current and future flood risk management, there has been an increased interest in individuals' flood risk perceptions[20–25] because they are thought to provide important insights for risk management and risk communication strategies. A main reason for this is their expected positive relationship with the willingness of individuals to undertake private mitigation measures.[20,22–23,25] This argument is in line with the "motivational hypothesis," which states that people undertake precautionary measures to reduce the risk they perceive as being high.[26] The reasoning behind the "motivational hypothesis" can be used to demonstrate the need for awareness raising among the population at risk, to reduce vulnerability by increasing the level of private mitigation. Accordingly, a growing number of empirical studies have recently investigated the factors that drive private mitigation behavior, among which flood risk perceptions have been the most dominant.[12,21,27–32]

However, recent empirical studies that have investigated the relation between flood risk perceptions and the adoption of private flood mitigation measures do not find a statistically significant relation at all, or report only a weak relation.[17,21,27–28,30–32] Since risk perceptions have dominated the literature on flood mitigation behavior, and because risk awareness raising is an important element of current and envisaged flood management,[10] it is imperative to understand the role that risk perceptions play in prompting private precautionary behavior. The aim of this study is to provide explanations for the weak relationship found by recent empirical studies between flood risk perceptions and precautionary behavior. It examines whether the focus on risk perceptions in the current literature can be justified on both theoretical and empirical grounds. Moreover, the study provides a review of factors that drive private flood mitigation measures. These factors are currently not clear due to the complexity of the existing literature on this topic.

This study focuses on flood risk perceptions and mitigation behavior because such a review has not been available for flood risk in the literature so far, although this has been provided for other natural hazards.[33–34] Such a study with a particular focus on flood risk is important, given the large contribution of floods to overall damage from natural hazards, for example, in Europe,[1] and the observed shift to more integrated flood risk management practices. Moreover, differences in the characteristics of natural hazards, such as in probabilities of occurrence, may also lead to differences in the relation between risk perceptions and precautionary behavior.

The remainder of this article is structured as follows. Section 2 discusses the empirical findings of the current literature on flood risk perceptions and their relation to private mitigation behavior. Section 3 provides a systematic overview of factors, other than risk perceptions, that drive private flood mitigation behavior. Section 4 concludes, and discusses the implications of the findings for risk communication and the stimulation of private precautionary behavior.

2. EMPIRICAL FINDINGS ON THE RELATION BETWEEN FLOOD RISK PERCEPTIONS AND PRIVATE MITIGATION BEHAVIOR

A growing number of studies have examined the factors that drive private flood mitigation behavior (Table I), and in particular risk perceptions. Since the term "risk perceptions" is ambiguous and used

Table I. Reviewed Studies that Examine Factors of Influence on Private Flood Mitigation Behavior

Authors	Study Area	*N*
Botzen *et al.* (2009)[12]	The Netherlands	509
Botzen and van den Bergh (2012)[66]	The Netherlands	~1,000
Grothmann and Reusswig (2006)[29]	Germany	157
Knocke and Kolivras (2007)[36]	USA,Virginia	300
Kreibich *et al.*(2005)[17]	Germany	1,248
Kreibich *et al.* (2011)[68]	Germany	235
Lindell and Hwang (2008)[32]	USA, Texas	321
Miceli *et al.* (2008)[31]	Italy	407
Siegrist and Gutscher (2006)[21]	Switzerland	1,213
Siegrist and Gutscher (2008)[69]	Switzerland	201
Takao *et al.* (2004)[27]	Japan	2,051
Terpstra (2011)[67]	Netherlands	1,071
Thieken *et al.* (2006)[28]	Germany	1,248
Thieken *et al.* (2007)[30]	Germany	1,697
Zaalberg *et al.* (2009)[65]	The Netherlands	516
Zaleskiewicz *et al.* (2002)[37]	Poland	66

Table II. Empirical Findings on the Relation Between Risk Perceptions and Already-Adopted Private Flood Mitigation Measures

Correlations (r-values) and Statistical Significance (p-values)			
Independent Variable	Paper	Correlation	p-value
Perceived probability	Kreibich *et al.*[17]	n.a.	n.s.
	Lindell and Hwang[32]	$r = 0.12$ and 0.18	$p < 0.05$
	Miceli *et al.*[31]	$r = 0.08$	n.s.
	Takao *et al.*[27]	n.a.	n.s.
	Thieken *et al.*[28]	n.a.	n.s.
	Thieken *et al.*[30]	$r = 0.2$[a]	n.s. to $p < 0.05$
Perceived risk	Grothmann and Reusswig[29]	$r = 0.21$–0.30	$p < 0.05$ to $p < 0.01$
Perceived risk to life	Knocke and Kolivras[36]	n.a.	$p = 0.01$
Perceived risk to property	Knocke and Kolivras[36]	n.a.	n.s.
Perception of flood risk scale (PFRS)	Miceli *et al.*[31]	$r = 0.11$	$p < 0.05$
Dread of flood	Zaleskiewicz *et al.*[37]	$r = 0.3$[b]	$p < 0.01$

Regression Coefficients (β), Coefficient of Determination (R^2), and Statistical Significance (p)				
Independent Variable	Paper	R^2	β	Significance
Perceived probability	Lindell and Hwang[32]	0.01 and 0.05	n.a.	$p < 0.01$
	Siegrist and Gutscher[21]	n.a.	−0.04	n.s.
	Miceli *et al.*[31]	n.a.	0.08	n.s.
Perceived risk	Grothmann and Reusswig[29]	0.03–0.06	0.02–0.03[c]	n.s. to $p < 0.01$
PFRS	Miceli *et al.*[31]	n.a.	0.13	$p < 0.05$

[a] r values for different geographical locations are only reported if $p < 0.05$ and if $r \geq 0.2$.
[b] The effect size has been calculated by the authors.
[c] Nonstandardized regression coefficient.
Note: n.a. = not applicable; n.s. = not significant.

with different meanings, we need to define the terms we use in this article. "Perceived risk," as defined here, refers to the combined measurement of "perceived probability" and "perceived consequences" of a certain event or activity. The term "perceived risk" is further differentiated into its two single dimensions: namely, the "perceived probability" (or likelihood) and the "perceived consequences" (or severity) of a certain event or activity. "Risk perceptions" is used as the generic term referring to all the three aforementioned definitions. This terminology and the distinction between the separate dimensions have been adopted because they reflect the way these terms have been used in the current empirical literature on the relation between risk perceptions and flood mitigation behavior. For our review, we selected all peer-reviewed articles that examine the relation between one or several independent variables and households' adoption of flood mitigation measures by means of correlation or regression analyses or by comparing the means of these variables between groups (Table I). Comprehensive research of the literature was conducted by entering the following search terms in varying combinations in the ISI Web of Knowledge database: flood, risk perception, protection, protection motivation theory (PMT), mitigation, preparedness, flood hazard perception, behavior, adjustment, precaution, risk reduction, and prevention in November 2011.[1] Moreover, the identified articles that are presented in Table I were checked for forward and backward citations. Following this procedure, we identified 16 studies that in total include more than 12,000 respondents from seven different countries (Table I).

Table II provides an overview of the results of correlation and regression analyses, as well as the statistical significance levels found by current studies that examine the relationship between flood risk perceptions and already-adopted private mitigation measures. It shows that the majority of the reviewed

[1] The following search terms were used: flood AND risk perception, flood hazard AND risk perception, flood AND adjustment AND behav*, flood AND mitigation AND behav*, flood AND preparedness, flood AND prevention AND behav*, flood AND precaution, flood AND protection AND behav*, flood AND risk reduction AND behav*, flood AND protection motivation, flood AND protection motivation theory.

studies find no or only weak relations between the two variables.

The reviewed studies apply different definitions of risk perceptions to examine their relationship to flood mitigation behavior. Grothmann and Reusswig[29] is the only study that uses a combined measurement of perceived probability and consequences, which is defined as perceived risk in this article. They find small to medium values for correlations between perceived risk and four indicators that measure precautionary behavior at statistically significant levels. Correlation values of ±0.1 are considered to represent a small effect; values of ±0.3 a medium effect; and values ±0.5 a large effect.[35] A multiple regression analysis shows that perceived risk can only explain an additional 3–6% of the variance in mitigation behavior, which indicates a weak relation at best.

Most of the reviewed studies measure risk perceptions by eliciting the perceived probability of a flood event.[17,21,27,30–32] Thieken *et al.*[30] find no statistically significant relation to flood mitigation behavior in five of six possible cases. A small to medium correlation is reported in one case. A small correlation is also reported by Lindell and Hwang.[32] However, a regression analysis shows that the perceived probability can explain only 1% of the variance in protective behavior, and 5.5% of the variance in the purchase of flood insurance.[32] All the other studies do not find a statistically significant correlation of the perceived probability with flood mitigation behavior. Siegrist and Gutscher[21] employ a multiple-regression analysis, with prevention behavior as the dependent variable, and report that perceived probability had no influence on precautionary behavior after controlling for experience. Miceli *et al.*[31] combine the perceived probability with the attitude "fear" to derive a "Perception of Flood Risk Scale" (PFRS), which shows a low correlation with mitigation behavior. However, it is concluded that it is especially the emotional item "fear" that influences mitigation behavior rather than the perceived probability.[31]

Knocke and Kolivras[36] examine the influence of two aspects of perceived consequences on tracking flash flood developments by individuals: namely, perceived risk to life, and perceived risk to property. Whereas the former is found to be significantly related to a higher frequency of tracking flash floods, no significant relation was observed for the variable perceived risk to property. Zaleskiewicz *et al.*[37] examine factors that influence people's decision to buy flood insurance in Poland before and after a major flood event in 1997. Risk perceptions are represented by a variable referred to as "dread of flood," which comprises measurements of fear of flooding, perceived unavoidability of the disaster, perceived severity of losses, and perceived likelihood of flooding in the future. A comparison between respondents with, and without, flood insurance before the flood in 1997 revealed no relation between the respondents' scores on the dread factor and the decision to buy flood insurance. A statistically significant difference between the two groups was found after the 1997 flood. However, the study concludes that it is predominantly the emotional item fear that determines whether people demand flood insurance.[37]

2.1. Excursus: Risk Perceptions, Private Mitigation Behavior, and Natural Hazards Other Than Flooding

Although this study focuses on flood mitigation behavior, it is of interest to put our findings in a broader context and to examine whether they can be generalized to other hazards. Therefore, here we provide an excursus on the relation between risk perceptions and mitigation behavior in the domain of other natural hazards. The aim of this excursus is to study whether similar findings are obtained for natural hazards other than flooding. Comprehensive review studies on the relation between risk perceptions and mitigation behavior already exist for seismic hazards,[33,34] which provide an excellent basis for our excursus. Moreover, we also add literature on volcanic hazards, tornadoes, and wildfires.

A large body of literature has investigated private mitigation behavior with respect to seismic hazards. In their review article on mitigation behavior with respect to seismic risks, Lindell and Perry[34] suggest that higher risk perceptions tend to lead to precautionary behavior,[38–40] but they also refer to studies that did not observe a significant relation between the two variables.[41–43] In a more recent review, Solberg *et al.*[33] point out, however, that the positive correlations between risk perceptions and mitigation behavior reported in the literature on seismic hazards are often small.[40] Moreover, they refer to a large number of studies in recent years that do not support the proposition that higher seismic risk perceptions result in mitigation behavior.[39,44–49] In their reevaluation of the international literature on the social psychology of seismic hazard adjustment, they conclude that "risk perception is only weakly related to seismic adjustment."[33]

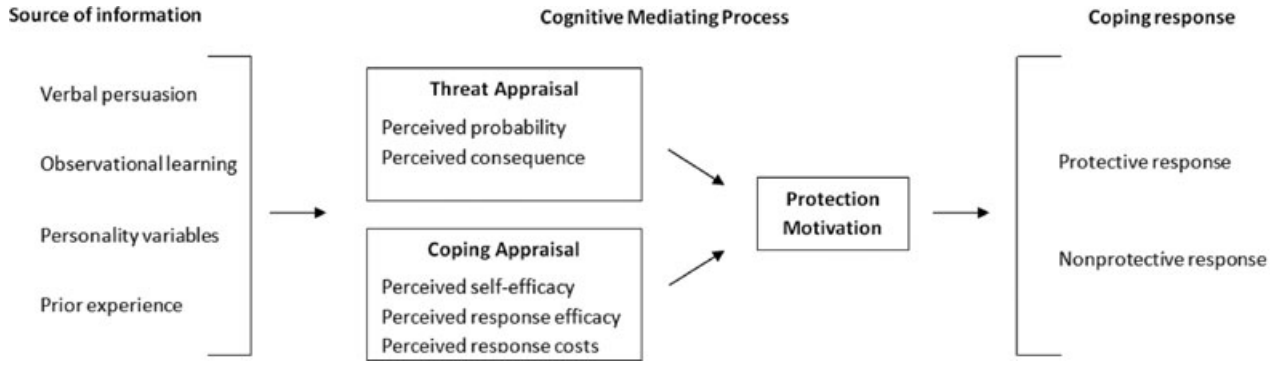

Fig. 1. A schematic overview of protection motivation theory (adapted from Rogers and Prentice-Dunn, 1997).

No significant relation between risk perceptions and private mitigation behavior was reported for respondents exposed to volcanic hazards,[50–51] wildfires,[51] and tornadoes.[52] However, a statistically significant relation between storm risk perception and protective behavior is found by Lindell and Hwang[32] and Peacock.[53]

In conclusion, in line with our findings on the relation between flood risk perceptions and mitigation behavior, most of the empirical evidence from similar research on other natural hazards domains supports the notion that risk perceptions are weak predictors of precautionary behavior.[31,33]

2.2. The Explanatory Power of Risk Perceptions for Protective Behavior

While it is obvious that people need to be aware of, and perceive, a certain risk to possibly react to it, the overview provided above suggests that high risk perceptions, as such, do not necessarily result in improved mitigation behavior, as is often suggested. An explanation for this is provided by PMT, which was introduced and revised by Rogers.[54,55] Fig. 1 depicts a schematic overview of how PMT explains protective behavior of individuals according to specific variables.

PMT initially aimed to identify how fear-arousing communication (verbal persuasion) can lead to changes in attitudes, and subsequently to changes in behavior. Later, other sources of information that possibly trigger protection motivation were also included, such as personality, observational learning, and prior experience. Protection motivation, in turn, is regarded as an intervening variable that arouses, sustains, and directs the activity of individuals to protect themselves.[56]

Today, PMT provides a widely adopted psychological model to explain decision making in relation to threats.[56] PMT has been predominantly used to explain and predict protective health behavior,[57,58] but has also been applied in the context of natural hazards,[29,59] as well as of technical and environmental hazards.[60] The model attempts to reflect the main cognitive processes that lead to a protection motivation in response to a specific threat. Two steps of cognitive processes are distinguished: namely, "threat appraisal" and "coping appraisal."[61] "Threat appraisal" describes how an individual evaluates how threatened he or she feels by a certain risk. It is composed of the variables "perceived vulnerability" (probability) and "perceived severity" (consequences) and has, therefore, also been referred to as "risk perception."[29] Once a certain level of threat appraisal is reached, people start to think about the benefits of possible actions and to evaluate their own competence to carry them out.[62] This process is referred to as "coping appraisal" and is comprised of the three variables "response efficacy," "self-efficacy," and "response cost."[57,58] *Response-efficacy* addresses to what extent an individual believes that a protective measure effectively reduces a risk. *Self-efficacy* reflects the belief of a person as to whether he or she is personally able to actually carry out the specific measure. *Response costs* are the person's estimate of how costly it would be for him or her to actually implement the particular risk-reduction measure. It is the combined effect of coping appraisal and threat appraisal that influences an individual's protection motivation, and results in a protective or nonprotective coping response (see Fig. 1).

Two meta-analyses of PMT studies have evaluated the overall usefulness of PMT for

predicting health-related protective behavior.[57,58] Interestingly, both these meta-analyses, which include 65 studies (n = approx. 30,000) and 27 studies (n = 7,694), respectively, come to the conclusion that the "coping-appraisal" component of the model was found to have greater predictive validity of health-related intentions and behavior than the "threat-appraisal" component. Milne *et al.*[57] conclude from their review that risk perceptions, as such, are poor predictors of private mitigation behavior. The current empirical literature on the relation between flood risk perceptions and precautionary behavior initially supports these findings (Table II).

The reason why the weak to nonexistent relation between risk perceptions and protective behavior is explained by PMT is that the responses of individuals to a perceived risk can be either protective or nonprotective. Nonprotective responses are, among others, fatalism, wishful thinking, or denial. Milne *et al.*[57] report positive correlations between high risk perceptions and nonprotective responses in their review of PMT studies on health-related behavior. Whether a high risk perception leads to a protective response seems to depend on an individual's coping appraisal.[57] Nonprotective responses would be adopted by an individual with a high risk perception but a low coping appraisal because they reduce the negative emotions produced by the high risk perception.[63] This finding is replicated by Grothmann and Reusswig[29] in the context of flood risk perception. Nonprotective responses, such as denial and wishful thinking, show a medium correlation with flood risk perception. In contrast, coping-appraisal components correlate negatively with nonprotective behavior, but mostly positively with the adoption of protective measures.[29] This supports the argument that the coping appraisal of individuals plays an important role in prompting private flood mitigation behavior.

2.3. Assessing the Relationship Between Risk Perceptions and Precautionary Behavior in Cross-Sectional Studies

An additional explanation for the weak relationship found could be provided by a methodological aspect that has been discussed by Weinstein.[26] All of the studies discussed so far are cross-sectional in nature, and investigate the relationship between risk perceptions and precautionary behavior by looking at correlations between the two variables within a given sample group at one point in time. By doing so, possible feedback from an already-adopted flood mitigation measure on the risk perception of the respondent is neglected. This can be illustrated by the following example, which is depicted in Fig. 2: suppose that a high risk perception would increase the willingness of individuals to undertake precautionary measures. As a result, a person with a high flood risk perception (R_1) at a given time (T^1) would have bought devices that reduce the risk of flooding: for instance, through elevating the building. It could be expected that the adoption of the respective flood mitigation measures would decrease the risk perception (R_2) of that person at that point in time (t_2). If the person did not believe in the risk-reducing effect of the measure, it would be hard to explain why he or she would invest in it. Suppose that this specific person is included at time (t_2) in a cross-sectional study to investigate the relationship between flood risk perception and mitigation behavior. In that case, the relationship (r^2) between R_2 and the adoption of mitigation behavior would be measured, and the result could turn out to be contrary to initial expectations. It would be found that a person with a low(ered) risk perception had undertaken a mitigation measure. However, the causal relation would not be that a respondent had adopted a flood mitigation measure even though he has a low risk perception. In fact, the respondent had a lower risk perception because he had adopted a flood mitigation measure. If the same person is included at time T^1, a positive relationship (r^1) between flood risk perceptions and mitigation behavior would be found. This example demonstrates the need to control for previously undertaken precautionary measures when assessing the relationship between risk perception variables and mitigation behavior in cross-sectional studies.

A possible way to avoid this methodological problem and to gain a more accurate understanding of the relation between risk perceptions and mitigation behavior is to ask respondents about their intention to perform mitigation measures in the future. Since the respondent has not undertaken the measure yet, the relation between risk perceptions and the intention to mitigate are not distorted by previous mitigation behavior. For instance, in the case that a respondent's risk perceptions are low due to an undertaken mitigation measure, asking for the intention can correctly capture that low risk perceptions lead to low intentions to undertake (additional) measures. Also, if a respondent has high risk perceptions, asking for the intention can correctly

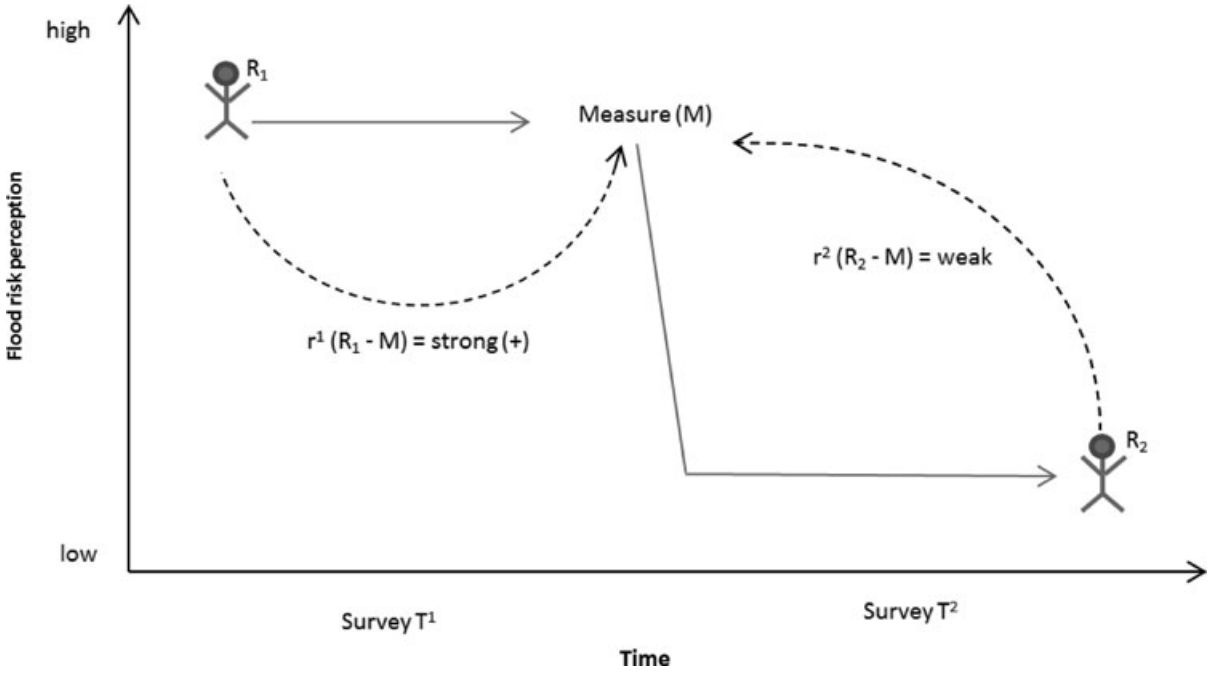

Fig. 2. Assessing the relationship between risk perceptions and precautionary behavior in cross-sectional studies: feedback of an already-adopted mitigation measure on risk perception.

capture the relation between the latter and the (high) intention to mitigate. It is important to notice, however, that, while providing a way to examine the relation between the two variables in general, asking for behavioral intentions cannot explain the specific relation between past risk perceptions and already-adopted measures, and hence the feedback loop depicted in Fig. 2 (r^1). This is the case because the motivation to implement a mitigation measure will remain low once effective measures have been undertaken as this reduces risk perceptions. The most elegant method would be to monitor over time how risk perceptions influence mitigation behavior, and examine how risk perceptions change after an individual has undertaken mitigation. A drawback of such a method is that it is impractical to monitor individuals over a long-time horizon, and it is more expensive than a cross-sectional study. An alternative way to gain insights into the relation between past risk perceptions and an already-adopted mitigation measure is to elicit risk perceptions under a scenario that asks the respondents to imagine that no precautionary measures are undertaken.[65] Subsequently, it can be asked whether the respondent has already undertaken mitigation measures or intends to undertake such measures. Another option would be to explicitly ask respondents who have already implemented a measure whether this has had an effect on their risk perceptions.

Table III provides an overview of the results of regression analyses, as well as of the statistical significance levels found by current studies that examine the relation between flood risk perceptions and the *intention* to adopt private flood mitigation measures. In contrast to the results reported earlier, studies that elicit the intention to undertake a flood mitigation measure do find significant relations with risk perceptions.

Botzen *et al.*[12] ask respondents for their intention to invest in flood mitigation measures, such as sandbags, and observe a positive relationship at statistically significant levels between the risk perceptions and the intention to invest in sandbags. Botzen and van den Bergh[66] elicit the willingness-to-pay (WTP) for flood insurance using a choice experiment, and find a positive relationship at statistically significant levels between the risk perceptions and the WTP for flood insurance. Zaalberg *et al.*[65] also find a significantly positive relation between perceived probability and the intention to undertake flood mitigation measures. In line with the two latter studies, Terpstra[67] finds a significantly positive relation between risk perceptions of flooding and flood mitigation intentions. Only for

Table III. Empirical Findings on the Relation Between Risk Perceptions and the Intention to Undertake Private Flood Mitigation Behavior

Effect Sizes, Coefficient of Determination (R^2), and Statistical Significance (p)				
Independent Variable	Paper	R^2	Standardized Beta Weights (β), Marginal Effects (ME)	Significance
Perceived probability	Botzen *et al.*[a(12)]	n.a.	ME = −0.20[c] ME = −0.0004[d]	$p < 0.05$ $p < 0.10$
	Botzen and van den Bergh[b(66)]	n.a.	ME = −0.20[c] ME = −0.002[e] ME = −0.08[f]	$p < 0.01$ $p < 0.05$ $p < 0.01$
	Terpstra[67]	0.09–0.28	β = 0.19–0.46	$p < 0.001$
	Zaalberg *et al.*[65]	n.a.	β = 0.23–0.37[g]	$p < 0.0001$
Perceived damage or consequences	Botzen and van den Bergh[b(66)]	n.a.	ME = 0.0009[h]	$p < 0.01$
	Zaalberg *et al.*[65]	n.a.	n.a.	n.s.
	Terpstra[67]	0.01–0.08	β = −0.09–0.2	*n.s.* to $p < 0.001$

[a]Estimates are of a probit regression model, and reported coefficient values indicate the marginal effect of a one-unit change in the independent variable on the probability that respondents intend to purchase sandbags.
[b]Estimates are of a mixed logit regression model, and reported coefficient values indicate the marginal effect of a one-unit change in the independent variable on the probability that respondents intend to purchase flood insurance.
[c]The independent variable represents respondents who expect that the return period of flooding equals zero.
[d]The independent variable is the log of the expected (positive) return period of flooding by respondents.
[e]The independent variable is the expected (positive) return period of flooding (in thousands) by respondents.
[f]The independent variable represents respondents who expect that they have a lower flood probability than an average resident in the Netherlands.
[g]Nonstandardized regression coefficient.
[h]The independent variable is the expected flood damage by respondents (in thousands of euro).
Note: n.a. = not applicable; n.s. = not significant.

one of three subsamples that consists of respondents from a coastal area who recalled a heavy storm event with high tide levels but had no direct flood experience are perceived consequences found to be insignificant. These findings indicate that it is important to control for prior mitigation behavior in cross-sectional studies, and that asking for intentions may solve the methodological problem outlined earlier.

3. ADDITIONAL FACTORS OF INFLUENCE ON PRIVATE FLOOD MITIGATION

In addition to flood risk perceptions, current research presents a large variety of factors that can potentially influence the adoption of private mitigation measures. If flood risk perceptions are a rather weak predictor of private mitigation behavior, then it is of interest to understand what other factors are found to be consistently related to flood mitigation behavior. This section provides a review of the factors that influence private flood mitigation behavior, which has not been available so far. It aims to identify the most important factors, thereby reducing the existing complexity in the current literature. An overview of the examined factors is provided in Table IV. The table provides the p-values of the examined factors and, where applicable, effect sizes such as correlation values, standardized regression coefficients, or marginal effects.

3.1. Experience with Flooding

Experience with hazards is often considered to have a powerful impact on the recognition of a risk, and seems to be an important factor of influence on private mitigation behavior.[64] Almost all studies that examine the relationship between personal experience and protective behavior in the context of natural hazards find it to be positive. Accordingly, experience with flooding is an explanatory variable for mitigation behavior that is examined by almost all reviewed studies. Except for Takao *et al.*[27] and Thieken *et al.*,[30] all studies find that previous experience of a hazard is statistically significantly related to the adoption of private mitigation measures. The latter study reports a weak positive correlation with mitigation behavior for two of six possible cases. Botzen *et al.*[12] find that flood experience relates positively to individual flood risk perceptions in the Netherlands and demand for flood

Table IV. Factors That Are Observed to be of Influence on Private Flood Mitigation Behavior

Independent Variable	Paper	Correlation (r), Standardized Beta Weights (β), Odds Ratios (Exp(B)), Marginal Effects (ME)	Significance (p)
Experience with Flooding			
Flood experience	Siegrist and Gutscher[21]	$\beta = 0.18$	$p < 0.001$
	Lindell and Hwang[32]	$r = 0.17$ and 0 .14	$p < 0.05$
	Thieken *et al.*[30]	$r = 0.28$–0.30[a]	n.s. to $p < 0.05$
	Siegrist and Gutscher[69]	Exp(B) = 2.5–8.6[b]	$p < 0.01$–$p < 0.001$
	Kreibich *et al.*[17]	n.a.	$p < 0.05$
	Takao *et al.*[27]	n.a.	n.s.
	Thieken *et al.*[28]	n.a.	$p < 0.01$
	Grothmann and Reusswig[c][29]	$r = 0.28$–0.34	$p < 0.01$
	Kreibich *et al.*[68]	n.a.	n.s. to $p < 0.05$
	Knocke and Kolivras[36]	n.a.	$p = 0.05$
(Severity of) damage suffered	Takao *et al.*[27]	n.a.	$p < 0.01$
	Miceli *et al.*[31]	$r = 0.14$	$p < 0.01$
	Grothmann and Reusswig[c][29]	$r = 0.29$–0.39	$p < 0.01$
Experience with evacuation	Botzen *et al.*[12]	ME = –0.1289	n.s.
	Botzen and van den Bergh[66]	ME = 0.18	$p < 0.01$
Fear of or Worry About Flooding			
Feeling of worry or fear	Miceli *et al.*[31]	$r = 0.15$ ($\beta = 0.17$)	$p < 0.01$
	Takao *et al.*[27]	n.a.	n.s. to $p < 0.01$
	Grothmann and Reusswig[c][29]	$r = 0.04$–0.13	n.s
PFRS	Miceli *et al.*[31]	$r = 0.11$	$p < 0.05$
Dread of flood	Zaleskiewicz *et al.*[37]	$r = 0.3$[b]	n.s. to $p < 0.01$
Knowledge About Flood Hazard			
Knowledge about floods	Thieken *et al.*[30]	$r = 0.23$–0.28[a]	n.s. to $p < 0.05$
	Botzen *et al.*[12]	ME = –0.1398	$p < 0.05$
	Thieken *et al.*[28]	n.a.	$p < 0.01$
	Kreibich *et al.*[17]	n.a.	$p < 0.05$
	Zaleskiewicz *et al.*[37]	0.03[b]	n.s.
Information on floods	Miceli *et al.*[31]	$r = 0.14$	$p < 0.01$
	Lindell and Hwang[32]	$r = 0.03$ and 0.12	n.s. to $p < 0.05$
Climate change causes higher flood risk	Botzen *et al.*[12]	ME = 0.1514	$p < 0.01$
	Botzen and van den Bergh[66]	ME = 0.07	$p < 0.01$
Socioeconomic and Geographic Variables			
Past tenure	Lindell and Hwang[32]	$r = 0.06$ and 0.03	n.a.
Tenure expectations	Lindell and Hwang[32]	$r = –0.02$ and 0.09	n.a.
Household size	Kreibich *et al.*[17]	n.a.	$p < 0.05$
	Zaalberg *et al.*[65]	$r = 0.067$ to –0.077	n.s.
Objective risk	Siegrist and Gutscher[21]	$\beta = –0.05$ to 0.00	n.s.
Ethnicity	Lindell and Hwang[32]	$r = –0.11$ and 0.16	n.a. and $p < 0.05$
Perceived elevation	Zaalberg *et al.*[65]	$r = –0.088$ to –0.355	n.s. to $p < 0.01$
Marital status	Zaalberg *et al.*[65]	$r = 0.093$–0.045	n.s.
Age	Grothmann and Reusswig[c][29]	$r = 0.08$–0.22	n.s. to $p < 0.01$
	Botzen *et al.*[12]	ME = –0.0013	n.s.
	Miceli *et al.*[31]	$r = 0.07$ ($\beta = 0.01$)	n.s. ($p < 0.05$)
	Lindell and Hwang[32]	$r = 0.02$ and 0.1	n.a.
	Knocke and Kolivras[36]	n.a.	$p < 0.01$
	Zaalberg *et al.*[65]	$r = –0.012$ to 0.066	n.s.
	Botzen and van den Bergh[66]	ME = –0.03	$p < 0.01$
Gender	Grothmann and Reusswig[c][29]	$r = 0.03$–0.1	n.s.
	Botzen *et al.*[12]	ME = –0.0158	n.s.
	Botzen and van den Bergh[66]	ME = –0.06	$p < 0.05$
	Miceli *et al.*[31]	$r = 0.12$	$p < 0.05$
	Lindell and Hwang[32]	$r = –0.02$ and 0.06	n.a.

(*Continued*)

Table IV. (*Continued*)

Independent Variable	Paper	Correlation (r), Standardized Beta Weights (β), Odds Ratios (Exp(B)), Marginal Effects (ME)	Significance (p)
	Knocke and Kolivras[36]	n.a.	n.s.
	Zaalberg *et al.*[65]	$r = -0.088$ to 0.005	n.s.
Education	Grothmann and Reusswig[c][29]	$r = -0.01$ to 0.05	n.s.
	Botzen *et al.*[12]	ME = 0.0490	$p < 0.1$
	Botzen and van den Bergh[66]	n.a.	n.s.
	Miceli *et al.*[31]	$r = 0.03$	n.s.
	Lindell and Hwang[32]	$r = -0.01$ and 0.07	n.a.
	Zaalberg *et al.*[65]	$r = 0.001$–0.004	n.s.
Income	Grothmann and Reusswig[c][29]	$r = 0.11$–0.36	n.s. to $p < 0.01$
	Botzen *et al.*[12]	ME = 0.000004	n.s.
	Lindell and Hwang[32]	$r = -0.06$ and 0.08	n.a.
	Zaalberg *et al.*[65]	$r = 0.017$ to –0.075	n.s.
	Botzen and van den Bergh[66]	ME = 0.07	$p < 0.01$
	Kreibich *et al.*[17]	n.a.	$p < 0.05$
Distance to river / water body	Miceli *et al.*[31]	$r = 0$ .14 ($\beta = 0.11$)	$p < 0.01$ ($p < 0.05$)
	Lindell and Hwang[32]	$r = -0.16$ and –0.08	n.a.
	Botzen and van den Bergh[66]	ME = 0.05	$p < 0.05$
Close to river	Botzen *et al.*[12]	ME = 0.0857	$p < 0.1$
Rural area	Botzen *et al.*[12]	ME = 0.3339	$p < 0.01$
	Botzen and van den Bergh[66]	ME = 0.13	$p < 0.05$
Ownership	Thieken *et al.*[30]	$r = 0.26$	n.s. to $p < 0.05$
	Kreibich *et al.*[17]	n.a.	$p < 0.05$
	Grothmann and Reusswig[c][29]	$r = 0.11$–0.45	n.s. to $p < 0.01$
	Zaalberg *et al.*[65]	$r = 0.063$ to –0.028	n.s.
Hindrances for Private Flood Mitigation			
Reliance on public flood defense	Grothmann and Reusswig[c][29]	$r = -0.30$ to 0.03	n.s. to $p < 0.01$
Nonprotective responses[d]	Grothmann and Reusswig[c][29]	$r = -0.28$to –0.41	$p < 0.01$
	Siegrist and Gutscher[69]	$r = -0.28$[b]	$p < 0.02$
High costs	Siegrist and Gutscher (2008)[69]	$r = -0.24$[b]	$p < 0.04$
Government is perceived as responsible	Botzen *et al.*[12]	ME = –0.3094	$p < 0.05$
Availability of	Botzen and van den Bergh[66]	ME = –0.07	$p < 0.01$
government relief for damage	Botzen *et al.*[12]	ME = –0.0899	$p < 0.05$
Coping Appraisals			
Effectiveness	Kreibich *et al.*[17]	n.a.	$p < 0.05$
	Zaalberg *et al.*[65]	$\beta = 0.69$–0.76[e]	$p < 0.0001$
Self-efficacy	Zaalberg *et al.*[65]	n.a.	n.s.
Coping appraisal	Grothmann and Reusswig[c][29]	$r = -0.02$ to 0.38	n.s. to $p < 0.01$

[a] r values for different geographical locations are only reported if $p < 0.05$ and if $r \geq 0.2$.
[b] The effect size has been calculated by the authors.
[c] Four different precautionary measures are assessed separately from each other, which results in four different correlation coefficients. Only statistically significant correlations ($p < 0.05$) are included in the table.
[d] Nonprotective responses refer to factors such as wishful thinking, fatalism, or hopelessness.
[e] Nonstandardized regression coefficient.

insurance,[66] but not to intentions to invest in mitigation measures once the effect of (higher) risk perceptions is controlled for.[12] This is probably because the influence of experience on the intention to mitigate is mediated via risk perceptions, as is also reported by Zaalberg *et al.*[65] Also, Kreibich *et al.*[68] find that the experience of an extreme flood event significantly increases the level of preparedness, both among private households and businesses. However, the reported correlation and regression values are

often small or medium in size.[21,29–32] It is furthermore suggested by the current literature that it is not the experience with flooding, as such, that drives private mitigation behavior, but that the severity of the experienced negative consequences plays an important role.[27,29,69] Grothmann and Reusswig[29] show that the severity of experienced flood damage can explain 10–20% of the variance in mitigation behavior. Moreover, the timing of the previous experience may play a role, since it can be expected that experiences with flooding that are in the distant past have only a small influence on individual risk perceptions and mitigation behavior later in people's lives. The International Commission for the Protection of the Rhine (ICPR) estimates that flood awareness mostly diminishes within seven years after a flood and that only catastrophic disasters are remembered in the long term.[7] This assumption is empirically supported by Wagner,[70] who shows that the half-life memory of damaging flash floods and landslides is 14 years. Wind *et al.*[71] and Kron and Thumerer[16] discuss that flood damage is significantly lower in areas where people have recently experienced a flood event, which is attributed to a better preparedness of the population in the direct aftermath of a flood. Terpstra[67] shows that the experience of the catastrophic flood in the Netherlands in 1953 still influences people's emotions toward flooding. On the basis of the empirical literature, it can be concluded that flood experience is an important factor of influence on private mitigation behavior. However, the literature also suggests that this influence can fade away a few years after a flood event.

3.2. Fear of or Worry About Flooding

Examining risk perceptions and their relation to protective behavior with cognitive variables, such as the "perceived likelihood" or "consequence," reflects a very rational concept of the term "risk," and is in line with expected utility theory.[72] According to this view, people's reaction to a risk can be explained by "assuming that people assess the severity and likelihood of the possible outcomes of choice alternatives, ... and integrate this information through some type of expectation based calculus to arrive at a decision."[73] This approach has been criticized on the grounds that it ignores the influence that feelings have on the decision-making process.[31] It has been shown that emotions influence the cognitive evaluation of a risk and the respective behavioral response to it.[73,74] Accordingly, a number of studies also include an independent variable of the affect component, such as "fear" of or "worry" about flooding.[21,27,29,31,65,67] Most of these studies do find a significant relation between these variables and the adoption of private flood mitigation measures. Except for Grothmann and Reusswig,[29] all studies find a statistically significant relationship between the variables "fear" or "worry" and the adoption of flood mitigation measures. The reported effect sizes are rather small.[29,31] In conclusion, the majority of the reviewed literature suggests that a positive relation exists between emotional items such as fear or worry about flooding and the adoption of flood mitigation measures.

3.3. Knowledge About Flood Hazards

An important aspect in terms of risk communication is the question whether people who have better knowledge about floods or who have received information about flood protection are more likely to adopt mitigation measures than those who do not have such information. Whereas several studies find that increased knowledge and information correlates weakly positively with precautionary behavior, in some cases,[30,31] Botzen *et al.*[12] even find a negative influence between people's knowledge about floods and their willingness to invest in sandbags. Lindell and Hwang[32] find no evidence that there is a direct effect of information sources and flood mitigation behavior when risk perception is controlled for. Siegrist and Gutscher[29] find that "lack of knowledge about flooding" does not relate to less mitigation behavior. Similarly Zaleskiewicz *et al.*[37] find that there is no significant difference in terms of knowledge about floods between respondents who bought flood insurance and those who did not. These results suggest that knowledge is not always a very useful predictor of flood mitigation behavior.

3.4. Socioeconomic and Geographical Factors

A number of studies also include socioeconomic and geographical factors to explain mitigation behavior, for instance, age, gender, income, and the objective risk. A factor that is found to have a small to medium effect on mitigation behavior in three studies is ownership of a building. Tenants, on the other hand, have a lower demand for mitigation.[17,29,30] This should not come as a surprise because tenants do not have to pay for the full damage of flooding to a building. Moreover, tenants usually need

the approval of the owner when making considerable changes to the building, such as installing structural flood protection.[29] Even though women tend to have a higher risk perception, in general, this does not seem to translate into a higher protective behavior compared with men.[12,29,32,36,65] As far as flood insurance is concerned, Botzen and van den Bergh[66] find that women are significantly less willing to pay for flood insurance than men. Lindell and Hwang[32] report no significant relation between being female and the purchase of flood insurance, and also Zaalberg *et al.*[65] find no influence of gender on the intention to undertake mitigation measures. Furthermore, both age and the level of education seem to have a very small or no impact on precautionary behavior.[29,32,36,65–66] Moreover, the distance to a river or water body appears to have little effect on actual mitigation behavior in most of the cases.[12,31–32] Botzen *et al.*[24] find that individuals who live close to a main river have higher risk perceptions, and that living close to a river relates marginally significantly to demand for mitigation, and significantly to flood insurance demand.[12,66] Nevertheless, the overall explanatory power of objective risk factors is low, which is in line with the findings of Siegrist and Gutscher,[21] who show that the objective risk, as defined by experts, does not relate to actual mitigation behavior. Moreover, Botzen and van den Bergh[66] observe that demand for flood insurance is not significantly related to the elevation of the respondents' house relative to potential water level or to the existence of flood protection infrastructure. It might be expected that individuals with a higher income are more willing to invest in flood mitigation measures because they have more financial resources. Nevertheless, the relation between income and mitigation demand is insignificant in the study of Botzen *et al.*,[12] although income is significantly related to insurance demand, albeit with a small marginal effect.[66] The former result is inconsistent with the finding of Lindell and Hwang[32] and Zaalberg *et al.*,[65] who observe insignificant correlation values between income and flood mitigation, whereas the latter result is consistent with the study of Grothmann and Reusswig.[29]

Lindell and Hwang[32] do not find a correlation at a statistically significant level between past tenure of the property and future tenure expectations and mitigation behavior or the purchase of flood insurance. The discussed results show that only a few socioeconomic and geographical factors are consistently related to flood mitigation behavior. This suggests that socioeconomic variables alone are not sufficient to explain precautionary behavior toward flooding.[65]

3.5. Hindrances for Private Flood Mitigation

An aspect that has received relatively little attention in current empirical work on mitigation behavior is factors that deter people from adopting precautionary measures. Botzen *et al.*,[12] and Grothmann and Reusswig[29] show that people who perceive the government as responsible for compensating flood damage are less likely to take flood mitigation measures than others. Botzen *et al.*[12] find that the availability of government compensation for flood damage, as well as the perceived responsibility of the government, relates negatively to the willingness of homeowners to buy sandbags. Moreover, Botzen and van den Bergh[66] find that demand for flood insurance is significantly lower if *ad hoc* compensation of flood damage by the government is available. Grothmann and Reusswig[29] report that the reliance on public flood protection could explain between 1% and 10% of the variance in mitigation behavior. Other factors that have been shown to have a significant negative effect on protective behavior are what are called nonprotective responses, such as wishful thinking, hopelessness, or fatalism. For these variables, Grothmann and Reusswig[29] find small to medium negative correlation values with mitigation behavior, and these values are consistently higher than those for risk perceptions. Siegrist and Gutscher[69] report that hopelessness and the high costs of mitigation measures play an important role in explaining why people with flood experience did not undertake a preventive measure. These results show that there are a number of variables that can explain why people actually refrain from undertaking precautionary measures. Interestingly, studies that include such variables find that these factors often have a larger effect on mitigation behavior than risk perception variables.[12,29]

3.6. Perceived Effectiveness and Coping Appraisal

Indicators of the coping appraisal of individuals, such as the perceived effectiveness of flood mitigation measures have received relatively little attention in the current literature on mitigation behavior. These are very interesting variables since they can be targeted in risk communication strategies. According to PMT, coping appraisal is decisive because it

influences whether people react to a perceived risk in a protective way. This is supported by the majority of studies that include such a variable. Reported correlation values range from small to medium.[17,29,65,69] Grothmann and Reusswig,[29] who apply PMT in the context of flood risk, find that coping appraisal could explain an additional 2–21% of the variance in mitigation behavior, which is a significantly higher R^2 value than for perceived risk. Zaalberg *et al.*[65] find that the perceived effectiveness of mitigation measures is positively related to the intentions to adopt flood mitigation measures, whereas the perceived self-efficacy is not. Overall, these findings support the argument that coping appraisal is an important determinant for private flood mitigation behavior.

4. CONCLUSION

Given the observed shift toward more integrated flood management strategies, flood risk perceptions have received growing attention because they are considered to be important indicators of flood management. The main reason for this is the supposed positive relation with flood mitigation behavior. This study has examined whether the current focus on flood risk perceptions as a means to explain and stimulate private flood mitigation behavior is supported on both empirical and theoretical grounds.

Our review of the current empirical literature has shown that the supposed positive relation between flood risk perceptions and the adoption of private mitigation measures is hardly observed in cross-sectional studies. Two arguments are provided that could serve as an explanation for the weak relationship that was found. First, on the basis of the PMT, a theoretical framework is discussed that explains why high risk perceptions do not necessarily lead to the adoption of mitigation measures. In order to result in a protective response, high risk perceptions of an individual need to be accompanied by high coping appraisal, and thus the belief in being able to cope with or to avoid the risk. Second, a possible feedback from previously adopted mitigation measures that lead to lower risk perceptions has hardly been considered by the current literature. This methodological reason can serve as an additional explanation for the observed weak relationship, and is supported by the observation that studies that examine intentions to mitigate mostly find positive relations with risk perceptions.

Since flood risk perceptions are found to be rather weak predictors of protective behavior, we also provided an overview of other factors that have an influence on mitigation behavior. The analysis in Section 3 showed that socioeconomic and geographical factors like gender, income, or the objective risk faced by respondents are also poor predictors of precautionary behavior. To better explain flood mitigation behavior, perceptual factors other than risk perceptions, such as the perceived effectiveness of measures, their estimated costs, and the perceived responsibilities in flood management, but also fatalism and wishful thinking, all need to be taken into account, as is apparent from the results of a number of studies. These empirical findings are in line with PMT, which considers these cognitive appraisal and response processes as important explanatory factors of precautionary behavior. The literature review provided in this article thus suggests that PMT can provide valuable insights for explaining flood mitigation behavior, which is useful for integrated flood risk management.

Currently, risk awareness raising as a means to stimulate flood mitigation behavior is an important tool in current and envisaged flood management.[13] Although it is obvious that people need to be aware of a certain risk to possibly react to it, our findings indicate that the predominant focus on risk awareness (or perception) will not be sufficient to manage the intended transition to more integrated flood management. It is suggested that a sole focus on risk awareness raising can potentially even lead to nonprotective responses, such as fatalism, denial, and wishful thinking.

Given the important role that coping appraisal and the perceived responsibilities for flood management play in translating a high risk perception into protective behavior, these aspects should receive greater attention in risk communication policies and future research on flood mitigation behavior. To stimulate the coping appraisal and thus protective response of people at risk of flooding, risk communications should be accompanied by additional information on the effectiveness of flood mitigation measures, and together with practical guidance on how to implement them. Additional research is needed that examines how different flood risk communication strategies influence flood coping appraisal. Even though coping appraisal is a construct of three cognitive processes: namely, response efficacy, self-efficacy, and response costs, it is often treated as a single variable by the existing literature. Better targeted flood risk communication strategies could be developed by gaining more insights into the separate influence of these three variables on flood mitigation behavior. Further research could focus on which of

the three elements of coping appraisal should be especially emphasized and supported by risk communication strategies.

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