Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

Natural Hazards and Earth System Sciences
Open Access
Discussions

Flash floods versus river floods – a comparison of psychological impacts and implications for precautionary behaviour

Jonas Laudan[1], Gert Zöller[2], Annegret H. Thieken[1]

[1]University of Potsdam, Institute of Earth and Environmental Science, Karl-Liebknecht-Strasse 24-25, 14476 Potsdam, Germany
[2]University of Potsdam, Institute of Mathematics, Karl-Liebknecht-Strasse 24-25, 14476 Potsdam, Germany

Correspondence to: Jonas Laudan (jlaudan@uni-potsdam.de)

Abstract. River floods are among the most damaging natural disasters that occur frequently in Germany, causing high economic losses and affecting many residents. In 2016, several Southern German municipalities were hit by flash floods after heavy rainfalls which have been unexpectedly severe and led to total economic losses of EUR 2.6 bn. This study investigates the psychological impacts of river floods and compares them to the impacts of flash floods, using computer-aided telephone interviews that were conducted among flood affected households 8 to 9 months in the aftermath of the events. By applying Bayesian statistics and negative binomial regressions, the suitability of psychological indicators to predict the precaution motivation of individuals is analysed. The results show that not the particular flood type, but rather the severity and local impact of the event is crucial for different and potentially negative impacts on mental health. Moreover, it is revealed that the derived psychological indicators “coping appraisal”, “threat appraisal”, “burden” and “evasion” only show a limited usefulness for predictions of the individual precaution motivation, which is displayed by a generally low explanation power and non-significant results. Further research is needed to better address established psychological assessment procedures and to focus on alternative data sources regarding floods and the connected precaution motivation of affected residents.

1 Introduction

In June 2013, eleven years after the severe 2002 flood event in Germany which caused an overall loss of EUR 11.6 billion (Thieken et al., 2006a), the country was challenged again by strong river flooding, affecting Saxony, Saxony-Anhalt, Brandenburg and Bavaria. Considering country-wide gauge data and peak discharges, the 2013 flood event can be described as even more severe than the costly river flood in 2002, yet causing less monetary losses of EUR 6 to 8 billion (Thieken et al., 2016a). Again in May and June 2016, heavy rainfall in Central Europe lead to severe surface water runoff, pluvial flooding and flash floods in Southern Germany, especially affecting municipalities in Bavaria and Baden-Wurttemberg and resulting in overall losses of EUR 2.6 billion (Munich Re, 2017).

The flash flood events in 2016 have been remarkably different from the river flood events of 2002 and 2013 in terms of processes, dynamics, duration and the type of induced damage on buildings (Laudan et al., 2017). In contrast to river floods, flash floods are defined as rapid flood events, typically occurring in steep, small catchments shortly after heavy rainfall with no prolonged lead time. The strong surface runoff, transport of large debris (also called debris flows) and the rapidness of the event identify flash floods as an unpredictable and potentially life threatening hazard (Gaume et al., 2009; Borga et al., 2014).

Flash floods are typically associated to regions with a pronounced orography. Therefore, the occurrence of severe flash floods in Germany outside alpine regions in 2016 can be described as unexpected, but yet highlights the topicality, considering the relatively high monetary losses of EUR 2.6 billion (Munich Re, 2017), damage and unfortunately eleven fatalities (four in Baden-Wurttemberg and seven in Bavaria along Simbach am Inn). However, there is a lack of studies that compare impacts of and preparedness to flash and river floods, especially with regard to protection motivation and the influencing factors.

Flood protection in Germany has a long history with several regulations and ongoing programs. Besides national initiatives such as the “Nationales Hochwasserschutzprogramm” (NHWSP) and a national framework legislation regulation, the Federal Water Act of 2009 and its updates, the management of water bodies and flood management are in Germany in principle regulated on state level. Superior regulations such as the European Floods Directive (2007/60/EC) set up framework conditions and thus had to be incorporated into the national legislation by 2010 (e.g. Thieken et al., 2016b). After the severe river flood events in 2002 and 2013, the flood risk management in Germany and the relevant legislation was revised while the focus was shifted to a more integrated flood management, considering structural as well as non-structural flood protection measures (Kienzler et al., 2015; Thieken et al., 2016b; Laudan et al., 2017). In this context, the German Act on precautionary flood protection in 2005 (Gesetz zur Verbesserung des vorbeugenden Hochwasserschutzes) requires residents in flood prone areas to take private precautionary actions within the individual bounds of possibility. As an overall result, regions which have been affected by recurrent river floods are now well managed, having tailored flood risk management plans in place, including private precaution. Still, despite the devastating events in 2016, flash floods and strong surface water runoff do not yet count as significant national risks and are therefore not considered in recent flood risk management. As a result, little is known about private precaution measures concerning flash floods in Germany.

In general, private precaution measures can significantly reduce damage to households and thus play a significant role in comprehensive flood management (Kreibich et al., 2005; Thieken et al., 2008; Merz et al., 2010). The state of private precaution can further be integrated in flood loss estimation models such as the flood loss estimation model (FLEMO) which results in more reliable damage estimations on different scales and therefore contributes to robust risk and vulnerability estimations (Thieken et al., 2008). Hence, understanding and predicting private precaution is essential for future planning and flood risk management not only with regard to river floods, but also with respect to flash floods and rapid surface runoff as an unfamiliar and potentially more frequent hazard in future. Here, the individual protective behaviour it is not yet fully understood, particularly if people are affected by different flood types. Questions must be raised whether affected individuals carry out private protective measures, to what extent they implement measures and what are motivating as well as demotivating factors. In this context, the protection motivation theory (PMT) (Rogers, 1975) has been frequently used as a psychological model to explain the risk-reducing/protective behaviour of affected individuals by analysing the influencing factors on coping strategies and potential positive or negative responses. Main findings suggest that besides socio-economic factors such as income and homeownership, psychological factors – not only in terms of risk perception, but also avoidance, wishful thinking, and the self-rated coping appraisal – can influence protective responses (Grothmann and Reusswig, 2006; Bubeck et al., 2012). Further, empirical evidence from Germany and France indicates that social norms and networks can be considered as important for better coping abilities after river floods (Bubeck et al., 2017).

Besides structural/financial losses to buildings and contents, severe river floods and flash floods are expected to have strong impacts on the psychology of affected residents. For instance, Mason et al. (2010) reveal that certain criteria for psychiatric disorders such as the post-traumatic stress disorder (PTSD) as well as high scores of anxiety and depression are met within one quarter to one third of flood-affected study participants among different communities in the UK. On the other hand, an increased exposure to floods may also be connected to negative mental health effects due to the disruption of daily routines, financial loss and evacuation stress, especially if social support by family and friends is missing (Bei et al., 2013). Besides negative responses to flood exposure, coping strategies also comprise protective behaviour which is dependent on personal knowledge, multiple socio-economic and psychological factors as well as individual character traits.

Previous studies have further shown that the motivation to protect oneself from flooding cannot be solely explained by risk information, the individual risk perception and/or socio-economic variables (e.g. Baan and Klijn, 2004; Bubeck et al., 2012; Morss et al., 2016). This suggests that certain psychological characteristics may have an influence on the individual flood protection motivation and may vary with regard to different flood types. Still, few studies consider individual psychology in flood preparedness decisions. Hence, the aim of this work is the identification of psychological impact patterns with regard to differences among individuals affected by either flash floods or river floods and the related protective behaviour. Accordingly, the following hypotheses were raised:

H1: Flash floods, in comparison to riverine floods, show a different psychological impact on affected people in which negative effects such as stress and feelings of being helpless are more pronounced, since flash floods are more dynamic and thus are a bigger threat for life.

H2: Negative psychological impacts are connected to a lower probability for precaution because negative feelings hamper the individual energy and self-confidence as well as the overall motivation to implement precaution measures.

H3: Identified psychological indicators are suitable for explaining precautionary behaviour because certain psychological characteristics are distinctly connected to the protection motivation.

The first hypothesis is tested by comparing psychological characteristics of people which are affected by different flood types and flood strengths. Thus, groups of similar psychological manifestations (psychological indicators) are created first, secondly the distributions are analysed by applying Kruskal-Wallis rank sum test and Dunn's Test. To answer the second and third hypotheses, a "planned precaution" indicator is created first, then the Bayesian approach and negative binomial regressions are applied and resulting probability distributions of conditional variable dependences as well as regression coefficients are evaluated. The Bayesian approach has been frequently used in psychology (e.g. Wetzels et al., 2011) and offers advantages due to the assessment of uncertainties which in general facilitates scientific studies that rely on relatively small datasets. Accordingly, this study considers Bayesian inference as a method to assess variable relations that are based on conditional probabilities and related uncertainties. Preliminary assumptions such as e.g. linear variable coherences are therefore not required. Furthermore, this approach evaluates the specific variable applicability for a potential prediction of a response variable, in this case the "planned precaution" indicator. As an additional advantage, the method enables prior knowledge to be taken into account, for example in following studies. However, to assess the potential direction of the predictor and response variable coherence, the Bayesian approach is supported by a negative binomial regression model. The implementation of all methods is addressed in the next section.

In summary it can be said that gaining insights into the psychological impacts of river floods and flash floods and the related precautionary behaviour is important for the following reasons:

- A good understanding of psychology and precaution motivation might result in an indicator which estimates the probability for a specific precaution level and could be integrated into flood loss modelling.
- The outcome might be beneficial for targeted information campaigns, supporting affected individuals while strengthening their motivation to implement useful private flood precaution measures (e.g. Morss et al., 2016).
- A better understanding of this connection might help to improve future vulnerability and risk estimations and may facilitate the use of alternative data sources to estimate the state of individual precaution. For example, by gathering data from different sources (online surveys, social media, communication platforms), psychological profiles could be created which could then be used to predict the individual precaution motivation in areas which have not been flooded recently.

The results of this study are presented and discussed in section 3. A further outlook on this topic is given in the conclusion.

2 Data and methods

In this section, the used data is presented and the applied data preparation steps as well as the methodology are explained.

2.1 Description of the river flood and flash flood datasets

The individual datasets consist of computer-aided telephone interviews which were conducted among residents affected by either the river flood of 2013 or the heavy rainfalls and flash floods of 2016. Within this study, the river flood of 2013 and the flash floods of 2016 are considered for comparison, since the two events were very different in terms of the flood dynamics. Still, both events were relevant on the national scale. Finally, the time lag between the particular event and the implementation of the survey is similar, i.e. around nine months after the flood event in both cases. The surveys were equally designed and initially focused on flood damage estimation of affected households and the assessment of damage driving factors. Hence, the biggest part comprised questions about socio-economic characteristics (e.g. age, gender, social status, income, education, homeownership), characteristics of the housing unit (e.g. number of stories or floor space, construction year, number of persons per unit, housing area) and different dimensions of private precaution (e.g. if certain single protection measures are already implemented or planned to be implemented in the near future). Yet, various psychological characteristics addressing the protection motivation theory (threat appraisal, coping appraisal, avoidance, memories of the event, optimism and further questions about the mental well-being) were recorded as well which are – combined with questions about the private precaution – used as the database for this study. An exhaustive list of the analysed psychological variables is given in Table 1. All psychological variable ratings were adjusted and equalised to follow a self-reported rating scheme of 1 (not once/I do not agree/very low) to 6(7) (few times a day/I fully agree/very high), which ensures their comparability. In this context, four out of nine variable ratings were reversed (see Table 1).

In total, 16 private precaution measures were analysed. They comprise information about flood protection and flood risk as well as information within seminars, insurance, networking, flood-adapted story usage, flood-adapted interiors, relocating heat and electricity, securing heat and oil tanks, improving flood safety, installing backflow prevention, installing water barriers, having no noxious liquids in the cellar, installing pumps, having generators available and anticipatory planning of supplies. For each private precaution measure, individuals were asked to mark them as "implemented before the event", "implemented after the event", "will be implemented in near future", and "not planned to be implemented".

The dataset of the 2013 river flood comprises 1652 responses in total, the 2016 flash flood 601 cases with an equal distribution of age and gender. This study considers only homeowners for all consecutive analyses, since homeowners – unlike tenants – suffer from flood damage on the building itself to a greater extent and also hold a greater flexibility to take potential protective actions (e.g. Grothmann and Reusswig, 2006). The proportion of homeowners within the river flood and flash flood dataset is 82% and 86% respectively, lowering the valid responses to 1366 (2013-flood) and 517 (2016-floods).

(Table 1)

2.2 Separation of weak and strong flash floods

In May and June 2016, several places in Germany were hit by flash floods or surface water flooding that differed, however, in strengths and dynamics as well as with regard to the perceived severity and the resulting damage. In many cases, the heavy rainfall only led to an increased surface water runoff in the vicinity of affected buildings and/or the water entering the basement. Yet, in some municipalities, entire villages (such as Braunsbach and Simbach am Inn) were suffering from enormous flash floods and debris flows with strong flow velocities and a very high suspension of debris – even large rocks – vigorously damaging buildings and infrastructure (Laudan et al., 2017). Therefore, it is crucial to separate severe and weaker flash flood events before comparing the psychological impacts among each other and to the 2013 river flood.

The approach to assess the flash flood strength comprises quantitative and qualitative methods and makes use of rainfall data and press articles which allow an estimation of inundation depths and flow velocities. Here, the hourly rainfall data was downloaded from the "Deutscher Wetterdienst" (DWD) for the days with known heavy rainfalls in May and June 2016. According to the definitions of the DWD, a severe weather alert is given for a particular region if the local rainfall is expected to exceed 25 mm per hour. Thus, if the rainfall exceeded 25 mm per hour at a gauging station, the region was marked to be potentially affected by a strong flash flood. In this context, only the municipalities and cities which were covered by the survey were considered. This was possible since the approximate address of each affected household was provided. In a next step, an online literature and press article review was conducted for each affected city to find a basis for the flash flood strength classification. This procedure can be described as a rather qualitative approach. According to the reported damage, impressions of photos and the level of media attention as well as associated rainfall in the area at the particular time, the surveyed households were classified to weak flash floods (if a low impact was noticed), to medium flash floods (if the impact was considered to between low and high) or strong flash floods (if a high flood impact could be assumed). For the analysis, only weak and strong flash floods among homeowners were considered. The count of cases for weak flash floods is n=293 and for strong flash floods n=116.

2.3 Defining main psychological indicators

To answer the first hypothesis, four main psychological indicators were considered within this study. The indicators are combined according to literature such as Creamer et al. (2003), Grothmann and Reusswig (2006) and Bubeck et al. (2012) and were further chosen for reasons of comparability as well as to minimise correlations among the single psychological variables. Subsequently, the four main indicators are defined as "threat appraisal", "coping appraisal", "burden" and "evasion" and are defined as follows.

Threat appraisal and coping appraisal are considered within the protection motivation theory (PMT) and represent two distinct psychological indicators that explain the risk reducing behaviour of individuals when they are faced with a threat.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

Threat appraisal consists of the perceived probability of being affected again by a severe event and the perceived impact of such a future event. Coping appraisal comprises self-efficacy, response efficacy and response cost which describes the self-rated ability to deal with a threatening event, the perceived efficiency of a protective measure and the cost of a protective measure in terms of money and effort, respectively (Grothmann and Reusswig, 2006; Bubeck et al., 2012).

The indicators burden and evasion were developed by following the general procedure in psychology surveys to combine expressive psychological items (e.g. Ware and Sherbourne, 1992; Kroenke et al., 2001) and taking high correlations among psychological variables into account. In this regard, Creamer et al. (2003) for example confirm the usefulness of the Impact of Event Scale - Revised (IES-R), a widely used item-based survey that measures traumatic stress, to assess symptoms of the post-traumatic stress disorder (PTSD) in male Vietnam veterans. However, they also find that the main factors of the IES-R, i.e. “hyperarousal”, “avoidance” and “intrusion” do not provide a good account of the data due to correlations among single items and suggest the use of less or diversely composed factors/indicators. Accordingly, the creation of the indicators burden and evasion required pre-processing of the data, correlation tests and the evaluation of preliminary results. Thus the preliminary results are shortly presented in this section.

The correlations among the single psychological variables were assessed using ordination plots (principle component analysis) and correlation tables (Spearman’s Rho, corrected after Holm (1979), done in R Studio 1.1.414, using the package “psych”). According to the tests, subjective stress which is still felt at the time of the interview and the frequency of remembrance of the event show a strong correlation of 0.54 (complete cases n=279) for weak flash floods, 0.46 (complete cases n=115) for strong flash floods and 0.50 (complete cases n=1152) for river floods with a p value of <0.05 in all cases. Further, avoidance and fatalistic thoughts reveal a correlation of 0.23 (complete cases n=275, p<0.05) for weak flash floods, 0.29 (complete cases n=113, p=0.34) for strong flash floods and 0.18 (complete cases n=1242, p<0.05) for river floods. Here, the low significance in the case of strong flash floods may be due to the small dataset of 113 complete pairwise observations. See the appendix for the correlation tables (Figures A, B and C).

Based on these results, the subjective stress still felt at the time of the interview and the frequency of remembrance was combined to the indicator burden, while avoidance and fatalistic thoughts constitute the indicator evasion. In this context, burden describes the degree of negative psychological load that is still apparent at the time of interview and evasion resembles avoidant behaviour, e.g. trying to supress the experience.

The distributions of threat appraisal, coping appraisal, burden and evasion were further analysed using the non-parametric Kruskal-Wallis rank sum test and Dunn’s Test which may be applied if the data follows an ordinal scale and does not fulfil assumptions of normality and equality of variance. By using these tests, significant differences in psychological impacts can be revealed which were predominantly caused by weak flash floods, strong flash floods and river floods.

2.4 Planned precaution indicator

To apply the Bayesian statistics and regression models, an indicator for the planned precaution had to be first derived from the flash flood and river flood datasets which is used as response variable in further analysis. In this context, the planned

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

precaution indicator was created according to existing studies on private flood mitigation in Germany. Here, Kreibich et al. (2005) compared the flood damage mitigation potential of different private precaution measures among German households that were affected by the severe river flood in 2002. The study revealed that flood adapted use, a better interior fitting and the relocation of heat and electrical utilities lower the damage ratio of buildings by 46%, 53% and 36% respectively (Kreibich et al., 2005). Thus, the indicator of already implemented precaution measures and the indicator capturing planned precaution, which is used in this study, consist of single precaution measures that are weighted according to their damage mitigation potential. For further details on the effectiveness of private precaution measures and additional findings see Kreibich et al. (2005), Thieken et al. (2005) and Büchele et al. (2006).

For the planned precaution indicator, the weighted score of measures which were planned to be implemented directly or shortly after the flood event (see section 2.1.) is summed up and related to the already implemented or non-applicable measures. The data is disregarded if the count of already implemented or non-applicable measures is equal or exceeds the half of the overall measure count of 16 measures (>= 8), since it is hardly possible to obtain meaningful results for the "planned precaution" in such cases, i.e. this value already reflects a very good level of private precaution. Hereby, it is also ensured that there is no bias towards low precaution motivation in the subsequent analysis caused by an already high precaution level, since it can be assumed that people who already implemented many protection measures have a lower planned precaution score. The procedure results in indicator scores ranging from 0 to 48, which are further reclassified into values ranging from 0 (low planned precaution) to 8 (high planned precaution). In the results and discussion section (section 3.2.), this indicator is compared to the state of precaution, i.e. the weighted score of already implemented precaution measures.

2.5 The Bayesian approach

Bayesian statistics can be applied to calculate probability distributions from a limited set of observations and to quantify related uncertainties. The statistical model takes prior knowledge into account (prior) and assesses the likelihood to observe the data, if specific model parameters are given (likelihood). This results in a probability density for the model parameters, conditioned on specific data (posterior) (Puga et al., 2015), where the Bayes theorem is (1):

$$P(model\ parameter|data) \sim P(data|model\ parameter) * P_0(model\ parameter) \quad (1)$$

The likelihood (L) is based on the binomial distribution for each response variable (planned precaution) and predictor variable value. The binomial distribution was chosen due to the fact that it provides probability estimations solely about the occurrence and non-occurrence of two variable values, as given in the dataset. It resembles a basic probabilistic approach to scientific questions without making preliminary assumptions (e.g. linear variable coherence). The binomial distribution is thus defined as (2):

$$P(k \mid p, n) = \binom{n}{k} * p^k * (1-p)^{n-k} \quad (2)$$

- n = count of specific predictor variable value
- k = count of specific response variable value, given n

Here, the estimated parameter (p) resembles the specific combination probability of two variable values. More precisely, it indicates the likeliness to observe a specific response variable value, if a specific predictor variable value is given. To our knowledge, no similar studies exist which are based on comparable datasets and equal psychological indicators, thus, no prior knowledge is taken into account in this study. This means that the prior, which influences the estimation of the parameter (p), was chosen to be uniformly distributed on (0, 1). Eventually, the Bayesian analysis results in posterior distributions that indicate the conditional probability density of the occurrence of two variable manifestations.

2.6 Average posterior distributions, Jensen-Shannon divergence and regression tests

In order to test the second and third hypotheses, the psychological indicators as well as the single psychological variables (see Table 1) were analysed with regard to their coherence to the planned precaution indicator, using the Bayesian approach, the Jenson-Shannon divergence and a negative binomial regression model. Both, the psychological indicators and the single variables were separately analysed to reveal differences between the general procedure in psychology to combine similar items/variables and studying all variables separately.

First, the weighted arithmetic mean of all posterior distributions (resulting from the Bayesian analysis, see section 2.5.) was calculated for each indicator and single variable, to reveal variable connections to the planned precaution indicator while excluding all non-existent combinations (Figure 1). The weighted posterior combinations allow for the assessment of likely probability distributions at once, giving ideas about the data structure and variability. In a next step, a weighted arithmetic mean posterior is calculated by randomising the respective variable while considering its individual distribution to describe the random occurrence of predictor and response variable. This step is necessary to obtain the particular reference posterior shape, which is exclusively influenced by the distribution of the predictor and response variable. In other words, if e.g. the response variable is not equally distributed, but heavily skewed to low values, these values are overrepresented in any weighted conditional probability calculation of two variables, even if the predictor variable is completely independent. Taking this into account, the difference of each weighted arithmetic mean posterior to the respective reference posterior was measured using a variation of the Kullback-Leibler divergence, i.e. the Jensen-Shannon divergence (JSD). The JSD is defined by (3):

$$JSD(P,R) = H\big(0.5 * (P+R)\big) - 0.5\big(H(P) + H(R)\big) \tag{3}$$

Where the Shannon-Entropy is defined by (4):

$$H(p) = -\sum_i p(i) \log\big(p(i)\big) \tag{4}$$

The divergence represents the degree of mutual information between both analysed variables and the resulting information gain, if one variable is explained by the other. This resembles the strength of variable connection and thus the overall applicability for predictions. The divergence is presented within a variable ranking.

(Figure 1)

Complementary to the Bayesian approach (i.e. the combined posterior distributions and divergence), negative binomial regressions were performed for each flood type, using the planned precaution indicator as response variable and the psychological indicators as well as the single psychological variables as predictors. Since the posterior distributions and divergence computations are solely based on probabilities, information gain and prediction applicability can be assessed, yet the direction of coherence with the response variable is not given. Thus it is supported by a negative binomial regression model which indicates significant positive or negative coherences of variables with the "planned precaution" indicator. The negative binomial regression was chosen due to the fact that the "planned precaution" indicator consists of ordinal discrete (count) values which are restricted between 1 and 8 and follow an overdispersed Poisson distribution (tested in R 1.1.414, using the packages "logspline" and "fitdistrplus").

3 Results and discussion

In this section, the differences in the distribution of the psychological indicators are presented and discussed first. In a next step, the planned precaution indicator is presented before the indicators and single psychological variables are analysed by evaluating the posterior distributions, the JSD and regression coefficients. Subsequently, the hypotheses are discussed and answered at the end of this section.

3.1 Psychological indicator distributions

Figure 2 illustrates the distributions of the four psychological indicators, i.e. coping appraisal, threat appraisal, burden and evasion, and also includes the Dunn's Test results.

(Figure 2)

Regarding coping appraisal (Figure 2, top left), the indicator distributions and Dunn's Test reveal significant differences between strong flash floods, river floods and weak flash floods. People affected by strong flash floods show generally lower ratings than people who suffered from strong flash floods or river floods while weak flash floods seem to be easier to handle in general. Still, most of the respondents reported medium coping appraisal ratings (Figure 2, top left).

The results indicate that people who were affected by strong and rapid flood events feel generally less able to cope with the situation and the implementation of protective measures, respectively. Although the effects are not strongly pronounced, a significant difference to weaker flash floods becomes apparent which might be due to the different (potential) flood impacts. A similar finding is revealed when comparing the difference between strong flash floods and river floods, yet the results are not significant. Although it has not been tested whether a lack of protection information strategies or other effects lead to a lower coping appraisal for strong flash floods in general, the effects could also be explained by the fact that people do not believe in a high efficiency of precaution measures in case of strong flash floods.

Concerning threat appraisal, the significant lower ratings of people affected by strong flash floods are remarkable, since it could be assumed that severe and damaging events lead to stronger feelings of threat in the first place (Figure 2, top right). Yet, these results could be explained by the fact that people which were affected by strong flash floods believe similar events to be very unlikely to happen again in near future, resulting in lower feelings of threat. Still, research has shown that there may be increase of severe flash floods in regions which were formerly not perceived as flash flood-prone, highlighting the importance of targeted information campaigns in that regard. Weak flash floods and river floods show a relatively similar distribution (not significantly distinct from each other) with a peak at medium threat appraisal ratings and a peak at the highest threat appraisal rating. This might be due to the weaker nature of the flash flood event and the higher perceived probability to be affected by a similar event again. With regard to river floods, a number of people in Germany have been affected more than three times within a relatively short period between 2002 and 2013, which might also contribute to a pronounced feeling of threat in residents who have been affected by river floods. This is in line with Mason et al. (2010), who find that the fear of reoccurrence of a flood event and anxiety is increased with repeated experience of damaging events.

The ratings of burden are significantly lower for people affected by weak flash floods, which indicates a lower psychological load and feelings of stress (Figure 2, bottom left). The distributions of strong flash floods and river floods are on the other hand shifted to higher ratings of burden. This clearly illustrates the connection between the “severity” of an event and the resulting negative psychological impacts, which is in line with Mason et al. (2010) and Bei et al. (2013), who report that a greater impact in terms of daily routine disruption, financial loss and evacuation is associated with significantly worse effects on mental health. In contrast to the “severity” of an event, the type of the event (flash flood or river flood) does not seem to have an effect on burden, since strong flash floods and river floods do not display any significant distribution differences (Figure 2, bottom left).

Similarly, the indicator evasion shows a significant difference in the distributions only with regard to weak flash floods (Figure 2, bottom right). This could be explained by the same effect that weak events or events leading to less severe impacts in general result in less pronounced feelings of avoidance and fatalism. Here, evasion especially differs between people affected by weak flash floods and river floods which also might be due to the frequent river floods in Germany and their severity which could lead to evasive behaviour of repeatedly affected residents. In fact, evasive behaviour can be described as a particular strategy to cope with severe events, enabling affected individuals to emotionally distance themselves from oppressive situations, as described by Mason et al. (2010).

3.2 Precaution indicators

Since the "planned precaution" indicator is used as response variable within all further analyses its distribution will be presented first in this section. Further, the planned precaution is compared to the already implemented precaution (Figure 3).

(Figure 3)

By evaluating the distributions of already implemented precaution measures (Figure 3, left side) and planned precaution (Figure 3, right side) it becomes apparent that people who have been affected by river floods show slightly higher scores of already implemented precaution measures. Regarding weak and strong flash floods, the score of already implemented precaution measures is considerably low while it can be noticed that the planned precaution scores are relatively low for all flood types. Especially in the case of river floods, affected people reveal a low motivation for (further) precaution in future. This result might also reflect a certain demotivation for precaution of residents who have been affected several times by river floods, i.e. by the river floods of 2002, 2005, 2006, 2010, 2011 and again 2013 which could be due to avoidant and fatalistic thoughts.

3.3 Posterior distributions and regressions of the psychological indicators

In general, the posterior distributions and regression results are based on a low number of data points, especially in the case of weak and strong flash floods (see Table 2, N). Yet, the results indicate certain positive and negative connections of the psychological indicators to the planned precaution indicator.

(Figure 4)

The weighted arithmetic means of all posterior distributions reveal in general a wide range of likely probabilities for the conditional dependence of variable ratings. In the case of weak flash floods for example, this means that if a single person who is affected by a weak flash flood is selected and surveyed, 52 per cent coherence of burden and 7 per cent coherence of coping appraisal with the planned precaution is most likely to be observed. For threat appraisal and evasion, the likely coherences are 10 and 19 per cent, respectively (Figure 4, top left). Other posterior peaks are however visible, yet less likely. As mentioned in section 2.6., the posterior shapes are greatly influenced by the distribution of the predictor and response variables. Since the planned precaution indicator is Poisson-distributed with the highest value counts among the lowest ratings, similar posterior shapes can be found in all cases with peaks around 10% and 50%. Yet, considering the reference posterior for burden (Figure 4, top left), the highest JSD is revealed for burden, respectively (Figure 5). The JSD for coping appraisal, threat appraisal and evasion however is low for weak flash floods. Additionally, the regression results indicate a significant positive relationship of burden and the planned precaution for weak flash floods (Table 2). It can be concluded that, if anything, burden is the most significant and useful indicator to predict the planned precaution among all indicators. Here, stronger feelings of burden seem to result in a higher precaution motivation. This result is in line with Lindell et al. (2009), who find that often thinking and talking about a hazardous event (earthquakes in that case) is positively correlated with the intention to adapt to the hazard. Our results indicate that this might also be the case for flooding.

The posterior peaks of strong flash floods are less pronounced which is due to the small dataset of 76 observations (Figure 4, top right & Table 2). In this case, a pattern is observable in which again burden and evasion show distributions slightly shifted to higher probabilities. Yet, the most likely coherence of the psychological indicators and the planned precaution is between 14% and 22% for strong flash floods. Regarding the JSD, Evasion reveals a certain information gain when describing the planned precaution, yet the effect is relatively weak (Figure 5). Simultaneously, evasion does not show any significant linear relationship with the planned precaution (Table 2). Thus, a distinct nonlinear pattern among the variables can be expected with regard to this dataset. All other indicators show almost no divergence and no information gain. According to the regression results, burden reveals a slightly negative coherence in this case, yet, the significance level is only between 0.1 and 0.05. In general, the results of the strong flash flood analysis should be interpreted with caution due to the low number of observations.

Concerning river floods, all psychological indicators show a peak around 50, up to 60 per cent and a relatively similar posterior shape that is caused by the distribution of the planned precaution indicator (Figure 4, bottom). In the case of burden, a posterior peak at 69 per cent is recognizable, which is remarkably different from the reference posterior shape. Accordingly, the JSD reveals a pronounced information gain for burden, while coping appraisal, threat appraisal and evasion reveal weak divergences (Figure 5). Yet, the regression results reveal only slight positive and negative coherences for the significant variables burden and threat appraisal (Table 2). These facts speak for a distinct, assumingly nonlinear coherence pattern for burden and the planned precaution, while the other psychological indicators show no significant information gain. However, similar to weak flash floods, stronger feelings of burden seem to result a higher protection motivation, which is again in line with Lindell et al. (2009).

(Figure 5)

(Table 2)

3.4. Rankings and regressions of single psychological variables

Figure 6 shows the JSD of the single psychological variables for weak flash floods, strong flash floods and river floods, indicating the information gain with regard to the planned precaution. In contrast to most of the other variables, the high divergence for “often thinking of the event” is remarkable for weak flash floods and river floods. Only for river floods, a relatively high JSD can be seen with regard to “response efficacy”, “response cost” and “fatalism”. Compared to Figure 5, it has to be concluded that variables which make up the indicators usually do not show an equal JSD. This is especially true for "often thinking of the event" and "stress still today", which constitute burden. Here, "often thinking of the event" seems to be decisive for high values of burden. In the case of evasion for strong flash floods, however, a combination of the respective variables fatalism and avoidance leads to a higher information gain. The variables that constitute threat appraisal, namely "fear of severe effects again" and "believe in being affected again" do not show any information gain, (Figure 6), which is also reflected in Figure 5.

(Figure 6)

Further, the regression results of the single variables indicate almost no significant relationships with the planned precaution indicator (Table 3). Regarding weak river floods, "often thinking of the event" is significantly connected to a higher planned precaution while for strong flash floods, "fatalism" reveals a significant negative connection. In the case of river floods, no variables are significant (Table 3).

(Table 3)

When comparing the analysis of the psychological indicators and the single variables, it can be summarised that a combination of items, as it is common practice in psychology, does not lead to more consistent and meaningful results in this case which is mainly reflected by similar JSDs. Moreover, the regression models of the single variables (Table 3) reveal a higher explanation power (R^2), especially in the case of weak flash floods, highlighting the importance of particular single psychological items. So the question remains, which method is the most suitable to combine variables. In this study, only few psychological items/variables were available while surveys to assess mental health comprise various indicators with up to 22 items (e.g. Ware and Sherbourne, 1992; Bei et al., 2013). By combining items, the inconsistencies among reported answers can be lowered and the predictive validity of indicators can be raised, facilitating the creation of psychological profiles (Ware and Sherbourne, 1992; Creamer et al., 2003). The analysis in this study follows this idea and indicates a certain importance of basic psychological indicators or variables for the motivation to implement precaution measures in future. However, the surveys which are used in this study primarily focus on direct damage and explanatory variables (see Thieken et al., 2017) and hence only comprise few significant questions which do not necessarily follow the established scheme of psychological surveys such as for example the 36-Item Short Form Survey (SF36), which is widely used to monitor the quality of life among patients. It has to be noted that more meaningful outcomes may be produced by more standardised questions and surveys. Within follow-up studies that rely on surveys, adjusting and adding questions should be considered for better psychological assessments.

3.4 Discussion of the hypotheses

H1: Flash floods, in comparison to riverine floods, show a different psychological impact on affected people in which negative effects such as stress and feelings of being helpless are more pronounced, since flash floods are more dynamic and thus are a bigger threat for life.

According to Figure 2, not the flood type, but the perceived strength/severity of the flood induces negative psychological effects. Among strong flash floods and river floods, no significant difference in stress becomes apparent except for threat appraisal where the distribution of strong flash floods is based on a relatively small dataset of 76 records (Figure 2, top right). Yet, this difference could be explained by the fact that the perceived threat of a strong flash flood event is lower, especially due to the severity and type of the event itself. Affected people perceive a strong flash flood event as less likely than people who have been repeatedly affected by river floods. Thus, future disaster risk management in Germany may also focus on the threat perception of affected residents and promote information campaigns in flash flood prone regions, especially if evidence from different sources suggests an increase in severe flash flood events. However, since all remaining burdensome and negative psychological effects vary with regard to the flood severity and do not significantly vary among different flood types, the first hypothesis must be rejected.

H2: Negative psychological impacts are connected to a lower probability for precaution because negative feelings hamper the individual energy and self-confidence as well as the overall motivation to implement precaution measures.

A high level of burden increases the protection motivation instead of affecting it negatively (Figure 5 & Table 2). Except this effect, no strong connections between strong psychological impacts and planned precaution were found. This may be explained by two reasons. Firstly, the assessment methods of psychological items as well as the items themselves do not follow established psychological assessment routines or surveys, presumably decreasing the data consistency and accuracy. Secondly, because of the relatively small datasets especially regarding flash floods, subtle effects on precautionary behaviour that are caused by psychological aspects may be superimposed by incidental effects. However, it is revealed that the indicator burden and, from a general point of view, thinking often of the event as well as the subjective stress are slightly positively connected to the precaution motivation among different flood hazards. This is contrary to the hypothesis but yet a valuable result, indicating a certain motivation of affected residents to protect themselves even after a severe and burdensome flood event. Here, the perceived “recency” and presence of the event may play a role in preparedness decisions. However, since negative psychological impacts are, if at all, positively connected to the precaution motivation, the second hypothesis must be rejected.

H3: Identified psychological indicators are suitable for explaining precautionary behaviour because certain psychological characteristics are distinctly connected to the protection motivation.

According to the correlation results, weak coherences (JSDs) as well as high uncertainties, the identified psychological indicators are mainly not suitable for explaining precautionary behaviour (see Figure 4, Figure 5, Table 2 & Table 3). As already mentioned, by applying standardized and established surveys to assess psychological characteristics, the accuracy and validity of the results may be increased. A very diverse and promising future field might also be the application of data mining techniques and the use of alternative data sources to facilitate the psychological profiling and predicting precautionary behaviour by different methods. Yet, a lot of research still has to be done in that regard. This study, however, reveals that stronger feelings of stress and often thinking of an event (i.e. the perceived burden) are connected to a higher precaution motivation, although the usability as a strong predictor within probabilistic models is limited due to the weak effect strengths. Thus, the third hypothesis can only be partly confirmed.

4 Conclusion

The aim of this study was to investigate psychological impacts in flood affected residents that are caused by different flood types as well as the connection of these impacts to the precaution motivation. Further, the usefulness of psychological indicators and individual psychological variables to predict precaution motivation was evaluated. In this context, four psychological indicators and a precaution motivation indicator were created and differences in psychological impacts among flood types were analysed by using the Kruskal-Wallis rank sum test and Dunn's Test. The connection of these indicators and the individual variables to the precaution motivation was assessed by applying negative binomial regressions and Bayesian statistics as well as evaluating the posterior distributions using the JSD.

The study shows that generally not the flood type, but rather the overall severity of a flood event leads to stronger mental impacts among affected individuals Except threat appraisal, where people affected by strong flash floods report lower values, strong flash floods and river floods result in higher values for the indicators burden and evasion when compared to weak flash floods. The examination of psychological variables reveals that a certain indicator such as burden can be derived which is potentially useful in predicting the planned precaution. Here it is remarkable that people who report stronger negative feelings indicate a higher motivation to implement private precaution measures in future. Yet, the overall strength of different variable connections and the predictive power are generally low, which may be partly due to small sample sizes. When combining psychological variables, or items to derive a more robust indicator of mental health, established procedures which are applied in pure psychological studies should be taken into account. Considering the surveys which are used in this study, the predictive validity can potentially be enhanced by combining items, yet, more specific and standardised questions may lead to more robust results. Therefore, standardised psychological assessments should be considered within follow-up studies. In terms of future development and regarding psychological assessments that are based on publicly available information, further research may also focus on comparisons to established mental health surveys and validity checks to gain knowledge about the usefulness of alternative data sources for predicting individual behaviour. This field of science is rather broad and has already been investigated not only from a scientific perspective. However, useful outcomes may be expected by applying different methods and using different data sources to improve and facilitate information campaigns and damage estimations with regard to flood hazards.

Overall it is indicated that, in particular, the frequency of remembering an event plays a role in preparedness decisions. Therefore, recommendations for disaster assistance and risk communication are difficult to derive, especially with regard to increase the protection motivation of flood-affected individuals and helping with the individual recovery. Further research is required to estimate the predictive power of different psychological models which rely on mental health assessments and aim to quantify protective behaviour in the context of flooding.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

This work was developed within the framework of the Research Training Group "Natural Hazards and Risks in a Changing World" (NatRiskChange; GRK 2043/1) funded by the Deutsche Forschungsgemeinschaft (DFG). The surveys were conducted as a joint venture between the GeoForschungsZentrum Potsdam, the Deutsche Rückversicherung AG, Düsseldorf, and the University of Potsdam. The survey on the 2013-flood was conducted in the framework of the research project “Flood 2013” funded by the German Ministry of Education and Research (BMBF; funding contract 13N13017). All survey data are owned by the authors.

References

Baan, P. J. A., and Klijn, F.: Flood risk perception and implications for flood risk management in the Netherlands. International Journal of River Basin Management, 2, 2, 113-122, doi: 10.1080/15715124.2004.9635226, 2004.

Bei, B., Bryant, C., Gilson, K .M., Koh, J., Gibson, P., Komiti, A., Jackson, H., and Judd, F.: A prospective study of the impact of floods on the mental and physical health of older adults, Aging & Mental Health, 17, 8, 992-1002, doi: 10.1080/13607863.2013.799119, 2013.

Borga, M., Stoffel, M., Marchi, L., Marra, F., and Jakob, M.: Hydrogeomorphic response to extreme rainfall in headwater systems: Flash floods and debris flows, Journal of Hydrology, 518, 194-205, 2014.

Büchele, B., Kreibich, H., Kron, A., Thieken, A. H., Ihringer, J., Oberle, P., Merz, B., and Nestmann, F.: Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks, Natural Hazards and Earth System Sciences, 6, 485-503, doi: 10.5194/nhess-6-485-2006, 2006.

Bubeck, P., Botzen, W. J. W., Laudan, J., Aerts, J. C. J. H., and Thieken, A. H.: Insights into Flood-Coping Appraisals of Protection Motivation Theory: Empirical Evidence from Germany and France, Risk Analysis, 38, 6, 1239-1257, doi: 10.1111/risa.12938, 2017.

Bubeck, P., Botzen, W. J. W., and Aerts, J. C. J. H.: A Review of Risk Perceptions and Other Factors that Influence Flood Mitigation Behaviour, Risk Analysis, 32, 9, 1481-95, doi: 10.1111/j.1539-6924.2011.01783.x, 2012.

Creamer, M., Bell, R., and Failla, S.: Psychometric properties of the Impact of Event Scale – Revised, Behaviour Research and Therapy, 41, 12, 1489-1496, doi: 10.1016/j.brat.2003.07.010, 2003.

Gaume, E., Bain, V., Bernardara, P., Newinger, O., Barbuc, M., Bateman, A., Blaškovičová, L., Blöschl, G., Borga, M., Dumitrescu, A., Daliakopuolos, I., Garcia, J., Irmescu, A., Kohnova, S., Koutroulis, A., Marchi, L., Matreata, S., Medina, V., Preciso, E., Sempere-Torres, D., Stancalie, G., Szolgay, J., Tsanis, I., Velasco, D., and Viglione, A.: A compilation of data on European flash floods, Journal of Hydrology, 367, 70-78, 2009.

Grothmann, T., and Reusswig, F.: People at risk of flooding: why some residents take precautionary action while others do not, Natural Hazards, 38, 1-2, 101-20, 2006.

Kienzler, S., Pech, I., Kreibich, H., Müller, M., and Thieken, A. H.: After the extreme flood in 2002: changes in preparedness, response and recovery of flood-affected residents in Germany between 2005 and 2011, Natural Hazards and Earth System Sciences, 15, 505-526, doi: 10.5194/nhess-15-505-2015, 2015.

Kreibich, H., Thieken, A. H., Petrow, T., Müller, M., and Merz, B.: Flood loss reduction of private households due to building precautionary measures — Lessons learned from the Elbe flood in August 2002, Natural Hazards and Earth System Sciences, 5, 117-126, 2005.

Kroenke, K., Spitzer, R. L., and Williams, J. B. W.: The PHQ-9. Validity of a Brief Depression Severity Measure, Journal of General Internal Medicine, 16, 9, 606-613, doi: 10.1046/j.1525-1497.2001.016009606.x, 2001.

Laudan, J., Rözer, V., Sieg, T., Vogel, K., and Thieken, A. H.: Damage assessment in Braunsbach 2016: data collection and analysis for an improved understanding of damaging processes during flash floods, Natural Hazards and Earth System Sciences, 17, 2163-2179, doi: 10.5194/nhess-17-2163-2017, 2017.

Lindell, MK., Arlikatti, S., and Prater, C. S.: Why People Do What They Do to Protect Against Earthquake Risk: Perceptions of Hazard Adjustment Attributes, Risk Analysis, 29, 8, 1072-1088, doi: 10.1111/j.1539-6924.2009.01243.x, 2009.

Mason, V., Andrews, H., and Upton, D.: The psychological impact of exposure to floods, Psychology, Health & Medicine, 15, 1, 61-73, doi: 10.1080/13548500903483478, 2010.

Merz, B., Kreibich, H., Schwarze, R., and Thieken, A. H.: Review article “Assessment of economic flood damage”, Natural Hazards and Earth System Sciences, 10, 8, 1697-1724, doi: 10.5194/nhess-10-1697-2010, 2010.

Morss, R. E., Mulder, K. J., Lazo, J. K., and Demuth, J. L.: How do people perceive, understand, and anticipate responding to flash flood risks and warnings? Results from a public survey in Boulder, Colorado, USA, Journal of Hydrology, 541, A, 649-664, doi: 10.1016/j.jhydrol.2015.11.047, 2016.

Munich Re: Topics Geo 2016 - Natural catastrophes 2016 - Analyses, assessments, positions, München, 2017.

Puga, J. L., Krzywinski, M., and Altman, N.: Bayesian statistics. Today’s predictions are tomorrow’s priors, Nature Methods, 12, 5, 377-378, doi: 10.1038/nmeth.3368, 2015.

Rogers, R. W.: A protection motivation theory of fear appeals and attitude change, Journal of Psychology, 91, 1, 93-114, doi: 10.1080/00223980.1975.9915803, 1975.

Thieken, A. H., Kreibich, H., Müller, M., and Lamond, J.: Data collection for a better understanding of what causes flood damage – experiences with telephone surveys. In: Flood damage survey and assessment: new insights from research and practice (Molinari, D., Menoni, S., and Ballio, F. Eds.), AGU, Wiley, 7, 95-106, doi: 10.1002/9781119217930.ch7, 2017.

Thieken, A. H., Bessel, T., Kienzler, S., Kreibich, H., Müller, M., Pisi, S., and Schröter, K.: The flood of June 2013 in Germany: how much do we know about its impacts?, Natural Hazards and Earth System Sciences, 16, 1519-1540, doi: 10.5194/nhess-16-1519-2016, 2016a.

Thieken, A. H., Kienzler, S., Kreibich, H., Kuhlicke, C., Kunz, M., Mühr, B., Müller, M., Otto, A., Petrow, T., Pisi, S., and Schröter, K.: Review of the flood risk management system in Germany after the major flood in 2013, Ecology and Society, 21, 2, 51, doi: 10.5751/ES-08547-210251, 2016b.

Thieken, A. H., Olschewski, A., Kreibich, H., Kobsch, S., and Merz, B.: Development and evaluation of FLEMOps – a new *F*lood *L*oss *E*stimation *MO*del for the *p*rivate *s*ector. In: Flood Recovery, Innovation and Response (Proverbs, D., Brebbia, C. A., and Penning-Rowsell, E. Eds.), WIT Transactions on Ecology and the Environment, 118, 315-324, 2008.

Thieken, A. H., Petrow, T., Kreibich, H., and Merz, B.: Insurability and Mitigation of Flood Losses in Private Households in Germany, Risk Analysis, 26, 2, 383-395, doi: 10.1111/j.1539-6924.2006.00741.x, 2006a.

Thieken, A. H., Müller, M., Kreibich, H., and Merz, B.: Flood damage and influencing factors: New insights from the August 2002 flood in Germany, Water Resources Research, 41, W12430, doi: 10.1029/2005WR004177, 2005.

Ware, J. E., and Sherbourne, C. D.: The MOS 36-Item Short-Form Health Survey (SF-36). I. Conceptual Framework and Item Selection, Medical Care, 30, 6, 473-483, 1992.

Wetzels, R., Matzke, D., Lee, M. D., Rouder, J. N., Iverson, G. J., and Wagenmakers, E. J.: Statistical Evidence in Experimental Psychology: An Empirical Comparison Using 855 t Tests, Perspectives on Psychological Science, 6, 3, 291-298, doi: 10.1177/1745691611406923, 2011.

Table 1: List and explanation of the psychological variables used in this study.

Variable	Original variable scale	Original question or statement (shortened)
Believe in being affected again	6 (I do not agree)… 1 (I fully agree)	**Statement**: It is likely to be affected again by a flood event.
Fear of severe effects again	6 (I do not agree)… 1 (I fully agree)	**Statement**: A future flood event will not be as bad as the recent event.
Self-efficacy	6 (I do not agree)… 1 (I fully agree)	**Statement**: I personally do not feel able to implement at least one private precaution measure.
Response efficacy	6 (I do not agree)… 1 (I fully agree)	**Statement**: Private precaution measures can reduce the flood damage.
Response cost	6 (I do not agree)… 1 (I fully agree)	**Statement**: Private precaution measures are too expensive.
Stress still today	1 (no stress)… 6 (high stress)	**Question**: Do you still feel stress and negative emotions caused by the flood event (at the time of the interview)?
Often thinking of the event	1 (not once)… 7 (few times a day)	**Question**: How often did you think about the event within the last six months (at the time of the interview)?
Avoidance	6 (I do not agree)… 1 (I fully agree)	**Statement**: I do not like to think of future flood events.
Fatalism	6 (I do not agree)… 1 (I fully agree)	**Statement**: One is in general helpless regarding future flood events and the damage.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

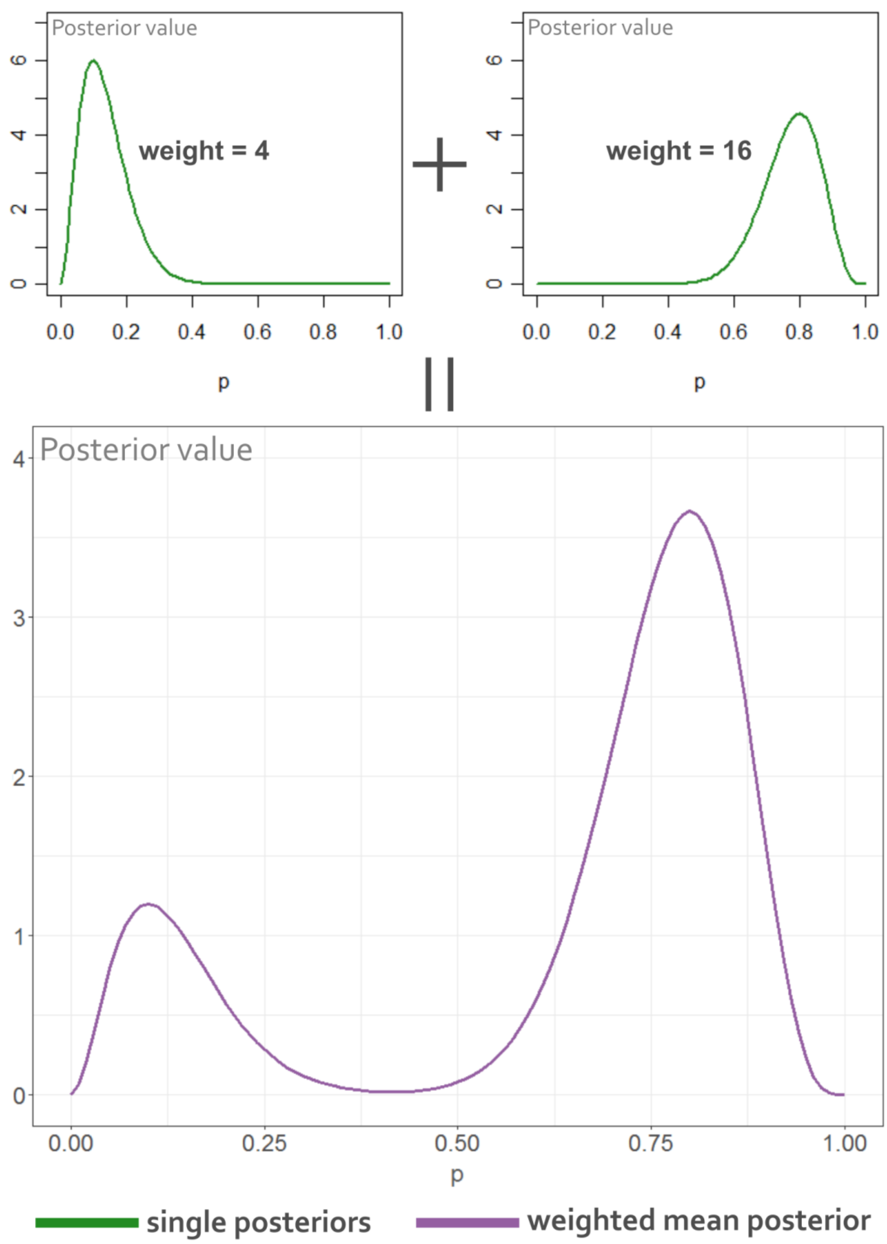

Figure 1: Example graphic explaining the creation of the weighted arithmetic mean posterior. The posteriors are weighted according to the sum of occurrences within the dataset. In this case the weighted mean posterior means that, given the example dataset of 20 data points, 80% coherence of the predictor variable with any value of the response variable is most likely to occur, if a random data point is chosen.

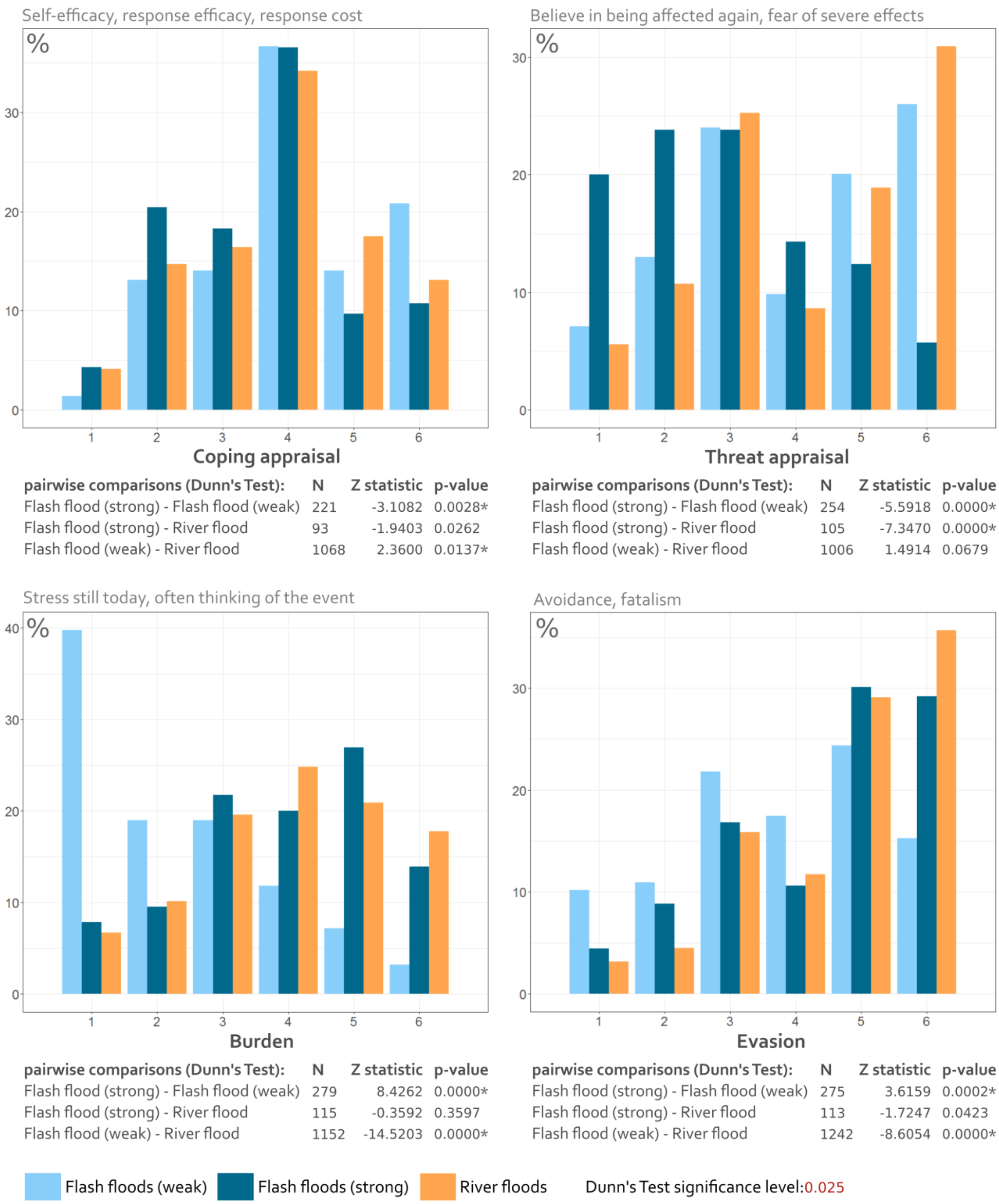

Figure 2: Relative distributions of the combined psychological indicators and Dunn's Test results.

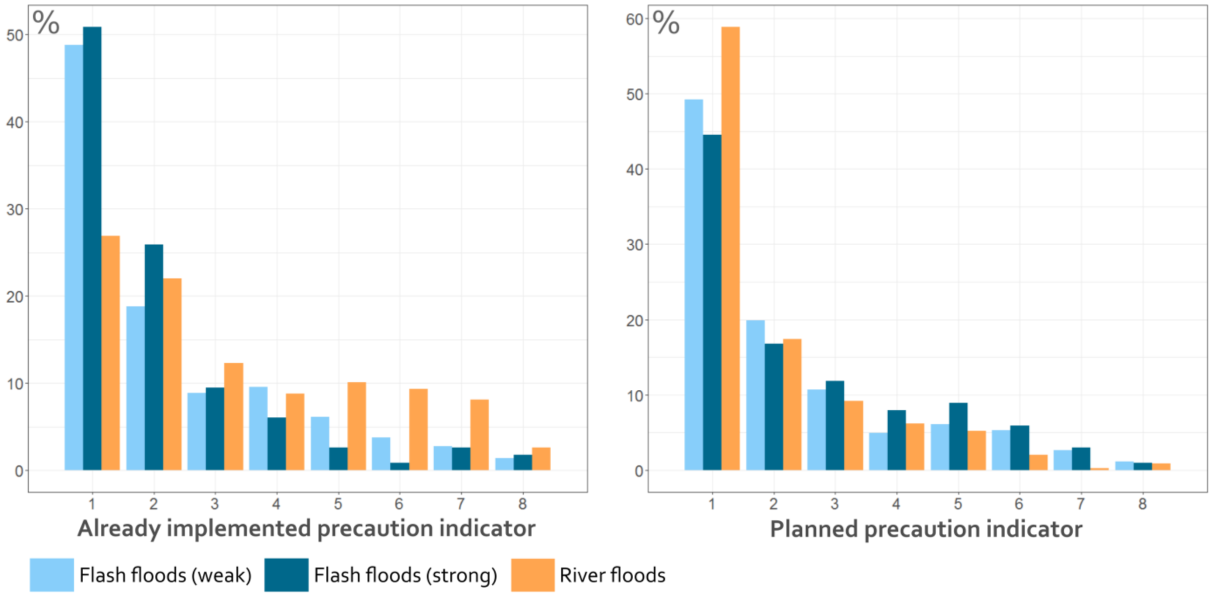

Figure 3: Relative distribution of the already implemented precaution indicator (left) and the planned precaution indicator (right) for weak flash floods (n=293), strong flash floods (n=116) and river floods (n=1366).

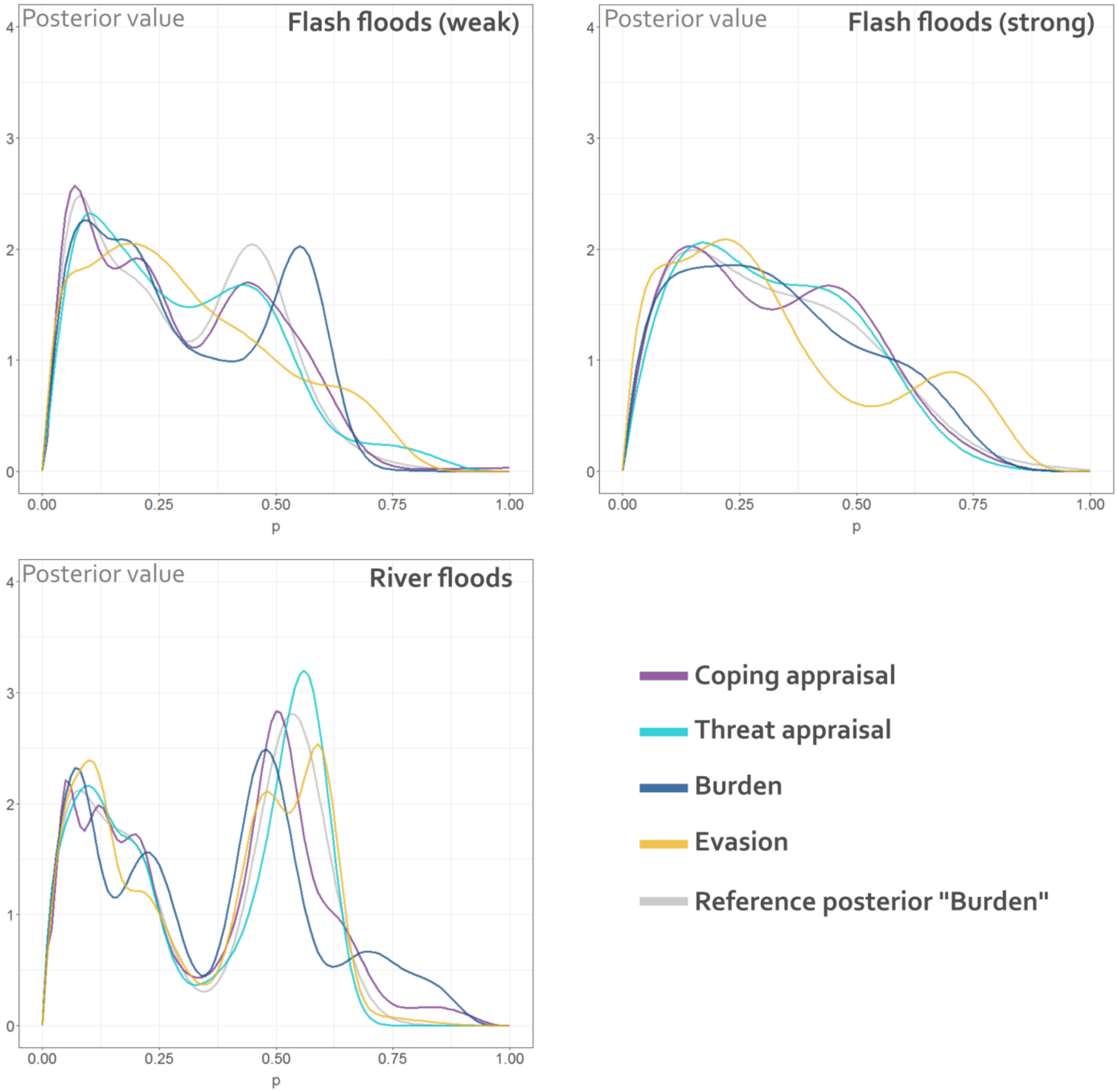

Figure 4: Weighted arithmetic mean of all posterior distributions for the psychological indicators "Coping appraisal", "Threat appraisal", "Burden" and "Evasion", given weak flash floods (top left) strong flash floods (top right) and river floods (bottom left). The reference posterior is shown for "Burden" only.

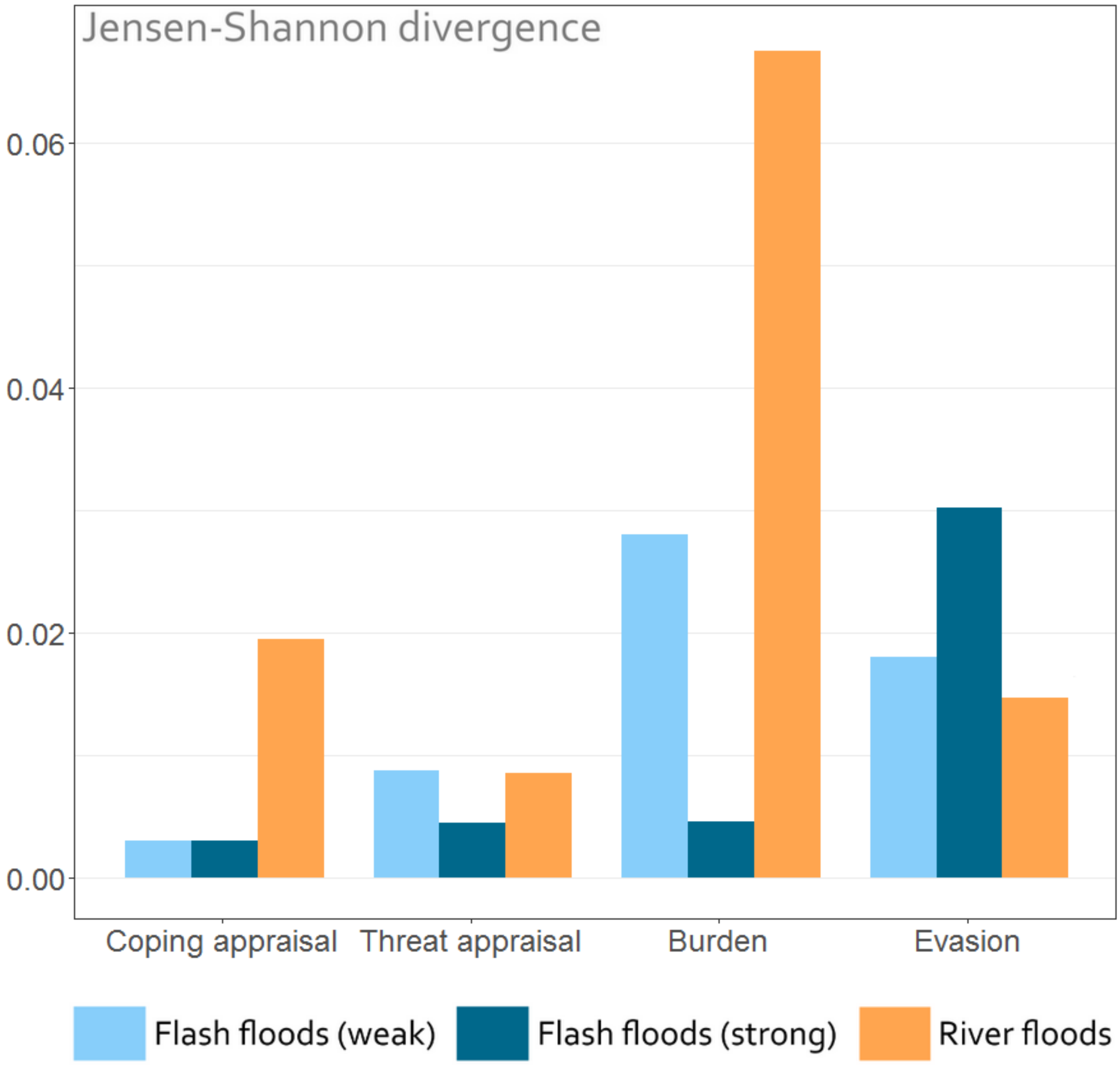

Figure 5: Jensen-Shannon divergence ranking of the psychological indicators. Higher values indicate a higher information gain, if the planned precaution is explained through the particular indicator.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

Table 2: Coefficients of the negative binomial logistic regression models for weak flash floods, strong flash floods and river floods with the psychological indicators as predictor variables and the "planned precaution" indicator as response variable.

Predictor variable	Flash floods (weak)	Flash floods (strong)	River floods
Intercept	0.673 *	1.585 **	0.483 *
Coping appraisal	0.012	0.011	0.024
Threat appraisal	-0.013	-0.016	-0.038 ‘
Burden	0.134 ***	-0.105 ‘	0.054 *
Evasion	-0.024	-0.059	0.020
AIC	667.26	293.01	1422.30
R^2	0.08 **	0.06	0.03 *
N	177	76	419

Note: ‘p-value <.10, *p-value <.05, **p-value <.01, ***p-value <.001.

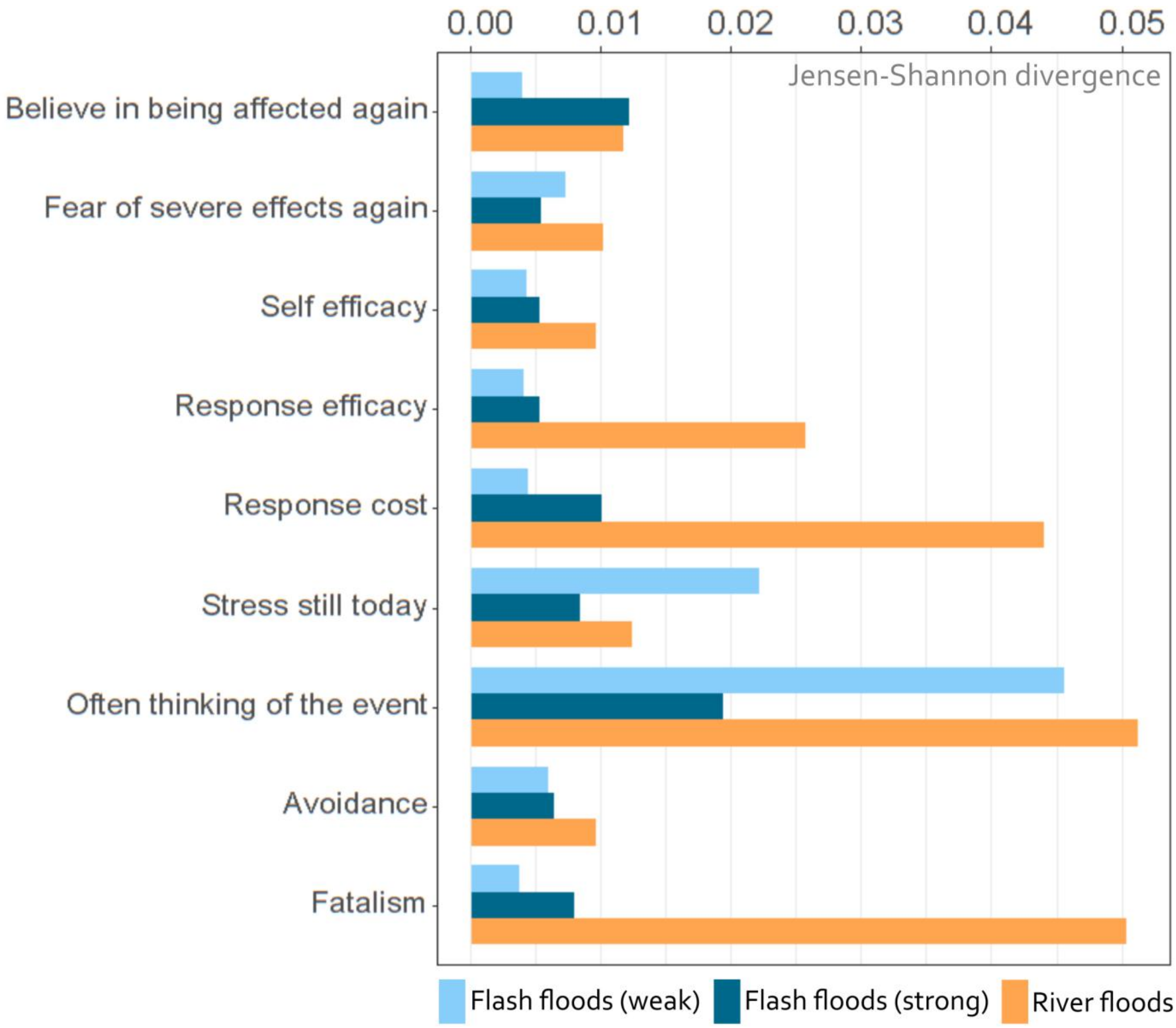

Figure 6: Jensen-Shannon divergence ranking of single psychological variables. Higher values indicate a higher information gain, if the planned precaution is explained through the particular variable.

Table 3: Coefficients of the negative binomial logistic regression models for weak flash floods, strong flash floods and river floods with the individual psychological variables as predictor variables and the "planned precaution" indicator as response variable.

Predictor variable	Flash floods (weak)	Flash floods (strong)	River floods
Intercept	0.619 ‘	1.644 **	0.510 ‘
Believe in being affected again	-0.031	0.032	-0.028
Fear of severe effects again	0.002	-0.024	-0.020
Self-efficacy	-0.003	0.002	-0.007
Response efficacy	0.042	-0.019	0.027
Response cost	-0.017	0.006	-0.002
Stress still today	0.040	-0.056	0.036
Often thinking of the event	0.102 **	-0.047	0.022
Avoidance	-0.044	0.030	0.012
Fatalism	0.020	-0.103 *	0.009
AIC	669.34	300.24	1429.10
R^2	0.12 **	0.10	0.04
N	177	76	419

Note: ‘p-value <.10, *p-value <.05, **p-value <.01, ***p-value <.001.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

Natural Hazards and Earth System Sciences
Discussions

Appendix

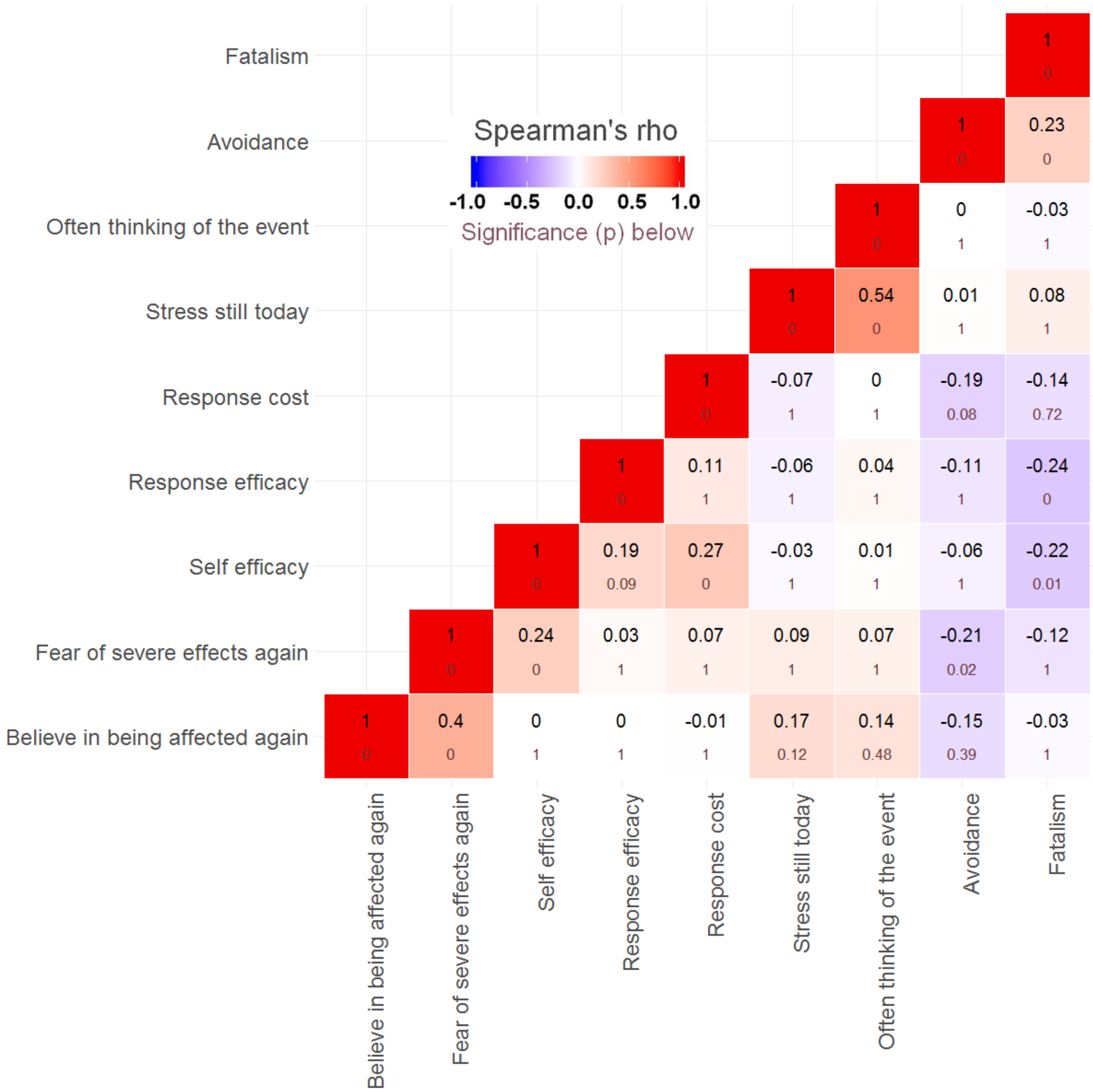

Figure A: Correlation table of single psychological variables for weak flash floods.

Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-407
Manuscript under review for journal Nat. Hazards Earth Syst. Sci.
Discussion started: 14 January 2019

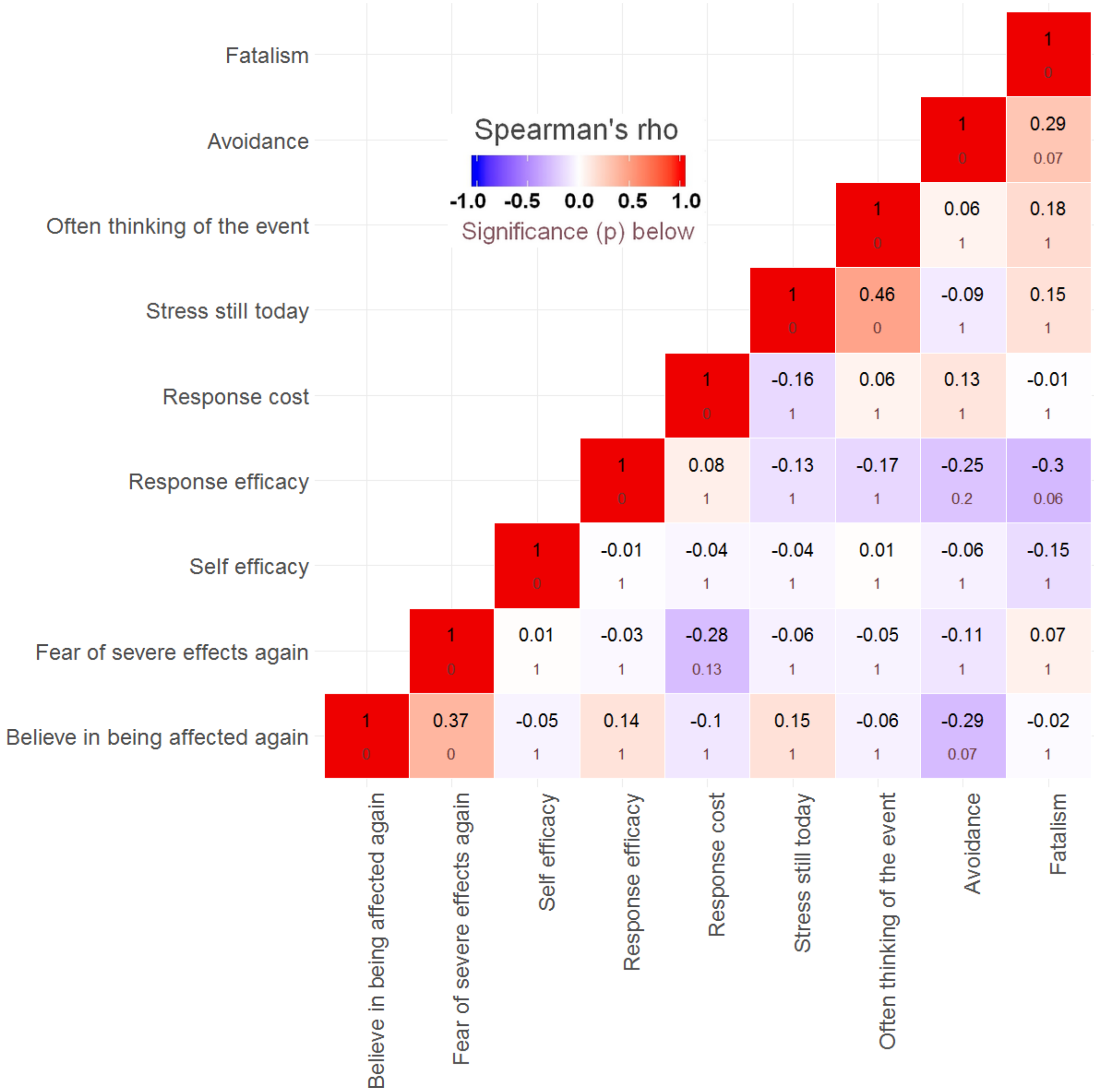

Figure B: Correlation table of single psychological variables for strong flash floods.

5

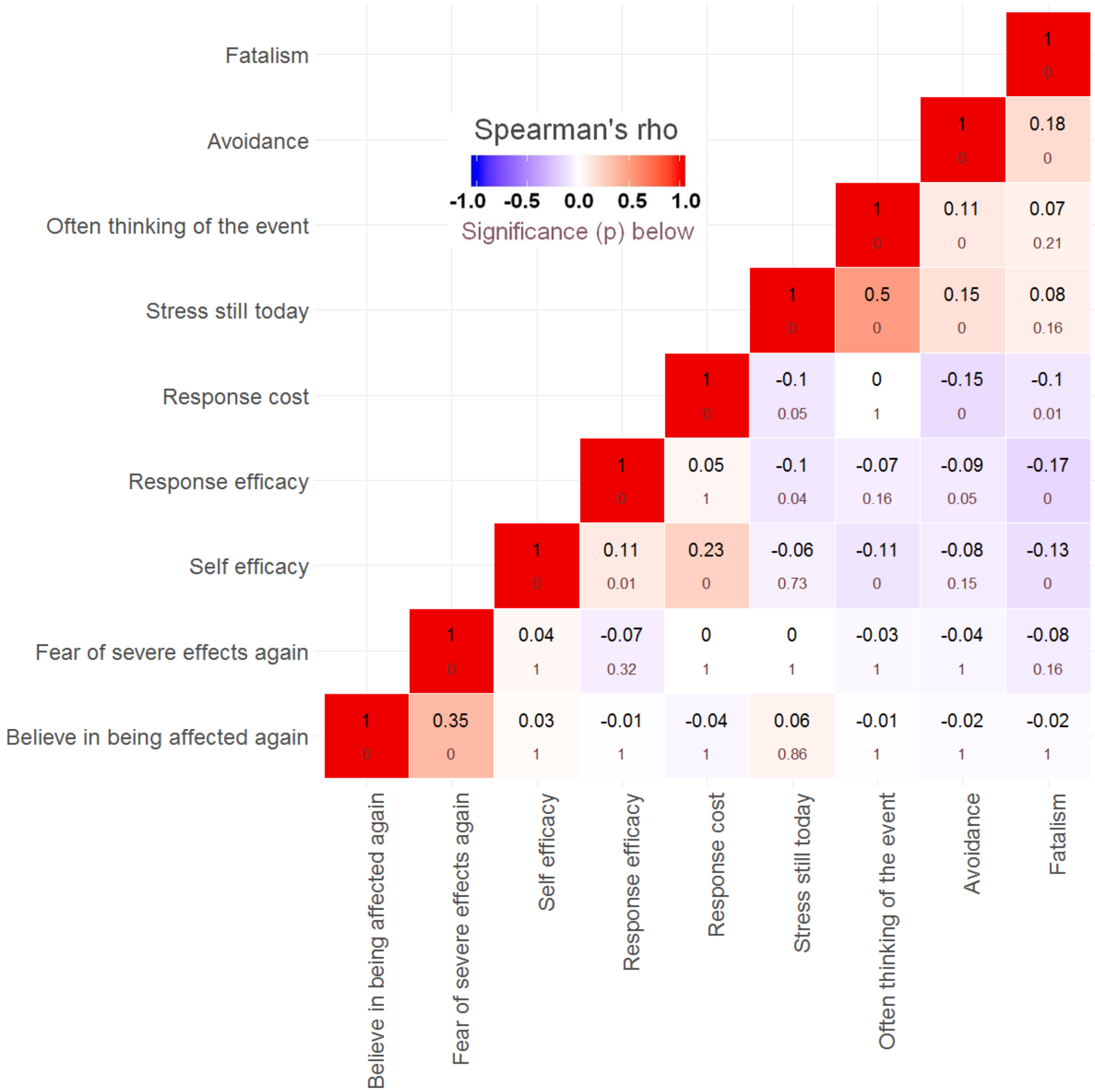

Figure C: Correlation table of single psychological variables for river floods.