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The importance of public risk perception for the effective management of pluvial floods in urban areas: A case study from Germany

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Abstract

Heavy precipitation events are expected to increase in frequency and intensity in many parts of Europe as a result of climate change. These events can affect regions located far from rivers that have never been affected before. As warning times are short, there are hardly any effective emergency measures to mitigate the severe damage caused by pluvial floods. Therefore, long-term mitigation measures are necessary for sustainable urban flood management. However, people first need to realise their personal risk in order to become active and take private precautionary measures. To get a better understanding of the processes underlying public risk perception of pluvial floods, a questionnaire-based telephone survey was conducted analysing two case studies in western Germany. Key findings reveal that risk perceptions need to be distinguished between personal and global perception. Personal risk perception was low among the participants, while their global risk perception was far higher. The determinants of global and personal risk perception on pluvial flooding were identified. The study also showed that mitigation behaviour is influenced by personal risk perception, knowledge, education, and housing conditions. These determinants should receive attention when future risk communication and flood management strategies are developed.

KEYWORDS

Germany, heavy precipitation, mitigation behaviour, multiple regression analysis, pluvial floods, risk perception

1 | INTRODUCTION

Following the fifth Intergovernmental Panel on Climate Change (IPCC) Synthesis Report, heavy precipitation events are expected to increase in terms of intensity and frequency for many regions in the mid-latitude and wet tropical areas (IPCC, 2014). As a result, the risk of pluvial flooding is also on the rise. Urban areas, where sealing hampers infiltration, are especially at risk. Heavy precipitation events can have catastrophic consequences like the event that occurred on July 21, 2012 in Beijing, China, resulting in 79 deaths and an economic loss of approximately $1.8 billion (Su, Zhao, & Tan, 2015). In Europe, many cities have already been affected by heavy precipitation, such as the City of Hull (England) in 2007 (Coulthard & Frostick, 2010), Copenhagen (Denmark) in 2011 (Garne, Ebeltoft, Kivisaari, & Moberg, 2013; Haghighatafshar et al., 2014), Amsterdam in 2014 (Spekkers, Rözer, Thieken, ten Veldhuis, & Kreibich, 2017), and Genoa (Italy) in 2014 (Faccini et al., 2018; Faccini, Luino, Sacchini, Turconi, & de Graff, 2015). Barredo (2007) and Porfido, Alessio, Gaudiosi, Nappi, and Spiga (2016) recorded heavy precipitation events before 2000. In Germany, heavy precipitation events between May 27 and June 9, 2016 led to insured material damages of EUR 715 million (GDV, 2018). In addition to the danger of pluvial flooding, urban areas are characterised by a large number of people and valuables occupying a confined space. For this reason, such areas need special protection to avoid flooding. In contrast to fluvial and coastal flooding, where flood-prone areas are located near the waterbody, pluvial flooding can occur in areas located far away from rivers and coasts that have never been affected before. Therefore, heavy precipitation can be described as an invisible hazard (Houston et al., 2011), when compared to fluvial and coastal flooding, where the potential threat is tangible and visible. This is probably one reason why the public risk perception of pluvial flooding is low (Rözer et al., 2016). As these people do not perceive pluvial flooding as a risk, they are hardly prepared for the rising threat. However, different from fluvial flooding, warning times are short in cases of pluvial flooding (typically in the order of up to 3 hr). As a result, there are fewer emergency measures that can be implemented successfully in such short intervals. Long-term mitigation measures and strategies need to be implemented jointly with the public in order to prevent severe damage caused by heavy precipitation.

As future effects of climate change are uncertain, flexible adaptation measures should be implemented (Babovic, Babovic, & Mijic, 2018; Buurman & Babovic, 2016; Deng et al., 2013; Manocha & Babovic, 2017; Zhang & Babovic, 2012). To raise the risk perception of pluvial floods among the public in order to encourage private precautionary measures, effective risk communication is crucial (Keller, Siegrist, & Gutscher, 2006). People need to be convinced that pluvial floods are relevant to their lives and mitigation measures need to be implemented (Maidl & Buchecker, 2015). A good understanding of risk perception is necessary for effective risk communication (Keller et al., 2006). Despite the severe damage caused by pluvial floods and the increasing risk of occurrence, research on public risk perception in this context is lacking. Risk perception research currently focuses on river flooding (Gray-Scholz, Haney, & MacQuarrie, 2019; Liu, Li, Shen, Xie, & Zhang, 2018; Ludy & Kondolf, 2012) coastal floods (Kellens, Zaalberg, Neutens, Vanneuville, & Maeyer, 2011), coastal flooding because of hurricanes (Shao, Xian, Lin, & Small, 2017), floods in mountain areas triggering landslides (Miceli, Sotgiu, & Settanni, 2008), and climate change in general (van der Linden, 2015).

The examination of fluvial floods show that damages are higher when the warning time is shorter, when the perceived probability of being affected and the knowledge of protective measures are low, and when fewer precautionary measures are implemented (Kienzler, Pech, Kreibich, Müller, & Thieken, 2015). Warning times for pluvial flooding will hardly increase in the coming years. Therefore, finding ways to effectively raise public risk perception through communication and to implement effective precautionary mitigation measures is the focus of this study.

The rest of this article is organised as follows. Section 2 presents an overview of the literature and the four research objectives in this study. Section 3 describes the methods and Germany as the region of focus. The results are presented in Section 4 and discussed in Section 5, while Section 6 concludes the paper.

2 | LITERATURE REVIEW

This section reviews the literature on risk perception, and its influence on protection behaviour and its determining variables. Studies on fluvial flooding have found low levels of risk perception (Armas, Ionescu, & Posner, 2015; Botzen, Aerts, & van den Bergh, 2009; Roder, Hudson, & Tarolli, 2019; Terpstra & Gutteling, 2008). In the case of pluvial flooding, the perceived risk in most households was rated as low (Rözer et al., 2016). People often underestimate risks with low probabilities of occurrence (Keller et al., 2006), such as pluvial flooding. Uzzell (2000) and Schultz et al. (2014) found that people are more concerned about problems at a global than at a local level. Thus, van der Linden (2015) separated risk perception into the personal and global levels (van der Linden, 2015).

2.1 | The importance of risk perception and its influence on protective behaviour

Risk perception seems to be an influencing factor in supporting and adopting protection measures. For example, Niles, Lubell, and van Haden (2013) and Frondel, Simora, and Sommer (2017) found that risk perception of climate change is a main factor for the support of climate-politic measures. Zhai, Sato, Fukuzono, Ikeda, and Yoshida (2007) showed that high risk perception of flooding increases willingness to pay for flood protection measures. Miceli et al. (2008) found a positive correlation between risk perception and disaster preparedness. Lindell and Hwang (2008) correlated risk perception positively with implementing mitigation measures and purchasing insurance. In addition to exposition, risk perception seems to be the main factor for the appropriate handling of flash floods (Knocke & Kolivras, 2007). A positive relationship between risk perception and mitigation behaviour was also found by Botzen and van den Bergh (2009), and Zaalberg, Midden, Meijnders, and McCalley (2009). The evaluation of an information campaign in Zurich found that the positive reflection of information and risk perception are the most influential factors for precautionary preparedness; and also showed that the campaign evaluated had a statistically significant influence on preparedness (Maidl & Buchecker, 2015). However, there was no proof that risk perception really leads to preparedness (Maidl & Buchecker, 2015).

Bubeck, Botzen, and Aerts (2012) concluded that the assumption that risk perception explains mitigation behaviour is unjustified because there were just weak or no relations between risk perception and mitigation measures in many studies such as Brilly and Polic (2005) or Bubeck, Botzen, Kreibich, and Aerts (2013). They explained their conclusion through the protection motivation theory (PMT) (Rogers, 1975). Protection motivation is determined by two constructs: threat appraisal and coping appraisal. The former can be interpreted as risk perception as it describes the perceived probability and perceived consequences of a threatening event. This combination of perceived probability and consequences is a typical definition of risk perception. It describes how people feel threatened by a hazard (Bubeck et al., 2012). “Coping appraisal” is an important determinant of protection behaviour (Grothmann & Reusswig, 2006). This construct comprises three components: perceived self-efficacy, perceived response efficacy, and perceived costs (Grothmann & Reusswig, 2006). Following Bubeck et al. (2012), the PMT can explain why risk perception is not positively correlated with mitigation behaviour in many studies. High risk perception can only result in mitigation behaviour when the “coping appraisal” is also high (Bubeck et al., 2012). A second reason for this is that people who implemented mitigation measures show lower risk perception, because they protected themselves. If high risk perception is not combined with high coping appraisal, behaviours such as avoidance and wishful thinking may manifest (Bubeck et al., 2013). While these behaviours are not able to protect people against monetary or physical damage, they may alleviate their negative emotions (Grothmann & Reusswig, 2006).

Some studies have highlighted the positive relationship between risk perception and mitigation behaviour. Grothmann and Reusswig (2006) claimed that after the accurate perception of risk, a coping appraisal may follow only if a certain threshold is reached. If this is true, risk perception can be a necessary condition for private protection. Thus, there is a need for further research to examine the extent to which risk perception and other factors determine mitigation behaviour (Maidl & Buchecker, 2015; Roder et al., 2019). Gray-Scholz et al. (2019) also highlighted the lack of research on the determinants of risk perception.

As risk perception is complex (Miceli et al., 2008) and involves cognitive aspects (like knowledge of backgrounds), experiential processing (i.e., affective evaluations and personal experience), socio-cultural factors (i.e., social norms), and socio-demographic aspects (van der Linden, 2015), the following section presents an overview of influencing factors as derived from the literature.

2.2 | Determinants of risk perception and mitigation behaviour

Risk perception and protective behaviour are two different constructs. Thus, the factors that affect them also differ. In empirical research, risk perception and the determinants are operationalised differently. Therefore, it is not always easy to compare the constructs. In Table A1, an overview of the literature with a focus on the significant determinants influencing risk perception is presented. It indicates that risk perception of natural hazards is often influenced by gender, age, education, location, knowledge, and experience. A similar overview of the determinants of mitigation behaviour is presented in Table A2. The data for the construction of these tables were not extracted through a structured approach. Therefore, the tables are not exhaustive. No study has examined the determinants of pluvial flooding. Thus, this study is particularly important. Both tables show that different studies have examined different variables or have operationalised the same variables differently, which makes it challenging to compare the results. For example, Botzen et al. (2009) examined the effect of the distance to the river on risk perception, while Kellens et al. (2011) examined whether the sea view had an effect on risk perception. The direction of the correlation is not always clear. For example, Botzen et al. (2009) found that younger people have a higher risk perception whereas Kellens et al. (2011) found that older people tend to have a higher risk perception. Another example for contradictory results is education. Liu et al. (2018) and Gray-Scholz et al. (2019) determined that higher education is connected with higher risk perception. However, Botzen et al. (2009) and Frondel et al. (2017) found evidence for the opposite. Another oft-mentioned determinant is experience of flooding. People who have experienced flooding have a higher risk perception than people who do not have personal experience (Kellens et al., 2011; Keller et al., 2006; Lindell & Hwang, 2008; Liu et al., 2018; van der Linden, 2015). The influence of experience on mitigation behaviour has been confirmed by Bubeck et al. (2013) and Osberghaus (2015).

Based on the literature reviewed, the main research objectives of this study are as follows:

1. To explore whether risk perception of pluvial flooding needs to be distinguished into personal and global risk perception;
2. To examine the degree of risk perception of pluvial flooding;
3. To identify the variables and their directions influencing risk perception of pluvial flooding; and
4. To investigate the relationship between public risk perception and the implementation of mitigation measures.

3 | METHODS

This section describes the two study areas in western Germany, namely Cologne and Essen (Section 3.1) and the methods used to conduct (Section 3.2) and analyse (Section 3.3) the telephone interviews in order to investigate the underlying processes of risk perception of pluvial flooding.

3.1 | Study area

Germany is located in the mid-altitudes and is thus, according to the IPCC Report, especially prone to an increase in heavy precipitation. The study area is located in the federal state of North Rhine-Westphalia, especially in the metropolitan region Rhine-Ruhr, where about 11 million inhabitants live. This region was selected for its high degree of urbanisation characterised by sealing and high asset values. The region also faces heavy damage when pluvial floods occur. The study was conducted in two neighbourhoods in two major cities, Cologne and Essen, within the metropolitan region. Cologne has about 1 million residents and is the biggest city in the metropolitan region. It is located along the river Rhine. Owing to its proximity to the Rhine, Cologne regularly faces fluvial floods. Within Cologne, the areas of Eil, Urbach, and Porz were chosen as they are located near a multifunctional retention area in which flood protection measures have been planned (Schwerdorf, Werker, & Waser, 2018). The study area has faced heavy precipitation events in the past (see Table 1). Since 2017, a hazard map for pluvial flooding in Cologne has been made available online for free.

Essen, a city with over 500,000 inhabitants and the region nearby are currently in a transition, moving from a former coal mining hotspot to a hub of post-industrial culture. The neighbourhood Altenessen-Süd was selected as the study area. There have been a few heavy precipitation events in that district in the recent past (see Table 1). Even if the city area borders River Ruhr in the south, the study area is far away from the next natural river. Therefore, fluvial floods are not as common as they are in Cologne. In contrast to Cologne, at the time of this study, there was no hazard map for pluvial floods in Essen. Despite the obvious differences, both cities are typical urban areas that face similar climatic conditions and the need to cope with changing precipitation conditions. Figure 1 shows the location of the study areas.

3.2 | Survey method

First, to measure risk perception, a questionnaire was developed (see Table A3). Risk perception is a latent variable and is thus not directly measurable (Krosnick, Judd, & Wittenbrink, 2005). Hence, it needs to be operationalised through the assessment of one or multiple statements (items) on a rating scale. The questionnaire design is based on surveys from related fields of research, as recommended by Kellens, Terpstra, and de Maeyer (2013). The surveys relied on for the design in this study were from: German Federal Statistical Office (1999), Zwick and Renn (2002), Plapp (2003), Terpstra, Gutteling, Geldof, and Kappe (2006), Martens, Erdwien, and Ramm (2008), Kellens et al. (2013), Osberghaus and Philiippi (2015) and German Federal Statistical Office (2016). The operationalisation of latent variables differs across studies and therefore the results can deviate (van der Linden, 2015). As this survey was conducted through computer-assisted telephone interviews (CATIs), the questionnaire was adapted to this mode. To ensure high quality survey results the checklist provided by Willis and Lessler (1999) was used.

As a short interview duration helps motivate participation and helps maintain concentration levels, the average interview duration was limited to 10 min. Therefore, some determinants of risk perception and mitigation reported in the literature, such as affects, social norms, and income, remain unaddressed in this survey.

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TABLE 1 Precipitation events with rainfall over 20 mm and return periods equal to or greater than 10 a

Essen (Altenessen-Süd)			Cologne (Eil, Urbach, Porz)		
Date	**Precipitation (mm)**	**Return period (a)**	**Date**	**Precipitation (mm)**	**Return period (a)**
May 30, 2016	35.6	10	July 19, 2017	56.7	100
October 7, 2009	53.0	10	September 4, 2016	30.7	20
July 3, 2009	44.6	30	August 10, 2015	42.9	15
			September 22, 2014	18.6	11
			June 20, 2013	37.8	30
			June 29, 2012	43.9	292
			August 17, 2010	33.5	19
			April 17, 2009	46.6	10

Note: Data sources: In Altenessen-Süd, data were based on two gauges form the Stadtwerke Essen AG. In Cologne, data provided by the StEB Köln from three gauges were used.

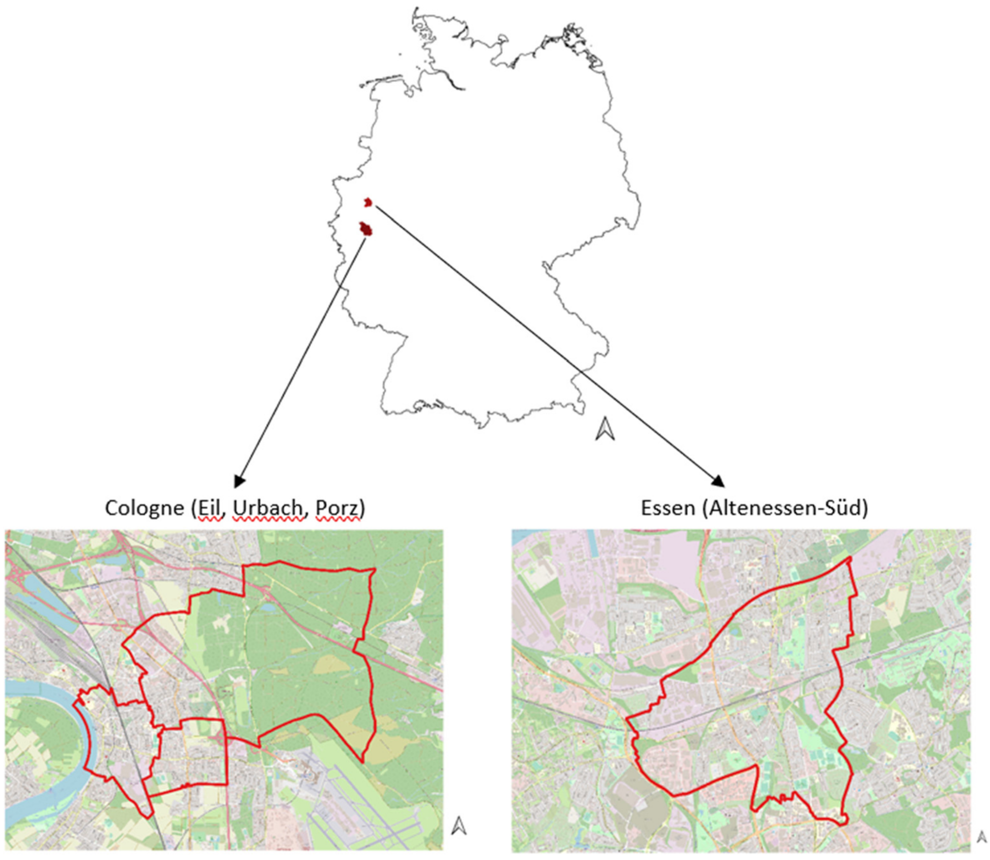

FIGURE 1 Location of the study areas. The background maps are based on OpenStreetMap data

Before the survey, two different pre-tests were conducted. First, face-to-face cognitive interviews framed by Schwarz and Oyserman (2001) and Lavrakas (2008) were used to make sure that the respondents interpreted the questions in the same way as the interviewer. Cognitive interviews examine, with the help of thinking aloud and probing techniques, the process a person undergoes while answering a question (Liebau, Schunter, Schurath, & Schwarz, 2019; Presser et al., 2004). Therefore cognitive interviews improve the quality of surveys and increase validity (Peterson, Peterson, & Powell, 2017; Willis & Artino, 2013). After the modification of the questionnaire based on inputs that emerged from the outcomes of the cognitive interviews, a quantitative pre-test with 40 respondents (10% of the envisaged number of interviews) was realised. The quantitative pre-test was conducted using CATI.

3.3 | Statistical analysis

To explore whether risk perception of pluvial flooding needs to be distinguished, principal component analysis (PCA) was relied on, by drawing from Zhang, Gao, Bi, and Yu (2014). PCA is a data reduction tool that clusters measured variables influenced by the same underlying psychological construct in a common homogeneous set (Zhang et al., 2014). Therefore, many items can be described by a few uncorrelated factors, also called principal components. PCA produces a predetermined number of factors whose interpretations are subjective (Zhang et al., 2014). The loadings of the initial items describe the influence that each item has on the construction of the principal component. Therefore, the loadings are a measure of the importance of an item in explaining a component. The higher the loading, the more that item contributes to the principal component. Averages of the items belonging to each principal component were calculated. For example, when the responses to three items belonging to one component are "strongly agree" (coding 1), "agree" (coding 2), and "partly agree, partly disagree" (coding 3), the average is 2. Based on these averages, a multiple linear regression analysis was conducted to identify the variables and their directions influencing risk perception of pluvial flooding. Risk perception was measured on a Likert scale. Whether the Likert scale is an ordinal or an interval scale is a subject of ongoing debate (Chyung, Roberts, Swanson, & Hankinson, 2017). In this article, it is assumed that the differences between the points on the scale are equal, therefore an interval scale was produced (Chyung et al., 2017; Wu & Leung, 2017), allowing for linear regression analysis.

The first model included all measured independent variables. A variable reduction approach, similar to Roder et al. (2019), was applied to identify the most important variables. *t*-Tests were used to assess the significance. The variable with the lowest *p*-value was removed, similar to Bubeck and Thieken (2018). The model was run again after each removal, until only the significant variables (*$p < .05$, **$p < .01$, ***$p < .001$) remained in the final model.

A logistic regression, with implementation of mitigation measures as a binary dependent variable, was conducted to investigate the relationship between public risk perception and the implementation of mitigation measures. As with the linear regression analysis, a step-by-step model selection was also conducted for the logistic regression analysis.

4 | RESULTS

This section presents the results of the survey that was conducted between May 2 and June 15, 2019. A total of 408 interviews were conducted: 204 each from Cologne and Essen. This survey only included people who used landline phones, which may result in a coverage error (Gabler & Häder, 2019), indicating an under- or overrepresentation of specific parts of the population when compared to the total population. Table 2 offers an overview of the distribution of socio-economic variables in the study areas and in the sample. For some variables like education, there are no data available for the total population in the study areas. The results show that the average age in the sample is about 20 years higher when compared to the total population. This may be because younger people are more likely to use mobile phones exclusively. Few people with a migrant background were included in the sample. Linguistic skills may have

TABLE 2 Characteristics of the study areas and the sample

	Total population				**Sample population**	
	Cologne			**Essen**	**Cologne**	**Essen**
	Eil	Porz	Urbach	Altenessen-Süd	Eil/Porz/Urbach	Altenessen-Süd
Population	9,200	14,900	12,600	27,122		
Percentage of women	51.9	51.9	51.5	49.7	48.5	59.3
Average age	43.1	42.8	44.8	40.5	66.6	63.6
Percentage of people with migrant backgrounds	42.6	51.8	41.9	41.3	6.9	8.3
Percentage of tenants					28.9	52.0
Low education level					6.9	3.9
Medium education level					34.8	47.6
High education level					58.3	48.5

Note: Data resources: City of Cologne (2017) and City of Essen (2018).

complicated participation in the survey. The sample is not representative of the total population in the study areas, but nevertheless provides valuable results for research.

4.1 | Principal component analysis

Four principal components were evaluated. Figure 2 shows the allocation of questionnaire items to the four principal components along with the highest standardised loadings. All items loading on component one are characterised by general perspectives, as they address the risk to the country. Therefore, the first component can be identified as global risk perception. The items loading on the third component focus on perceived threats and can thus be categorised as personal risk perception. The second main component describes a construct in which responsibility is seen in others, while in the fourth component, responsibility is attributed to the person him or herself.

4.2 | Relative response behaviour

The relative survey results for each item are presented in Figure 3. On average, 73% of the participants "strongly agree" or "agree" with the three statements indicating global risk perception. Thus, more than two-thirds of the participants have a high global risk perception. The items for personal risk perception are rated far lower. As many as 35.3% of the participants responded saying that they strongly agreed or agreed with the statement "heavy precipitation events are a threat to me, my property, and my belongings." On the other hand, 43.9% responded saying that they strongly agreed or agreed with the statement "I expect heavy precipitation events to occur in the next ten years at the house where I live." Only 25.5% expect to suffer personal damage from heavy precipitation in the next 10 years. On average, 34.9% responded to these three items for personal risk perception with either "strongly agree" or "agree," which, when compared to global risk perception showed a difference of 38.1%. It is also clear that responsibility for protection against pluvial floods

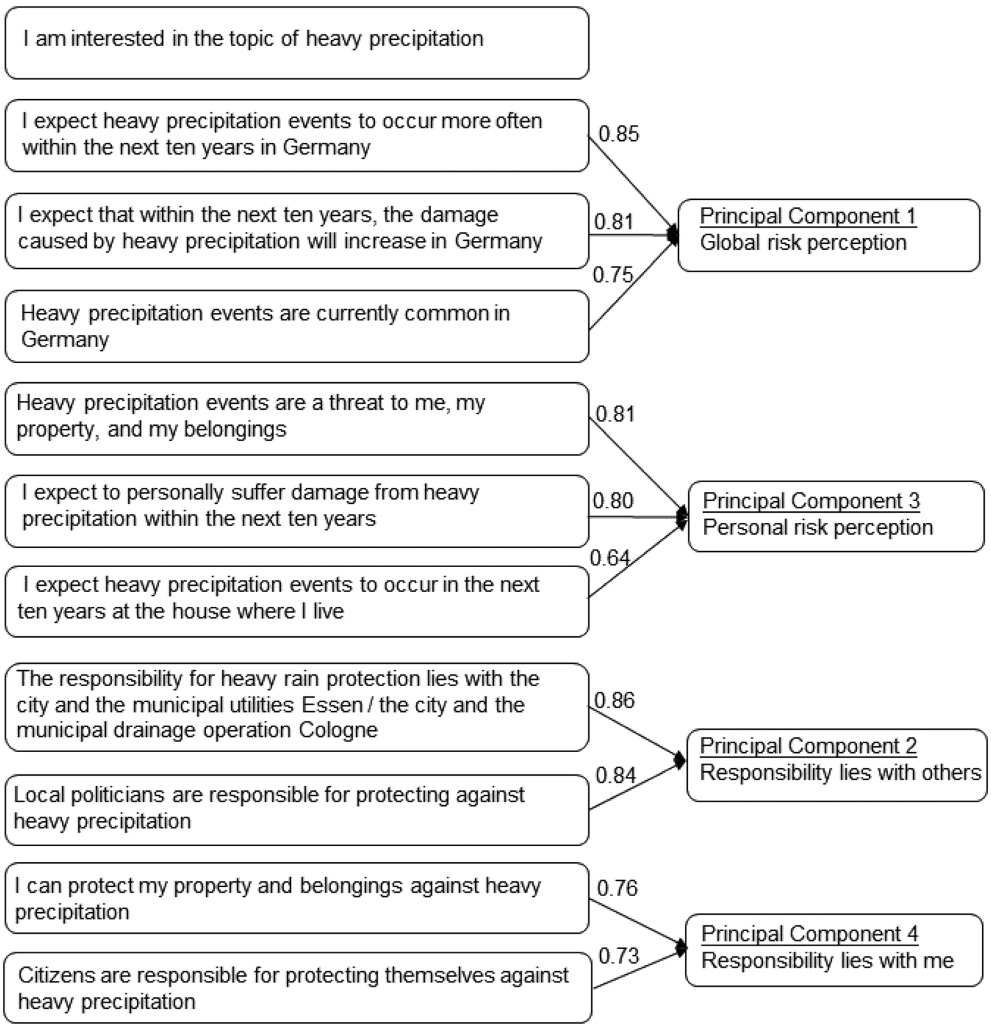

FIGURE 2 Allocation of items to principal components by showing the highest standardised loadings

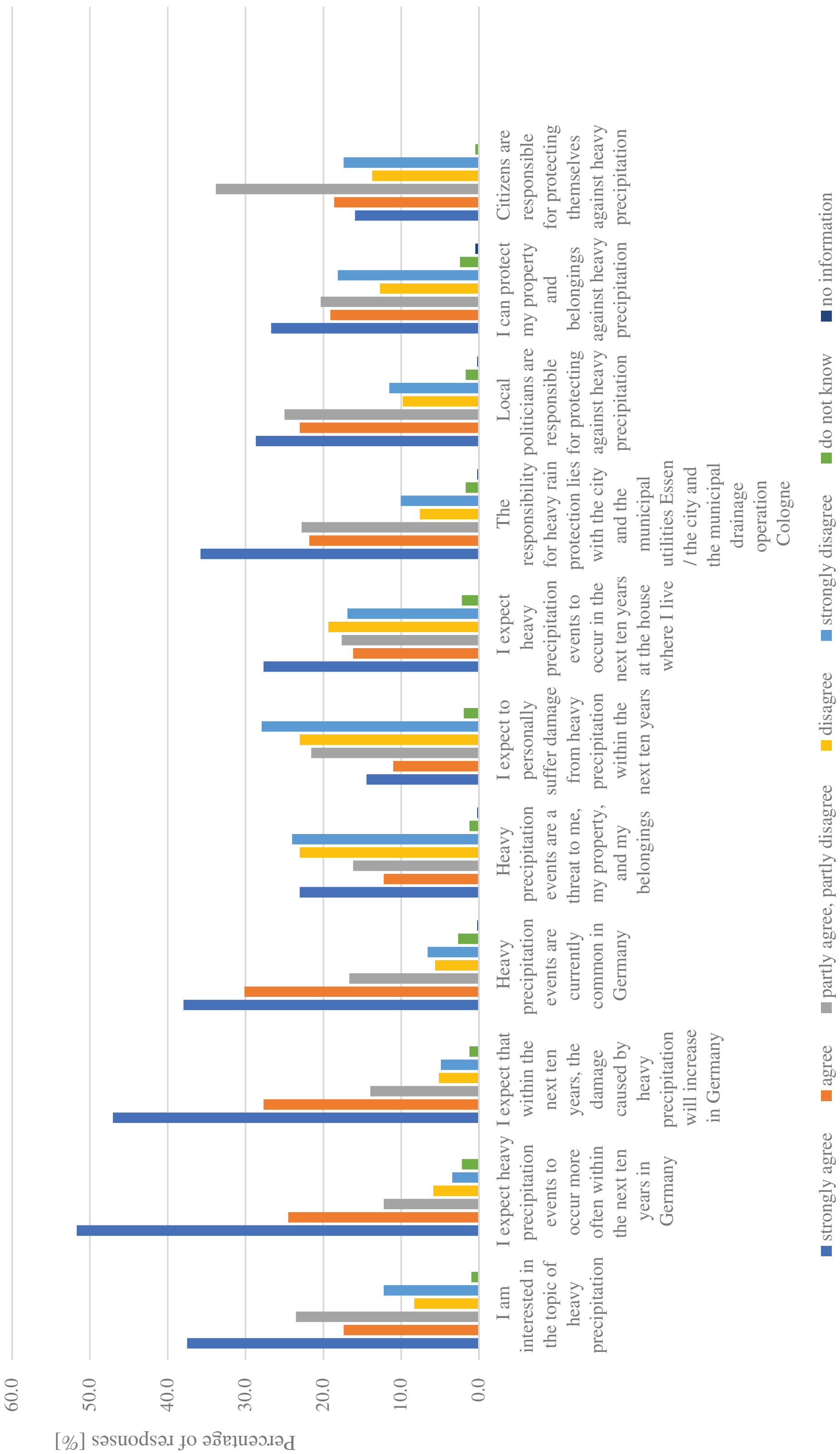

FIGURE 3 Relative response behaviour for the items analysed

was attributed to the municipal utilities (57.6% "strongly agree" or "agree") or local leadership (51.7% "strongly agree" or "agree"), rather than to the citizens themselves (45.8% and 34.6 "strongly agree" or "agree").

4.3 | Multiple linear regression analysis

To take the results of the PCA into account, separate regression models were built to differentiate between global and personal risk perception. Table 3 shows the significant results of both models for global and personal risk perception.

A detailed description of the variables is provided in Table A3. The only determinants that are significant in both models are interest and direct experience. Interest is positively related to both global and personal risk perception. People with high interest in the topic show higher risk perception. The relationship between risk perception and direct experience is negative. The results indicate that global and personal risk perception increases when people have experienced pluvial floods before. The place of living, which indicates whether the participants are from Cologne or Essen has no influence on risk perception. Table 3 shows that men exhibit lesser global risk perception than women. Further, people with higher knowledge show less global risk perception. Personal risk perception is influenced by age, as well. This relationship is negative and indicates that older people have higher levels of personal risk perception. People who do not

TABLE 3 Global and personal risk perception model results

Dependent variable	Global risk perception		Personal risk perception	
Independent variable	**Initial model**	**After step-by-step model selection**	**Initial model**	**After step-by-step model selection**
Gender	0.204*	0.207*	−0.117	
Age	0.05		−0.094	−0.128**
Migrant background	−0.188		0.147	
Children under the age of 14 years	0.007		−0.010	
Tenants	−0.083		0.099	
Existence of a cellar for storage	−0.257		0.031	
Existence of a cellar for living	−0.280		−0.135	
Live on the ground floor	0.049		0.108	
Live on the first floor	0.102		−0.065	
Live on the second floor or higher	−0.103		0.111	
Years living in the same place	−0.044		0.049	
Years living in the same house	−0.048		−0.020	
Place of living	0.024		−0.141	
Implementation of mitigation measures	0.085		−0.280**	−0.327***
Interest	0.201***	0.231***	0.244***	0.251***
Knowledge	0.190	0.230*	0.051	
Subjective knowledge	0.057		0.033	
Direct experience	−0.372***	−0.383***	−0.149	−0.197*
Indirect experience	−0.150		−0.129	
Personal risk perception	0.278***	0.275***		
Global risk perception			0.267***	0.270***
Responsibility lies with others/PC2	0.050		0.087*	0.086*
Responsibility lies with me/PC4	0.004		0.031	
Low education level	0.257		−0.524**	−0.589**
High education level	0.118		0.041	
Adjusted R^2	.266	.255	.295	.303
F-statistic	7.155	28.91	8.1	26.28

$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

believe that others, like public institutions or politics, are responsible for flood protection show lower levels of risk perception. Those with low education levels exhibit high personal risk perception levels, while those who implemented mitigation measures had higher personal risk perception.

4.4 | Logistic regression analysis

As the implementation of private protection measures is an important step towards adaptation, the determinants influencing mitigation behaviour are investigated using logistic regression. The results of the logistic regression are presented in Table 4.

Logistic regression coefficients with positive signs indicate that an increase in the independent variable increases the likelihood of implementing protection measures. Otherwise, a negative sign decreases the likelihood of mitigation behaviour. Tenants are less likely to conduct protection measures when compared to owners. People living in the ground or first floor are more likely to implement protection measures. Further, the results reveal that the likelihood of implementing measures is higher when people live longer in the same place. Next to these factors, knowledge seems to play an important role in mitigation. People with factual knowledge are more likely to implement measures. Similarly, people with low levels of subjective knowledge are less likely to adapt. People with low education levels are less likely to implement measures. Another determinant is personal risk perception. People with low levels of personal risk perception are less likely to protect themselves. Therefore, people with higher personal risk perception, are more likely to implement protection measures.

TABLE 4 Results of the logistic regression model for mitigation behaviour

Dependent variable	Implementation of mitigation measures	
	Initial model	After stepwise model selection
Gender	0.173	
Age	0.160	
Migrant background	0.765	
Children under the age of 14 years	−0.314	
Tenants	−0.904**	−0.837**
Existence of a cellar for storage	0.476	
Existence of a cellar for living	−0.319	
Live in the ground floor	0.573*	0.529*
Live in the first floor	0.585*	0.513*
Live in the second floor or higher	−0.069	
Years living in the same place	0.360*	0.230*
Years living in the same house	−0.091	
Place of living	−0.072	
Interest	−0.208	
Knowledge	0.535	0.566*
Subjective knowledge	−0.435**	−0.558***
Direct experience	0.307	
Indirect experience	0.316	
Personal risk perception	−0.440**	−0.484***
Global risk perception	0.126	
Responsibility lies with others/PC2	0.071	
Responsibility lies with me/PC4	−0.247	
Low education level	−1.782**	−1.649**
High education level	−0.217	
CoxSnell	0.257	0.226
Nagelkerke	0.343	0.302
McFadden	0.215	0.186

*$p < .05$. **$p < .01$. ***$p < .001$.

5 | DISCUSSION

Owing to the expected increase in heavy precipitation, there is a need for adaptation and protection. To promote mitigation behaviour, this study investigates how public risk perception and the implementation of mitigation measures can be influenced.

5.1 | The distinction between global and personal risk perception

PCA showed that global and personal risk perception are two different constructs, which is in line with Sjoberg (2000) and van der Linden (2015). Therefore, future studies clearly need to distinguish between these constructs. This distinction is especially important because individual constructs may be influenced by other factors, and their impact on mitigation behaviour may be different. For example, if an information campaign is to be conducted to increase personal risk perception and to promote the implementation of protection measures on the ground, it is important to address the factors influencing personal risk perception and mitigation, and not those that are specific to global risk perception. Thus, a differentiated consideration is necessary.

5.2 | Personal risk perception of pluvial flooding is low

The results show that the levels of global and personal risk perception are different. People are aware that heavy precipitation is a hazard in Germany, but most of them do not perceive it as a risk for themselves. Uzzell (2000) and Schultz et al. (2014) found that people are more concerned about problems at a global rather than at a local level. The results presented here confirm these findings. As the actual risk exposure of the participants could not be assessed, low levels of risk perception may have also resulted from the fact that the participants had not faced the risk of pluvial flooding. This may also influence the determinants of risk perception and mitigation behaviour. Additional reasons for the low level of personal risk perception can be the high degree of trust in technologies and the improved level of flood protection over time (Gray-Scholz et al., 2019). Walker and Burningham (2011) and Armas et al. (2015) concluded that poorer and less educated people are more exposed to flood risk. As data on the education level and income were neither available nor collected, these influences cannot be evaluated here. In Germany, about a quarter of all homeowners incorrectly believe that they are insured against flooding (Osberghaus, 2015), which may also lead personal risk perception to remain low.

5.3 | Global and personal risk perception of pluvial floods are influenced by different variables

The multiple linear regression analysis explained up to 26% of the variance of global risk perception and around 30% of the personal risk perception. van der Linden (2015) provided an overview of risk perception studies that have indicated a fluctuation in the variance ranging from 22 to 55%, while van der Linden (2015) himself explained 68% of the variance in climate change risk perception. Through a socio-psychological model of flood damage prevention, Grothmann and Reusswig (2006) assessed 26–45% of the explained variance as good to very good based on standards in research on psychology. Given these ranges of explained variance, the results can be assessed as acceptable.

Interest is significant in both models. Therefore, raising public interest in heavy precipitation can be seen as a necessary step to increase risk perception. Maidl and Buchecker (2015) showed that flood preparedness depends on individual risk perception and seeking out information, which is assumed to be closely linked to interest. The results also showed that global and personal risk perception increases when people have experienced pluvial floods before. Bradfort et al. (2012), Keller et al. (2006), Kellens et al. (2011), van der Linden (2015), Lindell and Hwang (2008), Liu et al. (2018), Roder et al. (2019), Salvati et al. (2014) also arrived at similar findings. The other risk component was a significant estimator. The results did not indicate whether there is a chronological sequence in the matter that global risk perception is a requirement for personal risk perception. However, a high global risk perception is an important factor for high personal risk perception.

The results showed that men have less global risk perception, which is in line with Kellens et al. (2011), van der Linden (2015), Frondel et al. (2017), and Liu et al. (2018). People with knowledge show less global risk perception. This finding is not in line with the literature. For example, Botzen et al. (2009) and van der Linden (2015) found that increased knowledge is ongoing with higher risk perception, but neither study focused on pluvial flooding. The variable knowledge was operationalised here by one item that can also result in uncertainties.

Personal risk perception is influenced by age. Older people have higher levels of personal risk perception, which is in line with Knocke and Kolivras (2007) and Kellens et al. (2011) and in contrast to Botzen et al. (2009) and Salvati et al. (2014). In contrast to Liu et al. (2018) and Gray-Scholz et al. (2019) the results of this study showed that low education levels are associated with high levels of personal risk perception. Similar results were found in Botzen et al. (2009) and Frondel et al. (2017). The study area in Cologne suffered more heavy precipitation events than the one in Essen in the recent past. A hazard map had been published in Cologne, but there was no such map in Essen at the time of this study. There was no difference in risk perception concerning pluvial flooding between the two study areas. As the actual risk could not be assessed, there may be no difference because all participants could be similarly exposed to the risk.

This study shows that personal and global risk perceptions are influenced in different ways. This has an impact on risk communication as other population groups need to be addressed in order to increase personal risk perception.

5.4 | A high public risk perception promotes the implementation of mitigation measures

Adequate precautions are particularly important to protect against future pluvial flooding, as just 34% of the people felt prepared for floods in the future (Bradford et al., 2012). The results revealed that tenants are less likely to conduct measures, which is in line with Grothmann and Reusswig (2006), who argued that tenants are often not authorised to conduct construction measures. Variables describing the location have an impact on mitigation behaviour. People living in the ground or first floor are more vulnerable to pluvial flooding. This may indicate that people who are more exposed to risks are better prepared. Similar but not directly transferable results were drawn by Miceli et al. (2008) and Botzen and van den Bergh (2009) who found that respondents living close to a main river are more likely to undertake mitigation measures.

The results presented here show that people with higher levels of subjective and factual knowledge are more likely to implement measures. Maidl and Buchecker (2015) arrived at similar findings for subjective knowledge, whereas Botzen and van den Bergh (2009) found that homeowners with little knowledge of flood threats are more likely to buy protection. People with low education levels are less likely to implement measures, which is in line with Botzen and van den Bergh (2009). No statement can be made based on this survey as data on other factors like income were not collected, despite having an influence on these relationships. There may be other influences. For example, Bubeck et al. (2013) and Osberghaus (2015) found one between income and the implementation of measures. In addition to the determinants mentioned above, personal risk perception has an influence on mitigation behaviour as well. People with high risk perception are more likely to implement protection measures. Lindell and Hwang (2008), Miceli et al. (2008), Botzen and van den Bergh (2009), and Zaalberg et al. (2009) also found a positive relationship between risk perception and preparedness, whereas Bradford et al. (2012) found none. While this is true for personal risk perception, global risk perception has no effect on mitigation behaviour. The results indicate that accurate personal risk perception is important for mitigation behaviour, which is in line with Salvati et al. (2014).

6 | CONCLUSION

Pluvial flooding is an increasingly significant issue in many parts of Europe. Owing to the complexity and uncertainties involved in forecasting heavy precipitation risk, precautionary mitigation measures are necessary for effective protection, instead of emergency measures. Different from previous studies on risk perception, this study is specifically focused on pluvial floods and explains that effective risk prevention needs risk perception. However, there is a need to distinguish between personal and global risk perception in research and risk communication practice, as they are two different constructs. Logistical regression proved that the implementation of mitigation measures is influenced by home ownership, location, education, knowledge and personal risk perception. Global risk perception has no influence on mitigation behaviour. While it was found to be high in this survey, there is a huge lack of personal risk perception around pluvial flooding. The low personal risk perception is a problem in view of the expected increase in heavy precipitation. Previous research has focused a lot on fluvial flooding, but pluvial floods are different from these events as they are invisible hazards that can occur away from water bodies and people are not aware of the extent of their personal risk. Therefore, there is a great need for future research on risk perception of heavy precipitation, on increasing personal risk perception, and on implementing mitigation measures for pluvial flood protection. This study can be seen as a starting point for further research. The determinants identified for personal risk perception and mitigation must be confirmed by future research. Future studies should include the actual pluvial flood risk (e.g., through hazard maps) in their research. Nevertheless, risk communication should take up these determinants to derive appropriate pluvial flood risk management strategies.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX

TABLE A1 Overview of significant estimators for risk perception in the literature

Explanatory variables	Reference	Dependent variable	Description of the effect
Gender	van der Linden (2015)	Climate change	Women show higher risk perception
	Liu et al. (2018)	Fluvial flooding	Women show higher risk perception
	Frondel et al. (2017)	Fluvial flooding	Women show higher risk perception
	Kellens et al. (2011)	Coastal flooding	Women show higher risk perception
	Botzen et al. (2009)	Expected flood damage	Females expect to suffer less damage than males
Age	Liu et al. (2018)	Fluvial flooding	The age group between 18 and 44 has the highest risk perception, followed by the group over 60 years of age; the under 18 years and finally the age group 45–60 years.
	Kellens et al. (2011)	Coastal flooding	Older individuals show higher risk perception levels
	Botzen et al. (2009)	Probability of fluvial flooding	Older individuals have a lower perceived flood probability
	Botzen et al. (2009)	Expected flood damage	Older individuals expect to suffer less flood damage
Education	Liu et al. (2018)	Fluvial flooding	Higher education is associated with higher risk perception
	Frondel et al. (2017)	Fluvial flooding	Higher education is associated with lower risk perception
	Botzen et al. (2009)	Probability of fluvial flooding	Individuals with a higher education levels have a lower perceived flood probability
	Botzen et al. (2009)	Expected flood damage	Individuals with a higher education level also expect to suffer less flood damage
	Gray-Scholz et al. (2019)	Fluvial flooding	Those having a bachelor's degree are more likely to perceive risk than those without
Income	Liu et al. (2018)	Fluvial flooding	People with high income show less risk perception
	Frondel et al. (2017)	Fluvial flooding	People with high income show less risk perception
Employment (in work, retired	Hopkins and Warburton (2015)	Perception of likelihood of local fluvial flooding in the next 10 years	Those in work perceive lower risks compared to retired people
	Hopkins and Warburton (2015)	Fluvial flooding	Those in work perceive lower risks compared to retired people
Ownership	Kellens et al. (2011)	Coastal flooding	No difference between tenants and owners in terms of risk perception was observed
Owning a cellar	Kellens et al. (2011)	Coastal flooding	No significant effect on risk perception
Presets of children in a household	Liu et al. (2018)	Fluvial flooding	Households with children under 12 years show higher risk perception than households without children
	Hopkins and Warburton (2015)	Fluvial flooding	No significant effect
Amount of people living in a household	Liu et al. (2018)	Fluvial flooding	The more people live in a household the less risk they perceive

TABLE A1 (Continued)

Explanatory variables	Reference	Dependent variable	Description of the effect
Years at residence	Gray-Scholz et al. (2019)	Fluvial flooding	The longer participants lived at their residence, the higher the perceived risk
Distance to main river	Liu et al. (2018)	Fluvial flooding	Individuals who live near the river show higher risk perception
	Botzen et al. (2009)	Probability of fluvial flooding	The further the individual is situated from a river, the lower is the perceived flood probability
	Botzen et al. (2009)	Expected flood damage	Individuals who live far from a main river expect to suffer lower flood damage
	Hopkins and Warburton (2015)	Perception of likelihood of local fluvial flooding in the next 10 years	People with higher risk perception live closer to the river
Seaview	Kellens et al. (2011)	Coastal flooding	No significant influence
Elevation relative to water level	Botzen et al. (2009)	Probability of fluvial flooding	The higher the elevation of the area relative to the potential water level, the lower are individual risk perceptions
	Botzen et al. (2009)	Expected flood damage	Individuals who live in areas that are relatively high expect to suffer lower flood damage
	Gray-Scholz et al. (2019)	Fluvial flooding	Those who live 3–6 m above the river are more likely to perceive risk than those who live 7 m or more above the rive
No dike protection	Botzen et al. (2009)	Probability of fluvial flooding	Individuals living in floodplains that are not protected by dikes have a lower perceived probability of flooding than individuals who live in protected areas
Living in the ground floor	Kellens et al. (2011)	Coastal flooding	No significant influence
Living in a low risk area	Frondel et al. (2017)	Fluvial flooding	Living in a flood-prone area (low risk) promotes the perception of future flood risks
Living in a high risk area	Frondel et al. (2017)	Fluvial flooding	Living in a flood-prone area (high risk) promotes the perception of future flood risks
Receiving risk information	Keller et al. (2006)	Fluvial flooding	Participants who received risk information concerning a longer time period (e.g., 30 years) perceived more danger compared with participants who received risk information for 1 year
Cause-knowledge	Botzen et al. (2009)	Probability of fluvial flooding	A lack of knowledge about the causes of flooding results in a lower perceived flood probability
	Botzen et al. (2009)	Expected flood damage	Expected flood damage is lower for individuals who do not know the causes of flooding
	van der Linden (2015)	Climate change	Increased knowledge is associated with higher risk perception
Impact-knowledge	van der Linden (2015)	Climate change	Increased knowledge is associated with higher risk perception
Response-knowledge	van der Linden (2015)	Climate change	Increased knowledge is associated with higher risk perception

(Continues)

TABLE A1 (Continued)

Explanatory variables	Reference	Dependent variable	Description of the effect
Total number of floods recalled	Hopkins and Warburton (2015)	Fluvial flooding	The more floods were recalled, the higher risk perception
Personal experience	van der Linden (2015)	Climate change	People with personal experience with extreme weather are associated with higher risk perception
	Liu et al. (2018)	Fluvial flooding	People with personal experience are associated with higher risk perception
	Frondel et al. (2017)	Fluvial flooding	People with personal experience are associated with higher risk perception
	Kellens et al. (2011)	Coastal flooding	People with personal experience are associated with higher risk perception
	Botzen et al. (2009)	Probability of fluvial flooding	Previous experience with flooding and evacuation is related to a higher perceived flood probability.
	Botzen et al. (2009)	Expected flood damage	Individuals who have experienced a flood and evacuation expect to suffer lower flood damage than individuals who did not have such an experience.
Involvement in clean-up following flash flooding	Hopkins and Warburton (2015)	Fluvial flooding	Those involved in the clean-up, show lower risk perception
Damages	Frondel et al. (2017)	Fluvial flooding	Those who suffered damages show higher risk perception
Descriptive social norms	van der Linden (2015)	Climate change	The more individuals perceive that others are taking action to help combat the risk of climate change the higher their risk perceptions of climate change
Prescriptive social norms	van der Linden (2015)	Climate change	The more people perceive taking measures is expected of them, the higher their risk perceptions of climate change
Number of neighbours known	Gray-Scholz et al. (2019)	Fluvial flooding	The more neighbours are known, the higher the risk perception
Attached to neighbourhood	Gray-Scholz et al. (2019)	Fluvial flooding	Those who feel strongly attached to the neighbourhood perceive lower risk
Biospheric value orientations	van der Linden (2015)	Climate change	Individuals with stronger biospheric value orientations also tend to view climate change as a greater risk
Affect	van der Linden (2015)	Climate change	Negative affective evaluations are associated with higher risk perception
	Keller et al. (2006)	Fluvial flooding	Negative affects result in higher risk perception
Actual flood risk estimated	Kellens et al. (2011)	Coastal flooding	Risk perception is high, when experts estimate an event
Political party identification	van der Linden (2015)	Climate change	Liberal political views are associated with higher risk perception

TABLE A2 Overview of significant estimators for mitigation behaviour in the literature

Explanatory variables	Reference	Dependent variable	Description of the effect
Gender	Osberghaus (2015)	Fluvial flooding	Women are more likely to conduct mitigation measures
Age	Bubeck et al. (2013)	Fluvial flooding	Older individuals are more likely to conduct mitigation measures
	Osberghaus (2015)	Fluvial flooding	Older individuals are more likely to conduct mitigation measures
	Miceli et al. (2008)	Flood and resulting landslide	Older individuals are more likely to conduct mitigation measures
	Soetanto, Mullins, and Achour (2017)	Perception of social responsibility for flood protection	Older individuals are likely to be more socially responsible for flood protection
Education	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	More educated is associated with more willingness to buy sandbags
Income	Bubeck et al. (2013)	Fluvial flooding	Households with higher income are more likely to implement measures
	Osberghaus (2015)	Fluvial flooding	Households with higher income are more likely to implement measures
Living in an urban area	Bubeck et al. (2013)	Fluvial flooding	Living in urban areas is associated with a lower likelihood to implement measures
	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	Homeowners in rural areas are willing to undertake mitigation is almost one third larger than respondents in urban areas
Living in a protected area	Bubeck et al. (2013)	Fluvial flooding	Living in a protected area is associated with a higher likelihood to implement measures
Elevation house and barrier is lower than water level	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	Homeowners who live in an area that is too low for effective mitigation with water barriers are less likely to undertake the mitigation measure
Closeness to water courses	Miceli et al. (2008)	Flood (and resulting landslide)	Respondents with a home close to a water course are more likely to undertake the mitigation measure
	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	Respondents with a home close to a main river are more likely to undertake the mitigation measure
Cost–benefit evaluation of protection measures	Maidl and Buchecker (2015)	Intention for private mitigation measures	Less belief that investments in protective measures were worth the effort resulted in less intent to implement such measures
	Maidl and Buchecker (2015)	Preparedness (already adopted measures)	Less belief that investments in protective measures were worth the effort resulted in less intent to implement such measures
Response efficacy	Bubeck et al. (2013)	Fluvial flooding	The more people believe in high response efficacy, the more likely are they to implement measures
Self-efficacy	Bubeck et al. (2013)	Fluvial flooding	The more people believe in high self-efficacy, the more likely are they to implement measures
Experience	Bubeck et al. (2013)	Fluvial flooding	Depending on the mitigation measures, experience can be positive or negative associated with mitigation behaviour
	Soetanto et al. (2017)	Perception of social responsibility for flood protection	Individuals with previous experience are likely to be more socially responsible for flood protection
Damage experience	Osberghaus (2015)	Fluvial flooding	The propensity to mitigate flood damage increases with damage experience

(Continues)

TABLE A2 (Continued)

Explanatory variables	Reference	Dependent variable	Description of the effect
Participation in civil Defence activities	Miceli et al. (2008)	Flood and resulting landslide	Individuals who participated in civil Defence activities are more likely to implement measures
Professional or voluntary background in natural hazards	Maidl and Buchecker (2015)	Preparedness (already adopted measures)	Respondents who had been professionally or voluntarily involved in dealing with natural hazards were more likely to have implemented measures
Knowledge about floods	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	Homeowners who have little knowledge about the flood threat are more likely to buy protection
Self-assessed knowledge	Maidl and Buchecker (2015)	Preparedness (already adopted measures)	Those who reported being well informed had implemented more protective measures than others
Evaluation (of the information material	Maidl and Buchecker (2015)	Intention for private mitigation measures	The better the information material is evaluated, the more intention to implement measures
Information need	Maidl and Buchecker (2015)	Intention for private mitigation measures	The higher the information need, the higher the intention to implement measures
Perceived insurance coverage	Osberghaus (2015)	Fluvial flooding	Insured households are more likely to implement measures than uninsured
Expectation of government relief of homeowners	Osberghaus (2015)	Fluvial flooding	When government reliefs are expected, mitigation is higher for homeowners
Government compensation is available	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	Probability of buying sandbags to mitigate flood damage is smaller if the government provides partly compensation of flood damage
Government is perceived as responsible	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	People who perceive that the government is responsible for flood protection, are less likely to undertake mitigation measures
General risk aversion	Maidl and Buchecker (2015)	Preparedness (already adopted measures)	People with a more general risk aversion, show more preparedness
Avoidance	Bubeck et al. (2013)	Fluvial flooding	Avoidance is associated with a lower likelihood to implement measures
Wishful thinking	Bubeck et al. (2013)	Fluvial flooding	Wishful thinking is associated with a lower likelihood to implement measures
Postponement	Bubeck et al. (2013)	Fluvial flooding	Postponement is associated with a lower likelihood to implement measures
Social environment	Bubeck et al. (2013)	Fluvial flooding	The behaviour of neighbours and friends significantly influences the decision to protect oneself! When they protect themselves, people also protect themselves
Risk perception	Miceli et al. (2008)	Flood (and resulting landslide)	High risk perception is associated with higher preparedness
Perceived probability	Bubeck et al. (2013)	Fluvial flooding	When the perceived probability is high, people tend to mitigation behaviour
Perceived consequence	Bubeck et al. (2013)	Fluvial flooding	When the perceived consequences are high, people tend to mitigation behaviour
Personal damage expectation	Osberghaus (2015)	Fluvial flooding	The propensity to mitigate flood damage increases with expectations
Negative effects of climate change	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	The probability to undertake mitigation in larger, if negative effects of climate change are perceived
Climate change causes higher flood risk	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	The probability to undertake mitigation in larger, if it is expected that climate change will increase flood risk

TABLE A2 (Continued)

Explanatory variables	Reference	Dependent variable	Description of the effect
Lower flood risk than average resident	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	If homeowners perceive their flood risk as being lower than an average resident, it is less likely that they will undertake mitigation
Zero expected return period flood	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	The larger the respondent perceives the probability of a flood in his or her living area the larger is the probability that the respondent will undertake the mitigation measure
Expected return period flood	Botzen and van den Bergh (2009)	WTB sandbags for fluvial flood protection	The larger the respondent perceives the probability of a flood in his or her living area the larger is the probability that the respondent will undertake the mitigation measure
Risk awareness	Maidl and Buchecker (2015)	Intention for private mitigation measures	A higher level of risk awareness leads to more intention for private mitigation

Abbreviation: WTB, willingness to buy.

TABLE A3 The questionnaire. The following telephone interview deals with the topic of heavy precipitation. By heavy precipitation, we mean an extreme rain event, in which roads and buildings can also be flooded. You will often be asked during the interview to rate your consent to certain statements. Please use a scale of 1–5, where 1 is fully agree; 2 is partly agree; 3 means partly agree, partly disagree; 4 stands for partly disagree and 5 is fully disagree (This scale was used for the items interest, global risk perception, personal risk perception, responsibility lies with others and responsibility lies with me). Please rate the following statements

Variable	Operationalisation
Interest	I am interested in the topic of heavy precipitation
Global risk perception	Heavy precipitation events are currently common in Germany I expect heavy precipitation events to occur more often within the next 10 years in Germany I expect that within the next 10 years, the damage caused by heavy precipitation will increase in Germany
Personal risk perception	I expect heavy precipitation events to occur in the next 10 years at the house where I live I expect to personally suffer damage from heavy precipitation within the next 10 years Heavy precipitation events are a threat to me, my property and my belongings
Responsibility lies with others	Local politicians are responsible for protecting against heavy precipitation The responsibility for heavy rain protection lies with the city and the municipal utilities Essen/the city and the municipal drainage operation Cologne
Responsibility lies with me	Citizens are responsible for protecting themselves against heavy precipitation I can protect my property and belongings against heavy precipitation
Implementation of mitigation measure	Have you implemented measures to protect against pluvial flooding at home? (0: No; 1: Yes)
Subjective knowledge	How would you assess your own knowledge of heavy precipitation events and their possible risks? ("very good"; "good"; "medium"; "low"; "very low")
Knowledge	In what time of year do heavy precipitation events typically occur most often? (0: Winter; 0: Spring; 1: Summer; 0: Autumn; 0: Equally distributed over all seasons)
Direct experience	Have you ever personally experienced a heavy precipitation event in Germany? (0: No; 1: Yes)
Indirect experience	Have you ever had a person close to you, such as family or friends, who suffered financial or health damage caused by pluvial flooding? (0: No; 1: Yes)
Age	Please tell me your year of birth.
Gender	The interviewer assigns the gender. (0: Women; 1: Men)
Migrant background	Were you and your two parents born with German nationality? (0: No; 1: Yes)
	What is the highest general education degree?

(Continues)

TABLE A3 (Continued)

Variable	Operationalisation
Low education level/high education level	What is your highest vocational qualification or university degree?
Children under the age of 14 years	How many children or adolescents under the age of 14 live permanently in your household?
Tenants	Are you a tenant or owner of the living spaces you live in? (0: Owner; 1: Tenant)
Existence of a cellar for living	Which floor, or which floors, do you inhabit? (0: Not selected; 1: Selected)
Life in the ground floor	
Life in the first floor,	
Life in the second floor or higher	
Existence of a cellar for storage	Do you have a cellar that you use as a storage room?
Years living at the same place	How many years have you lived in this district?
Years living in the same house	How long have you been living in the house or apartment you are currently living in?
Place of living	Assigned by the interviewer

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