Better prepared but less resilient: the paradoxical impact of frequent flood experience on adaptive behavior and resilience

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Abstract. To better understand factors shaping adaptive behavior and resilience is crucial in designing policy strategies to prepare people for future flooding. The central question of our paper is how frequent flood experience (FFE) impacts adaptive behavior and self-reported resilience. The applied empirical methods are binary logistic and linear regression models using data from a panel dataset, including 2462 residents (Germany, state of Saxony). Four main conclusions from the investigations can be drawn. First, more flood experienced respondents are statistically significantly more likely to have taken precautionary measures in the past. Second, FFE has a statistically significant negative impact on self-reported resilience. Third, the impact of FFE on the capacity to recover and the capacity to resist is statistically significant non-linear. Fourth, putting together these results reveals the paradox of more flood-experienced respondents being better prepared but feeling less resilient at the same time. It can be concluded that more research is needed to obtain deeper insights into the drivers behind self-reported resilience and that this study can be seen as a piece of the puzzle, taking frequent flood experience as the primary entry point.

1   Introduction

The number and severity of floods are increasing globally (IPCC, 2023). The devastating flood in southwestern Germany in 2021 revealed unseen vulnerabilities, thereby shedding light on the current lack of knowledge regarding appropriate behavior and risk assessment (Fekete and Sandholz, 2021) and failures regarding early warning (Thieken et al., 2022). According to the IPCC Report 2023, global climate change is one reason for the increase in flood events (IPCC, 2023). This development challenges the status quo, putting individuals' mental and physical health, economic endowments, and important infrastructures at risk (GDV, 2021; Sieg et al., 2019; Thieken et al., 2016).

Despite this development in face of climate change, the hazard can be made less of a disaster by reducing structural vulnerability, promoting adaptive behavior, and increasing resilience (Adger, 2006; Cutter, 1996; Aerts et al., 2018; Birkmann, 2011; Kreibich et al., 2017). For being able to promote adaptive behavior effectively, it is necessary to understand the underlying drivers better. While such drivers have long since entered the realm of science (e.g., Bubeck et al., 2018; Heidenreich et al., 2021; Kuhlicke et al., 2020a; Kuhlicke et al., 2020b; Tasantab et al., 2022), it is less well understood how to improve resilience, being defined as the capacity to resist a hazardous event, recover from and adapt to it (IPCC, 2012). Additionally, previous research has focused on how flood experience generally affects the uptake of precautionary measures (Bamberg et al., 2017). In contrast, less work has been done investigating the effects of *frequent* flood experience (FFE). Additionally, only a few studies investigate experience's influence on resilience.

In our study, we aim to shed some light on the role of FFE, both with respect to adaptive behavior and self-reported resilience. It particularly contributes to the literature by focusing on the *number* of floods experienced. Our study suggests a paradoxical relationship between the development of resilience and the uptake of adaptive measures after experiencing multiple flood events. Whereas the likelihood to adapt such measures increases with the number of experienced flood events, self-reported resilience decreases. Additionally, we explore if the relationship between FFE and resilience is non-linear (Kuhlicke et al., 2020a). In other words, we test if individuals with very frequent flood experience report much lower resilience compared to individuals who have experienced fewer flood events.

The paper starts with an overview of related theories and existing knowledge to place this study and formulate its contribution (section 2). This is followed by a description of the empirical modeling approach and the applied survey data of residents from flood-prone areas in the federal state of Saxony (Germany, section 3). In section 4, the results are presented and discussed in section 5.

2   Theoretical background and existing knowledge

2.1   Flood experience and resilience

The concept of resilience has different definitions depending on the field in which it is applied. In ecology, it is defined as the capacity of a system to keep its functioning and relations to other systems in case of a disturbance (Holling, 1973). This definition aligns with that in sociology, where resilient systems are viewed as such that stay functional despite changing environmental conditions (Blum et al., 2016). In psychology, it is defined as the capacity of people to cope with and adapt to stress factors. It is a dynamic ability that alters with demographic conditions and life situations (Rutter, 1987; Norris et al., 2008). Connor & Davidson (2003) argue that individuals become more resilient through learning from challenging experiences and developing specific character traits that enable them to cope with a comparable situation better in the future. According to this argumentation and contrarily to that of Rutter (1987) and Norris et al. (2008), individuals stay resilient once they develop these character traits. Bonanno (2021) points out that it is difficult to predict which individuals will react resiliently to shocks since the determinants of resilience vary in their impact depending on the specific situation. Moreover, Bonanno (2021) argues that resilience is connected with the ability of "flexible self-regulation," enabling people to make decisions adjusted to the situation.

In natural hazard research, resilience is understood, among others, as the capacity to resist a hazardous event's negative aftermaths, adapt to and recover from it (IPCC, 2012; Cutter et al., 2008). Hudson et al. (2020) explain the capacity to resist as the ability to limit the impacts of a hazardous event, the capacity to adapt as the ability to be prepared for upcoming hazards of the same kind, and the capacity to recover as the time that the system needs to return to the pre-disaster state. In our study, we focus on the capacity to resist and to recover.

Existing studies aim at better understanding how flood experience affects people's resilience. It has been shown that floods have strong and long-term impacts on people's life both with respect to their physical health (Few et al., 2004; Jonkman and Kelman, 2005; Tapsell et al., 2009) as well as with respect to their psycho-social well-being (Bubeck & Thieken, 2018; Masson et al., 2019; Terpstra, 2011; Thieken et al., 2016). By comparing two independently collected survey data sets, Kuhlicke et al. (2020a) explore the interrelation between multiple flood experiences and resilience. They find that the resilience of households only increases with regard to respondents' perceived abilities to withstand impacts on equipment and mobile goods (e.g., cars, TV, and radios). A possible explanation they raise is the evolvement of routine-based knowledge. This positive influence of learning from floods is also pointed out by Kuang & Liao (2020), stating that it influences the capacities to resist, recover and adapt. Concerning the self-perceived ability to reduce financial consequences, Kuhlicke et al. (2020a) observe non-linear trends, indicating that the relationship between flood experience and resilience changes when experiencing more floods. Lastly, the resilience of flood-prone households can be decreasing due to an under- or overestimation of the risk (Burton et al., 1978; Mol et al., 2020).

2.2   Flood experience and adaptive behavior

The IPCC (2012) defines adaptation as actions to adjust to changing conditions stemming from climate change aimed at reducing risks. A prominent approach to explaining adaptive/protective behavior is the protection motivation theory (PMT) (Kuhlicke et al., 2023). Accordingly, if individuals' coping appraisal and risk perception are high, people are motivated to undertake actions (Grothmann & Reusswig, 2006; Heidenreich et al., 2021; P. Hudson et al., 2020; Maddux & Rogers, 1983). This is supported by Grothmann et al. (2013), who additionally summarize that the motivation to act is a primary psychological

driver of actual adaptation. Next to the discussion of factors promoting adaptive actions, there is also a discussion on what psychological drivers hinder people from undertaking adaptive actions. These are, for example, ignorance, uncertainty, optimism bias, worldviews, and denial (Gifford, 2011).

Existing research explores whether and how flood experience shapes people's motivation to act. Studies indicate different relationships: while some suggest no relationship (Dessai and Sims, 2010; Whitmarsh, 2008), others observe a positive relationship (Grothmann & Reusswig, 2006; Hudson et al., 2017; Kuhlicke et al., 2020a; Osberghaus, 2017; Siegrist & Gutscher, 2008). One explanation for a positive relationship could be the factor of risk perception. In their meta-analysis, Bubeck et al. (2012) find that risk perception tends to be positively influenced by experience. Additionally, risk perception has been found to be a factor that increases individuals willingness to undertake protective actions (Lazrus et al., 2016; Demski et al., 2017; Plapp, 2004; Siegrist and Gutscher, 2008). By applying a longitudinal study design including individuals before and after a flood event, Osberghaus (2017) shows a statistically positive impact of flood damage on private flood mitigation. Additionally, they find a correlation between self-reported flood experience and mitigation behavior. Tasantab et al. (2022) distinguish between flood experience and coping experience to explore how both influence people's intention to adapt. By extending protection motivation theory (PMT), their analysis indicates that flood experience, as well as coping experience, positively influences respondents' intentions to adapt. Both factors thus complement already established PMT factors such as fear, adaptation appraisal, and flood risk perception (Maddux and Rogers, 1983).

The adaptive actions of interest in our paper are storing important goods safely, having insurance against natural hazards, and undertaking property-level adaptation. Insurance against natural hazards is a private risk prevention through the distribution of financial damages over time that supports affected people after an event (Grothman, 2005; cited in Marg, 2016: 37-38). Property-level adaptation prevents damage through avoidance, resistance, conceding, and securing before an event (DKKV, 2003; cited in Marg, 2016: 37-38).

The literature review reveals that the research fields of resilience and adaptive behavior to environmental hazards generally have been captured by many scholars' attention, and different perspectives have been developed. The specific investigation of the impact of experience with floods on adaptive behavior has also been studied well but with inconsistent results. However, the impact of experience on self-reported resilience has been studied to a fewer extent, and also with varying outcomes regarding their relationship. The investigation of the impact of FFE in our study aims to deliver more robust results on these relationships by not only focusing on whether people have experienced floods or not but considering the specific number. The knowledge of the specific number of experienced flood events also allows for testing non-linear relationships, whereas in existing research, the focus is mainly on linear relationships. Lastly, in existing studies, the focus is mostly on the intention to adapt. However, our study focuses on the actual behavior in the past as this is a more tangible and comparable outcome. Stemming from the existing literature and paradoxical research outcomes, our study contributes to the existing body of knowledge by aiming to answer the following research questions:

RQ 1: How does FFE motivate people to undertake adaptive actions?

RQ 2: How does FFE influence an individual's resilience in terms of self-reported capacity to resist and recover?

RQ 3: How does past adaptive behavior impact reported resistance to future flood events?

3   Case study and methodology

The research area of our study is located in Germany, in the State of Saxony. The German federal state was impacted by five flood events between 2002 and 2013 (LfULG, 2015), with the events in 2002, 2010, and 2013 being the most severe (BfUL, 2018). According to a report by the Saxon State Office for Environment, Agriculture, and Geology (LfULG, 2015), the flood event in 2013 caused damages in 378 of the 439 municipalities. In their report of 2018, the Saxonian Ministry for Environment

and Agriculture highlights that 3.6% of the federal state's surface belongs to the designated flood plains (BfUL, 2018). To meet our study's research goals, we follow a quantitative empirical modeling approach, applying regression analyses.

3.1 Survey sample

The used data stems from a two-wave paper-and-pencil survey collected in the PIVO project (Siedschlag et al., 2023). Data were collected in 11 communities in Saxony in 2020 and 2021, which were selected randomly out of a total of 25 communities.
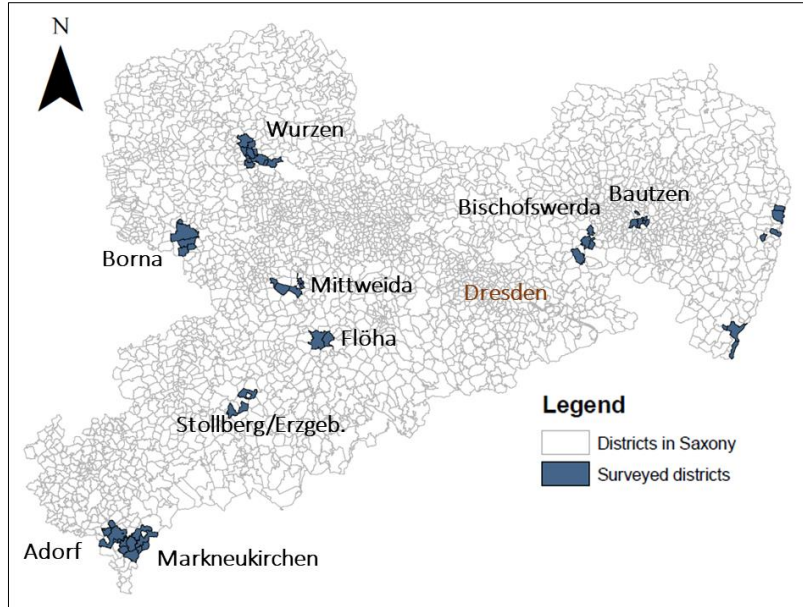
Figure 1. Surveyed cities and districts (created with ArcGIS; basic map downloaded from Landesamt für Geobasisinformationen (Sachsen, 2022))

The respondents from within the household were selected randomly by using a "next-birthday approach" (i.e. the questionnaire should be completed by the household member whose birthday is next and who is 18 years and older). The questionnaire was handed over personally and collected one week later allowing individuals to complete the surveys privately. The sample of the first survey wave (2020) contains 1833 individuals; the sample from the second survey wave (2021) contains 1319 individuals, from which 690 (28.03 %) are part of both survey waves. For this paper, both survey waves are part of the investigation. This approach increases the overall sample size and allows us to benefit from the advantages of panel analyses, which are decreasing the problem of heterogeneity, considering intra-individual variations, and estimating the impact of changed external conditions (Brüderl, 2010).

Table 1. Number of respondents per survey wave

Survey wave	Only included in survey wave 1 (2020)	Only included in survey wave 2 (2021)	Included in both survey waves
Number of respondents	1143	629	690

3.2 Regression analysis and empirical model

3.2.1 Dependent variables and theoretical constructs

For the scope of our paper, multiple regression analyses with different dependent variables are performed. These are clustered in variables measuring adaptive behavior and self-reported resilience. Since the behavior and resilience variables are

distributed differently, two different empirical modeling approaches are applied, binomial logistic and linear regressions. The reason for running separate regressions for the variables that are aimed at measuring the capacity to resist is that differences between reported resilience during past events and with regard to future events should be displayed.

The dependent variables and their distributions are presented in table 2.

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Table 2. Description of the dependent variables

Research objective	Construct	Dependent variable and distribution	Applied empirical model
adaptive behavior		Adaptation actions in general in the past [0= none; 1=at least one of the mentioned]	Binomial logistic regression
		Safe storage of valuable goods [0=none; 1=yes]	Binomial logistic regression
		Property-level adaptation in the past [0= no; 1=yes]	Binomial logistic regression
		Taken out insurance in the past [0=no; 1=yes]	Binomial logistic regression
Self-reported resilience	Expected resistance during future floods	Helplessness [1=not at all; 7=to a large extent]	Linear regression
	Reported resistance during the last flood	Felt powerlessness during the last flood event [0=no prior personal flood experience; 1=not at all; 7=to a large extent]	Linear regression
		Reported severity of the last flood event [0=no prior personal flood experience; 1=not severe; 7=very severe]	Linear regression
	Reported recovery from the last flood	Reported burden today resulting from last experienced flood event [0=no prior personal flood experience; 1=not at all; 7=to a large extent]	Linear regression

3.2.2 Independent variables

The independent variables refer to individuals' demographic backgrounds, their buildings' characteristics, and past flood experiences. For the investigation of the drivers of reported resilience, the fact if individuals have undertaken property-level adaptation in the past is included as an independent variable. Lastly, as some of the respondents included in the second survey wave were surveyed before and some after the devastating flood event 2021 in western Germany, the binary distributed variable *flood21* is included in the model to account for changes in the answers that are externally stemming from that event.

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Table 3. Description of the independent variables

Category	Independent variables	PIVO Sample 2020	PIVO Sample 2021
Demographic Background	Age	Mean: 57.6 years (n1740)	Mean: 59.4 years (n1278)
	Gender	Male/Female/diverse: 53.6% / 46.1% / 0.4% (n1770)	Male/Female/diverse: 54.8% / 45.1% / 0.2% (n1296)
	Tenure	tenants/owners: 24.5%/75.5% (n1744)	tenants/owners: 24.4%/75.6% (n1260)
Building characteristic	Building type	Single/semidetached/apartment/double: 48% / 7.2% / 30% / 7.1% (n1751)	Single/semidetached/apartment/double: 49 %/ 64.8 %/ 30.4 % / 8.8 %
Frequent Flood Experience (FFE)	Number of experienced flood events	None / one/ two/ three or more 39.4 % / 22.4 % / 21.5 % / 16.7 %	None / one/ two/ three or more 40.6 % / 25.1 % / 19.4 % / 14.9 %
Adaptative behavior	Property-level adaptation	None / at least one 73.1 % / 26.9 %	None / at least one 74 % / 26 %
Indirect exposure	Flood21	Surveyed before flood 2021/ surveyed after flood 2021 100 % / 0	Before/After 70 % / 30 %
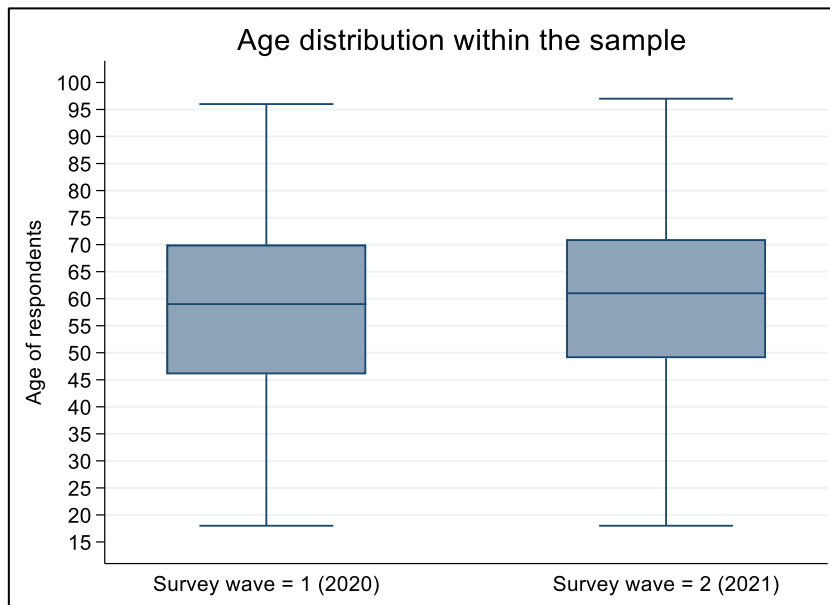
Figure 2. Age distribution in the sample, depending on survey wave

3.2.3 Regression Model

The resulting regression equations to measure adaptive behavior (1) and self-reported resilience (2) are:

(1) $\log(Behavior_{(i)}) = \beta_0 + \beta_1 * age_i + \beta_2 * gender_i + \beta_3 * tenure_i + \sum \beta_{4-6} * buildingtype_i + \beta_7 * experience_i + \beta_9 * flood21_i + \varepsilon_i$

$$(2) \quad \text{lin}\left(Resilience_{(i)}\right) = \beta_0 + \beta_1 * age_i + \beta_2 * gender_i + \beta_3 * tenure_i + \sum \beta_{4-6} * buildingtype_i + \beta_7 *$$
$$experience_i + \beta_8 * experience_i^2 + \beta_9 * experience_i^3 + \beta_{10} * adaptation\_building_i + \beta_{11} * flood21_i + \varepsilon_i$$

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The model is run as a panel regression with random effects since some individuals are included in both survey waves. The reason for applying random effects is that both, the variance within an individual between the two survey waves and the differences between individuals, are of interest. The analyses in section 4 have shown non-linear relationships between FFE and reported resilience. Therefore, the squared and cubic forms of the mean-centered experience variable are included in

195 equation (2).

4   Results

4.1   Bivariate analyses of the relationship between flood experience, adaptive behavior, and self-reported resilience

The correlation analyses of the relationshipbs between FFE and the outcome variables show that respondents who have

200 experienced more flood events were also more likely to have implemented adaptive measures in the past. At the same time, individuals with more flood experience also report lower resilience. These outcomes lead to a paradoxical relationship. While FFE correlates positively with the uptake of adaptive measures, it negatively correlates with the self-reported resilience (table 4).

205 **Table 4**. Correlation coefficients: flood experience, adaptive behavior, and resilience

Spearman (N)	Adaptive behavior [0;1]				Self-reported resilience [1;7]			
	Adapted any	Safe storage	Taken out insurance	Property-level adapt.	Helpless-ness	Severity last flood	Power-lessness last flood	Still existing burden
Survey wave 1 / Survey wave 2 Flood experience [0;3]	0.1328** (1806)/ 0.1640** (1302)	0.1492** (1702)/ 0.1724** (1246)	0.0718** (1694)/ 0.1535** (1242)	0.1386** (1657)/ 0.1799** (1228)	0.1848** (1750)/ 0.1484** (1272)	0.3381** (1193)/ 0.2814** (797)	0.2639** (1191)/ 0.1889** (797)	0.2436** (1194)/ 0.2279** (803)
Survey wave 1 / Survey wave 2 Flood experience [1;3]	-	-	-	-	0.2218** (1059)/ 0.1959** (754)	0.1564** (1064)/ 0.1252** (756)	0.1876** (1061)/ 0.1959** (761)	

*p<0.05; **p<0.01

Figures 3-6 show the percentage of people that have adapted the respective measure depending on the number of floods experienced for both survey waves. In figure 3, the values in both years were the same.

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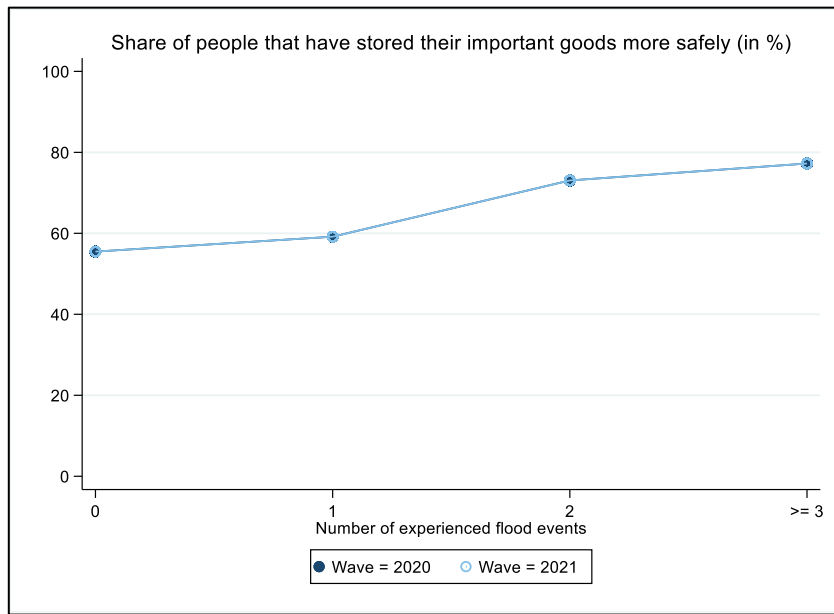
Figure 3. Share of people that have stored their important goods more safely, depending on flood experience
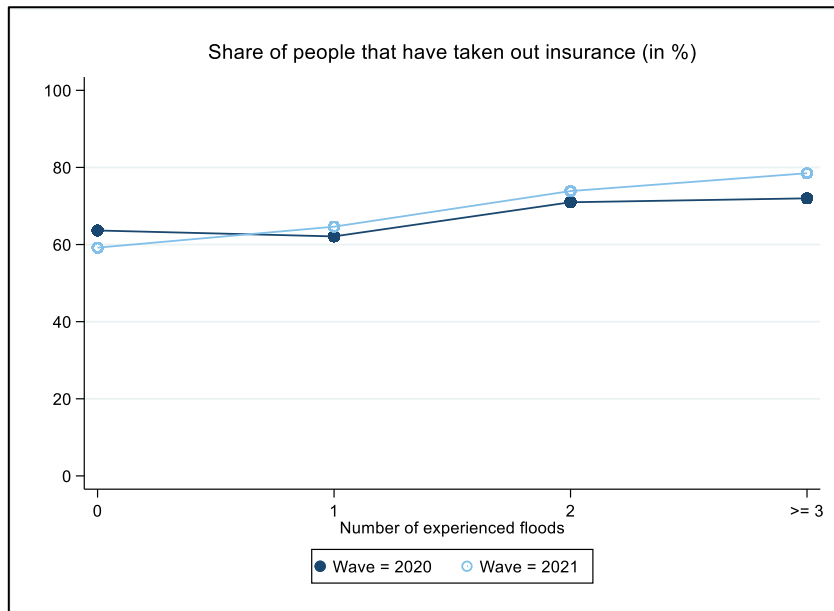
Figure 4. Share of people that have taken out insurance, depending on flood experience
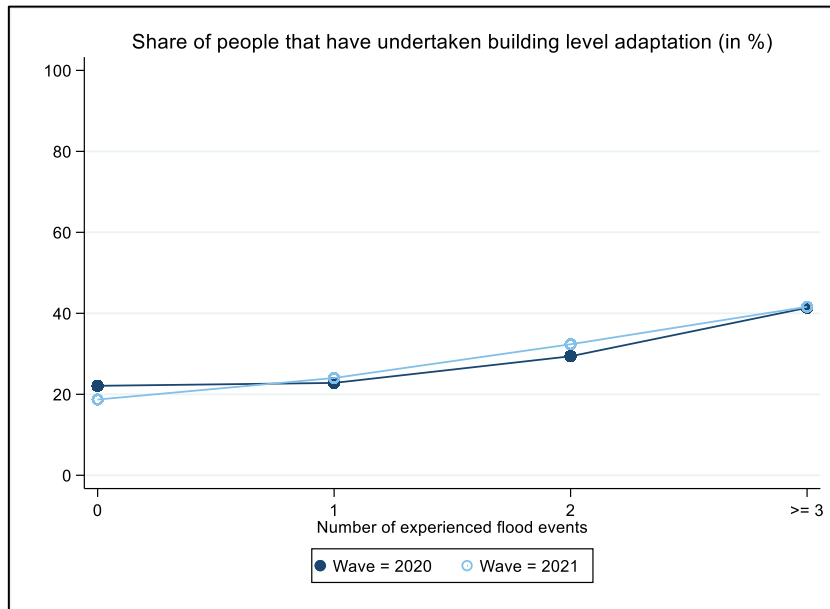
Figure 5. Share of people that have undertaken property-level adaptation, depending on flood experience

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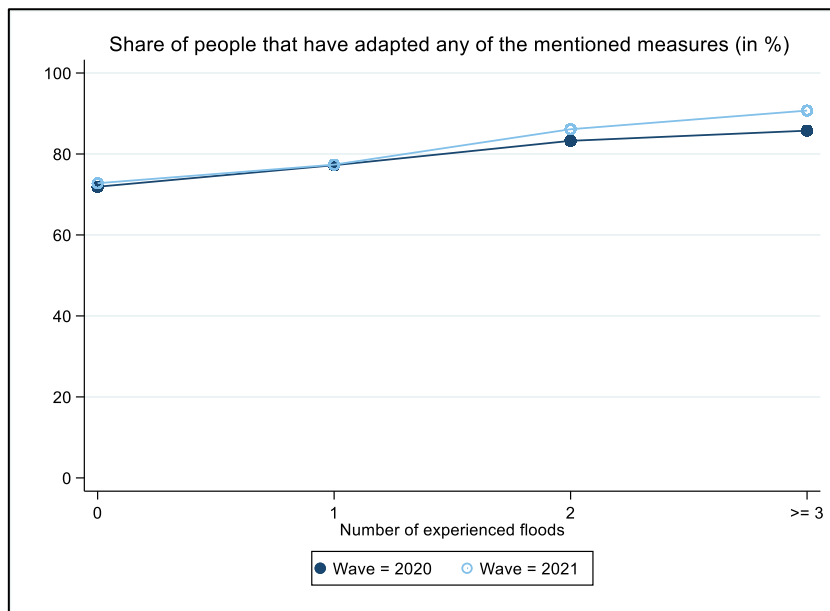
Figure 6. Share of people that have adapted any of the measures, depending on flood experience

Stemming from figures 3-6, there are several key findings. First, independently of the number of floods experienced, respondents have more often applied measures of relatively low costs compared to measures with high costs, which was also found by Dillenardt et al. (2022; see Kuhlicke et al., 2020b). On a 1-7 Likert-scale, the individuals in our dataset indicated that they associate the least effort with the action of storing important goods more safely (mean=2.34; median=2; sd=1.54), followed by buying insurance against natural hazards (mean=3.09; median=3; sd=2.03). They expect the highest effort from undertaking property-level adaptation (mean=4.52; median=5; sd=2.3). Figure 7 shows these values for individuals who did not implement the respective measure yet.
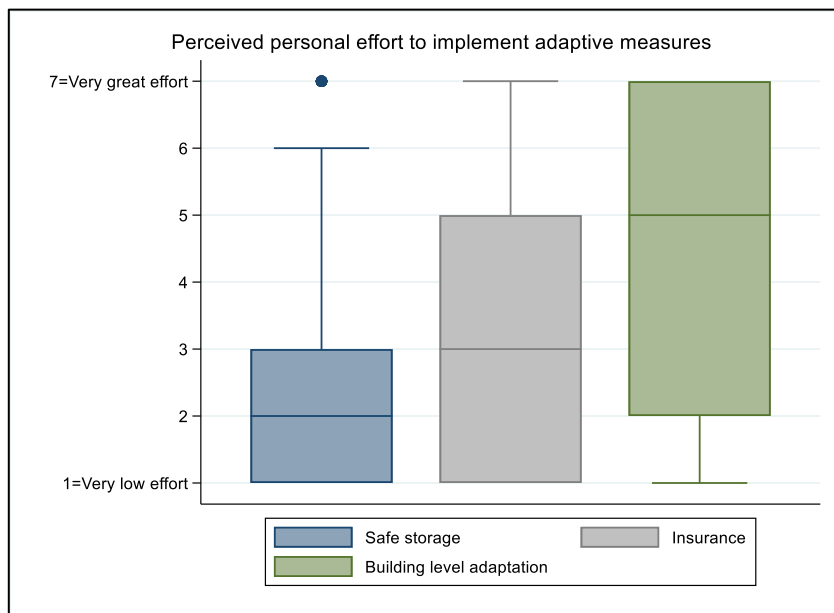
Figure 7. Perceived personal effort to implement adaptive measures

235   Second, respondents with high numbers of experienced floods (i.e., two and more) have taken more often measures than respondents with lower numbers (once or none). This applies to all constructs measured. Third, the least apparent relationship between FFE and behavior exists for insurance against natural hazards. This could be because many people already have insurance, independently of the exact number of flood events (about 67% of the individuals in the dataset and 50% of households in Saxony (GDV, 2022), which is above the German median).

240   Concerning self-reported resilience, several key findings can be reported (figures 8-11). First, the highest average value can be observed for the perceived powerlessness during the last flood event, independently of the number of experienced flood events. The lowest average value can be observed for the still-existing burden indicating that most respondents recovered quite well from the last flood event experienced. Second, respondents that had undergone three flood experiences reported considerably lower resilience across all variables measured than respondents with an one-time experience. Third, the impact

245   of FFE on self-reported resilience varies. The relationship between experience and felt powerlessness during the last flood event and the extent to which the last flood is still perceived as a burden seems to follow a cubic relationship (reaches a plateau between the first and second flood and only increases again when a respondent experiences the third flood). A noticeable change in the slope, but without the previously described stagnation, can also be seen in the reported severity of the last flood event.

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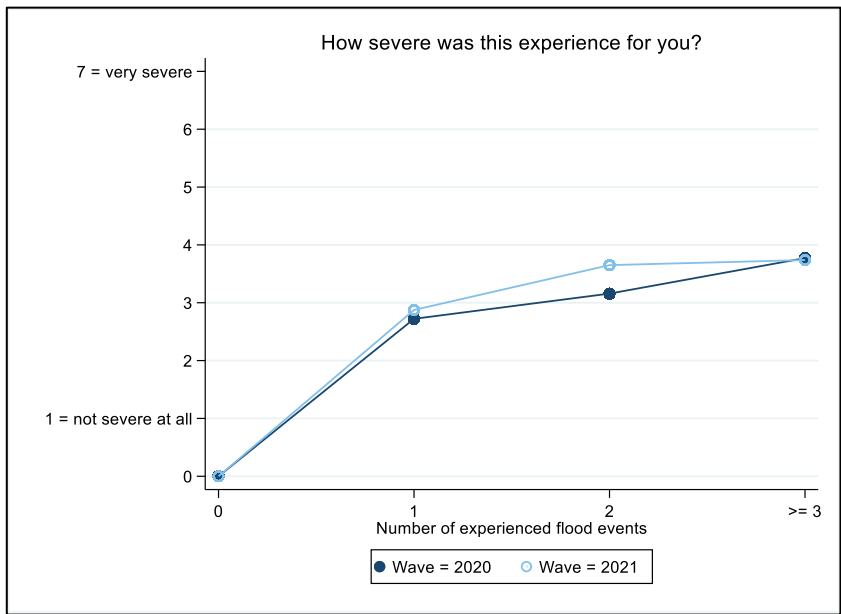
Figure 8. Descriptive analysis of the relationship between perceived severity of the last flood and flood experience, both survey waves

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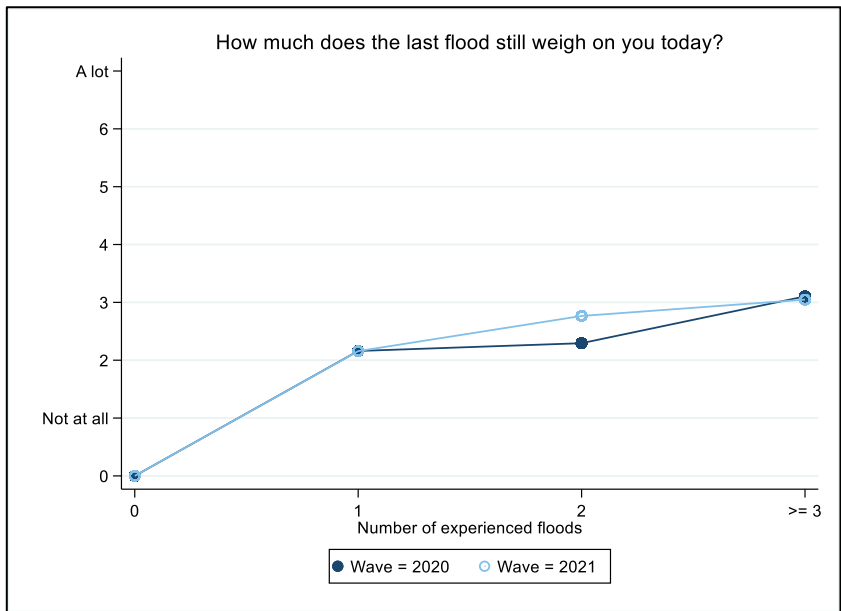
Figure 9. Descriptive analysis of the relationship between still existing burden from the last flood and flood experience, both survey waves

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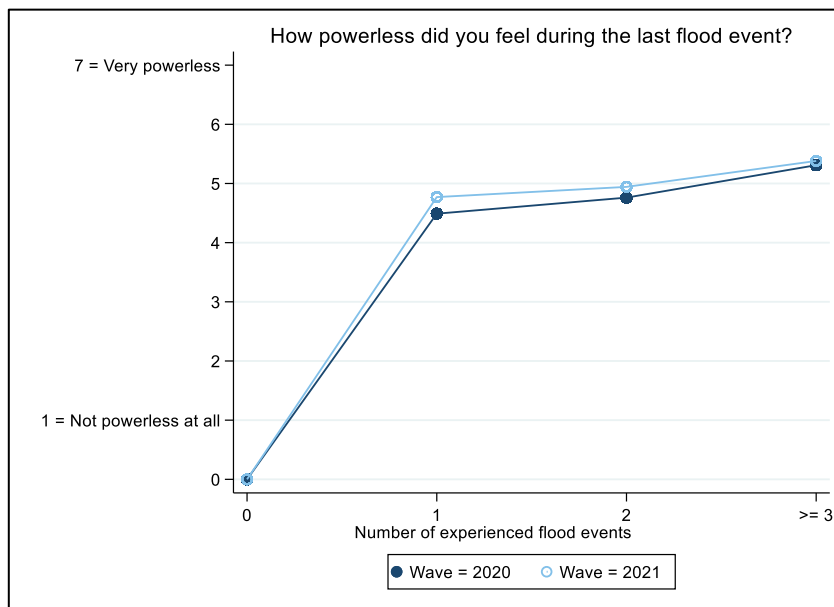


Figure 10. Descriptive analysis of the relationship between felt powerlessness during the last flood and flood experience, both survey waves

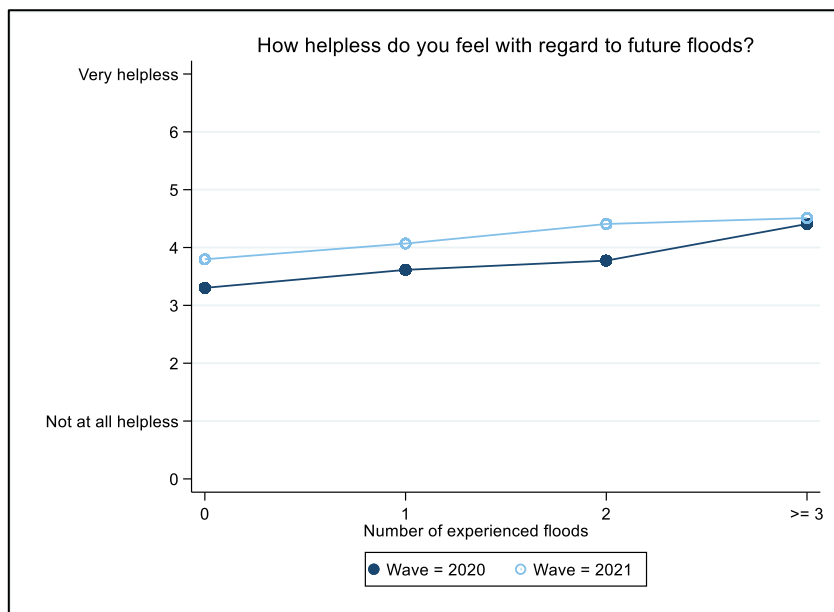



Figure 11. Descriptive analysis of the relationship between expected helplessness during the next flood and flood experience, both survey waves

4.2 Empirical analyses

4.2.1 Adaptation behavior

The results of the regression analyses presented in table 6 show that FFE plays a fundamental role in impacting adaptive behavior. Both in terms of effect strength, but also in terms of statistical significance. According to the regression analyses, there is only a statistically significant linear relationship between FFE and adaptive behaviors. Therefore, only the linear form of the experience variable is included in the final model. The regression table, which includes the squared and cubic forms of the mean-centered experience variable, can be found in the appendix (table C2). The decision to eliminate the squared and

cubic variables is also supported by the values for the AIC and BIC, which are, in any case, lower for the models that only include the linear experience variable. The AIC and BIC measures can be found in the appendix (table D1), too.

For a better understanding of the outcomes, the marginal effects instead of the odds ratios (OR) are presented. The original regression tables, including the OR, can be found in the appendix (table C1). The marginal effects do not vary fundamentally between the different actions. The FFE's most substantial effect exists on whether individuals have stored their valuable goods more safely, with a marginal effect (ME) of 0.07. This indicates that a person with one more flood experience is 7%-points more likely to have stored their valuable good more safely than a comparable person with one experience less. The most negligible impact exists regarding the fact if people have taken out insurance (ME = 5%-points). However, the descriptive analyses in figure 4 suggest that this result has to be seen with caution since the relation between the number of experienced flood events and the percentage of individuals taking out insurance does not follow a clear pattern.

Table 6. Marginal effects of independent variables on adaptive behavior at the means

	Adaptation actions general	Safe storage	Property-level adaptation	Insurance
Model	Binary logistic	Binary logistic	Binary logistic	Binary logistic
Age	-0.0006	0.003**	0.0006	0.001
Tenure (0 = tenant, 1 = owner)	0.011	0.03	0.3	0.02
Building_single	0.15**	0.06	0.09**	0.12**
Building_semidetached	0.07*	0.04	-0.03	-0.02
Building_apartment	-0.02	-0.03	-0.09**	-0.19**
Building_double	0.1**	0.03	0.08	0.05
Experience	0.06**	0.07**	0.06**	0.05**
Flood21	0.03	-0.01	-0.01	0.01
N	2844	2719	2668	2710

*p<0.05; **p<0.01

4.2.2 Self-reported resilience

Compared to the influence on behavior, the impact of FFE on self-reported resilience is more diverse.

For the reported capacity to resist the aftermaths of a flood event, the impact of the flood experience depends on the reference event that is asked for: reported resilience during the past event or regarding future events. A statistically significant non-linear relationship exists between the variables *reported severity* of and *felt powerlessness* during the last flood event and FFE. However, if the reference event is a future flood, there is no statistically significant impact, neither linear nor quadratic nor cubic. For the ability to recover from a past flood event, in terms of how much an individual still perceives the last flood event as a burden, the FFE has a statistically significant positive impact. This indicates that people need more time to recover when having experienced more flood events. As for the felt powerlessness and perceived severity of the last flood event, the outcomes of the regression analyses suggest a non-linear relationship between FFE and self-reported recovery.

To conclude, FFE has a statistically significant negative impact on resilience by lowering self-reported resistance during and recovery from the last flood event. Additionally, the impact of FFE is only statistically significant when measuring its impact on self-reported resilience during past events. Same counts for nonlinearity.

Table 7. Linear regression output self-reported resilience

Self-reported resilience	Reported severity	Powerlessness	Helplessness	Still existing burden
Age	0.01**	0.01**	0.01**	0.01**
Tenure (0 = tenant, 1 = owner)	-0.06	0.006	-0.09	-0.03
Building_single	0.03	0.02	0.2	0.17
Building_semidetached	0.24	0.09	0.06	0.18
Building_apartment	0.11	-0.01	0.04	0.04
Building_double	0.22	0.18	0.3	0.27*
Experience	0.91**	1.03**	0.19	0.65**
Cent.Exp^2	-0.98**	-1.88**	-0.04	-0.73**
Cent.Exp^3	0.36**	0.78**	0.05	0.32**
Property-level adaptation	0.18**	-0.02	-0.16	0.06
Flood21	-0.02	0.12	0.62**	0.14*
Constant	1.19**	3.15**	2.88**	0.74
R^2	0.56	0.7	0.05	0.47
N	2056	2042	2088	2056

*p<0.05; **p<0.01

A comparison of the fitted values from the estimation and the real average values can be found in the appendix (figure B1-B4).

4.3 Including past adaptation behavior in the analysis of self-reported resilience

The analyses for the first and second research questions show that even though more experienced people are better prepared, their self-reported resilience decreases. Since this outcome is paradoxical, the interest of the third research question is to bring anticipated helplessness during a future flood and past adaptive behavior into relation. Therefore, the adaptation actions safe storage, insurance, and property-level adaptation are included as independent variables in the model, taking anticipated helplessness during a future flood event as the outcome variable. The regression analysis shows that property-level adaptation in the past has a statistically significant negative influence on individuals' felt helplessness, whereas people who have previously taken out insurance feel statistically significantly more helpless. There is no statistically significant influence on storing important goods more safely.

Table 8. Linear regression output helplessness, including past adaptation behaviors as independent variables

	Helplessness
Age	0.01**
Tenure (0 = tenant, 1 = owner)	-0.1
Building_single	0.19
Building_semidetached	0.09
Building_apartment	0.1
Building_double	0.32
Experience	0.17
Experience^2	-0.03
Experience^3	0.05
Safe storage	-0.1
Insurance	0.29**
Property-level adaptation	-0.21*
Flood21	0.61**
R^2	0.05
N	2057

*p<0.05; **p<0.01

5   Discussion

5.1   Discussion of results

330   The outcomes of our analysis show that FFE has a positive impact on adaptive behavior, a negative impact on self-reported resilience, and that the influence of past behavior on future resilience depends on the measure.

RQ 1: *How does FFE motivate people to undertake adaptive actions?*

Drawing conclusions from the existing literature and research output, the assumption was that FFE motivates adaptive behaviors (Siegrist and Gutscher, 2008; Kuhlicke et al., 2020a; Osberghaus, 2017; Hudson et al., 2017). The statistical analyses
335   of our paper support that assumption and previous findings.

A particularly interesting part of our study is that conclusions can be drawn from the chronological sequence of undertaken adaptation measures. Even though the regression analysis indicates that the relationship between FFE and behavior is generally linear, the bivariate analyses indicate some differences in timing. The first flood event has the most substantial impact on storing valuable goods more safely. The second flood on whether people have taken out insurance, and the (at least) third flood
340   event on property-level adaptation. There could be several reasons for this order. First, the late shift of property-level adaptation could be because people still had to develop knowledge of appropriate measures, as discussed in Marg (2016: 497). Second, economic considerations might play a role as property-level adaptation comes with financial investments. It has also been shown that the respondents in our sample expect the greatest effort in adaptation at the property-level. Consequently, its perceived usefulness may only increase with the number of experienced floods, when people are more likely to perceive
345   flooding as a reoccurring risk. Accordingly, the cost-benefit ratio might change with an increasing number of experienced floods, which positively impacts adaptive behavior at the property-level. To put it the other way, after the first flood event, that evaluation could result in favoring a rather low-effort action, such as storing valuable goods more safely. To sum up, the selection process of the appropriate adaptive behavior by comparing the needed protection level, necessary efforts, and available capacities might depend on the number of floods experienced. Lastly, as outlined in existing theories, the impact of
350   experience on adaptive behavior could also be through the canal of risk perception (Grothmann & Reusswig, 2006; Heidenreich et al., 2021; P. Hudson et al., 2020; Maddux & Rogers, 1983). However, this has not been tested in our study and might be an objective for future work.

RQ 2: *How does FFE influence an individual's resilience in terms of self-reported capacity to resist and recover?*

355   The investigation of existing literature and research outputs has shown that the influence of FFE on resilience does not follow a clear pattern. Whereas some studies conclude that an individual's resilience to flood events increases when experiencing more flood events through, for example, learning effects (Connor and Davidson, 2003; Kuhlicke et al., 2020a; Kuang and Liao, 2020) and adaptive actions (Bubeck et al., 2012; Thieken et al., 2007), others come to result that resilience decreases due to psychological consequences (Bubeck & Thieken, 2018; Masson et al., 2019; Terpstra, 2011) or an under- or overestimation
360   of the risk (Burton et al., 1978; Mol et al., 2020). The empirical investigation of this paper shows that resilience, in terms of self-reported resistance during past events as well as future events, and reported recovery after the last event, decreases when people experience multiple flood events. Comparing the reported expectation regarding individuals' resistance to future events with the reported resistance during the past event experienced indicates two major differences. First, the reported resilience during the last flood event most substantially decreases after the first flood experience. Contrarily, the most substantial decrease
365   with regard to future floods happens after the third event. Second, people tend to have higher values for the felt powerlessness during the last flood event than for the anticipated helplessness during future events. One explanation for this outcome could be that adaptive behavior has a mediating impact. Our analyses show that adaptation behavior is positively influenced by flood experience. Accordingly, people that have experienced more floods have more likely undertaken actions and might therefore

feel more protected and less helpless with regard to future floods, as it substantially adds to the reduction of flood-related damages (Bubeck, Botzen, & Aerts, 2012; Kreibich et al., 2015; Thieken et al., 2007). However, our investigations for the third research question show that this explanation would only hold for the action of property-level adaptation as taking out insurance and storing important goods more safely do not have a statistically significant negative impact on reported helplessness. Lastly, under the assumption that both helplessness and powerlessness conceptualize the loss of control (Drew, 1990), the results could imply that people are better at memorizing past loss of control than assessing future loss of control. Aligning with that, individuals could perceive the past loss of control as more severe than they imagine the future loss.

The other pillar of resilience, the capacity to recover, follows a similar pattern as the capacity to resist future events. Accordingly, the most substantial development in the reported recovery occurs when individuals experience (at least) three flood events, with people having the most experience indicating the most long-lasting recovery. A possible explanation could be that people with more flood events are still busy with coping work related to earlier flood events. Additionally, the strain put on them from earlier floods might be difficult to separate from the strain that stems only from the last flood event.

The result that individuals' resilience decreases with the number of experienced flood events contradicts the development of resilience through experiences, as argued by Connor & Davidson (2003) and partly found in Kuhlicke et al. (2020a).

Linking the results of the first and second research questions reveals that, even though individuals indicate that they perceived their first flood event as severe and felt powerless, only the share of people that have adapted the most low-threshold behavior of storing essential goods more safely changes substantially. One reason could be the psychological factor of optimism bias (Gifford, 2011). Applied to flood events, could this mean that people assume that the likelihood of experiencing a flood event decreases after being affected once. Uncertainty could also play a role (Gifford, 2011). Accordingly, experiencing one flood event might not deliver sufficient predictions of future events and their frequency for people to act. That could explain the shift in taking out insurance after the second flood event. After a reoccurring flood, more people may perceive it as a persisting risk and undertake actions, as described in Grothmann et al. (2013).

RQ 3: *How does past adaptive behavior impact self-reported resistance to future flood events?*

The assumption was that adaptive behaviors increase the self-reported capacity to resist future events since people might feel better protected. Additionally, before deciding on an action, the anticipated information-seeking process could result in better knowledge of flood risks and possible actions during an event, leading to a higher perceived capacity to resist future events. However, this is not proved by the results of our study.

The empirical analyses show that undertaking property-level adaptation and storing essential goods more safely have a statistically negative impact on feeling helpless. However, only the influence of property-level adaptation is statistically significant. Individuals who have taken out insurance feel statistically significantly more helpless. There are several possible explanations for that outcome. First, it might be the case that people living in a high-risk area are more likely to take out insurance and generally feel more helpless. To consciously take that as an explanation, the analysis would have to include a measure for objective risk. Second, the reason could be the chronological order of flood hazards and the effect of the insurance. Accordingly, insurance is a post-hazard coverage that financially compensates people when a hazard has happened (a household receives financial assistance from their insurance after their home was damaged by a flood). It could be the case that assumptions about feelings during the flood rather trigger the feeling of helplessness than flood-inherent obstacles after the event. Third, the reason could lie in the nature of insurance, covering damages financially. The feeling of helplessness might be rather influenced by the fear of losing personal belongings or the fear of damaged public infrastructure than the damage of goods that private insurance can compensate for (Grothmann, 2005). Fourth, the reason could be a matter of immaterial investments. Accordingly, even though people get financially compensated, the organization of reconstruction remains mainly their responsibility (DKKV, 2003; cited in Marg, 2016: 38). This could be related to high time investment and physical and psychological efforts.

To conclude, our study shows that with FFE in terms of the number of experienced flood events, individuals have lower self-reported capacities to resist during a flood event and a slower self-reported recovery. These developments are accompanied by increasing adaptive behavior. Consequently, people are better adapted to flood events in physical terms, but their psychological preparedness does not follow.

5.2 Limitations

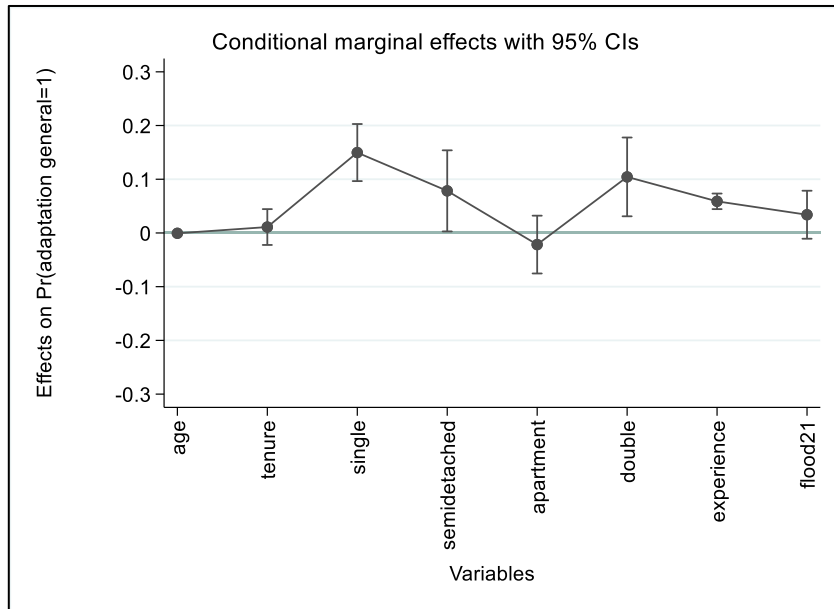
One limitation is that people were not asked for their exact number of flood events experienced after they had experienced three. Due to that, the impact of three experienced flood events might be overestimated since people with more flood experience are also in this group. Same counts for the difference between individuals with two and three experienced flood events. However, a problem with asking people for their exact number of experienced flood events could be that people do not correctly remember the number of floods leading to biased results. Additionally, when asking for the correct number, the sample sizes of the groups of people with higher numbers of experienced floods might be too small and different from each other to obtain comparable results. A second limitation is that the dataset has no information on the objective risk of the last flood people experienced. Therefore, it is not known how severely they were impacted, which would be valuable information to objectively compare people's self-reported resilience. External data would have to be collected to get more information, for example, by applying flood hazard maps to the surveyed streets. Lastly, it is unknown if people took adaptive actions before or after the last flood event.

5.3 Implications and future research

As discussed in the limitations part, there is no variable in the model that measures the impact of objective risk on the outcome variables. Therefore, in a future investigation, it might be interesting to include a measure for the objective severity to examine if that might have a different impact than the number of experienced floods. Adding to this, the investigation of the impact of flood experience on resilience shows that other factors must positively impact resilience independently of experience. These could be factors related to personality, neighborhood effects, and the physical severity of floods. A future investigation could include these factors. Bringing these outcomes into relation with existing research supports that it remains a scientific goal to understand better the development of resilience and how other factors impact it.

6 Summary and conclusions

The paper's central question was how the number of floods experienced impacts adaptive behavior and self-reported resilience. The result is that flood experience has a statistically significant positive impact on adaptive behavior and generally a statistically significant negative impact on self-reported resilience. The decrease in resilience does not happen linearly but stagnates after the second experienced flood event and increases again after the third. To conclude, the group that has adapted the most is, at the same time, the group with the lowest self-reported resilience. An assumption is that experience also influences risk perception, decreasing self-reported resilience. However, this does not explain why the most adapted people need the most recovery time. Here, more research is needed. To sum up, the field of natural hazard research is very well presented in science. Particularly the field of adaptive behavior has been investigated to a large extent. However, the field of resilience and particularly the drivers of it, still demands much interdisciplinary research to get better insights. Here, the paper contributes to existing knowledge by investigating the impact of the number of experienced flood events on self-reported resilience. Due to the sample composition of having different groups depending on the number of experienced flood events, conclusions can be drawn on the timely sequence of the change in self-reported resilience.

Appendix A: Marginal effects on adaptive behavior

455   **Figure A1**. Conditional marginal effects on the probability of having adapted any of the measures

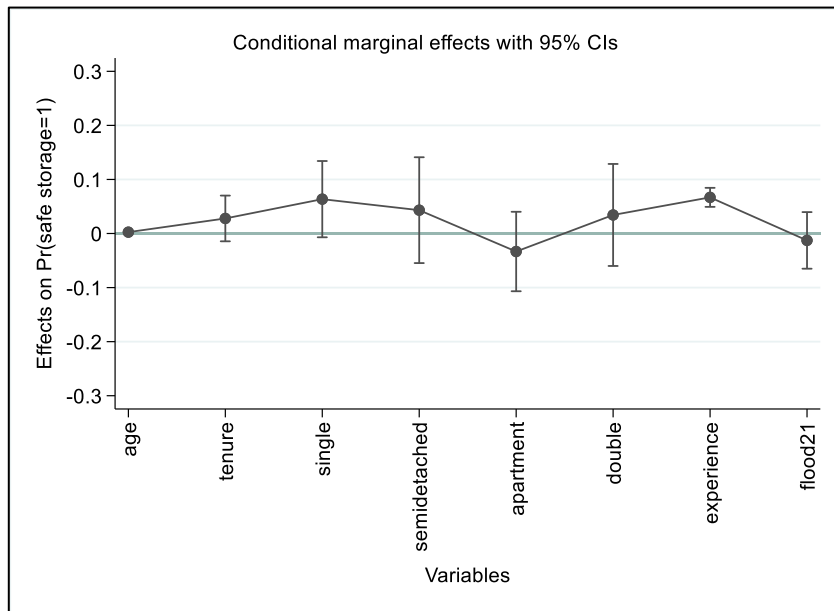
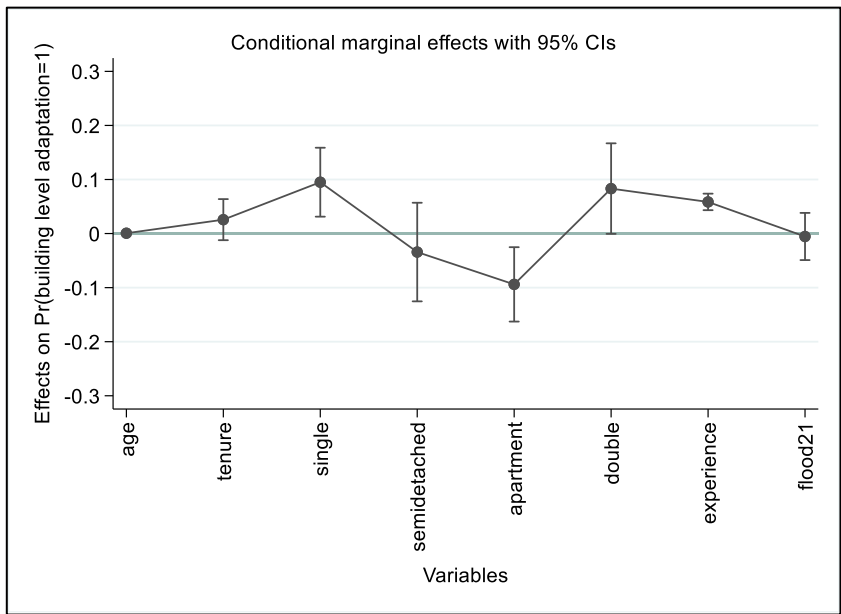



Figure A2. Conditional marginal effects on the probability to have stored valuable goods more safely

460   **Figure A3**. Conditional marginal effects on the probability to have undertaken property-level adaptation

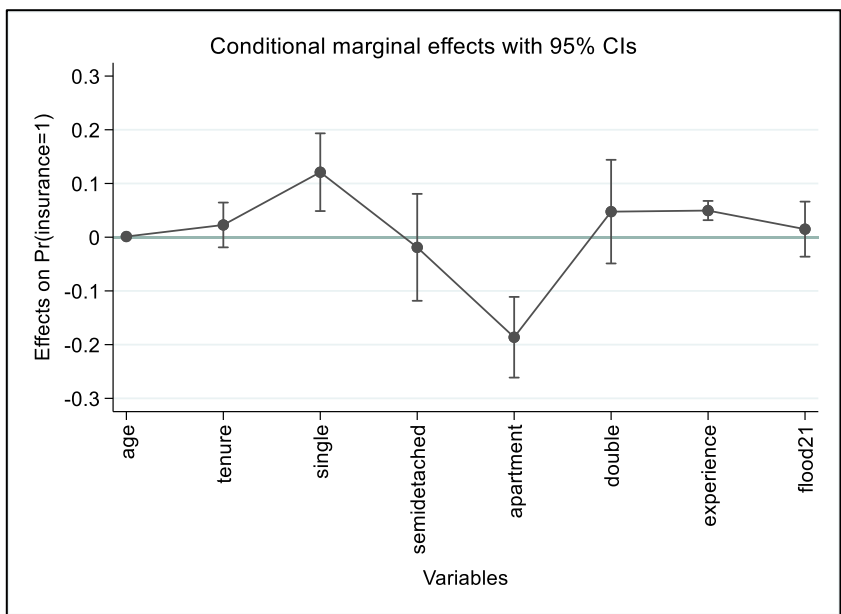



Figure A4. Conditional marginal effects on the probability of having taking out insurance

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 Appendix B: Comparison of mean outcomes of the fitted model and real data

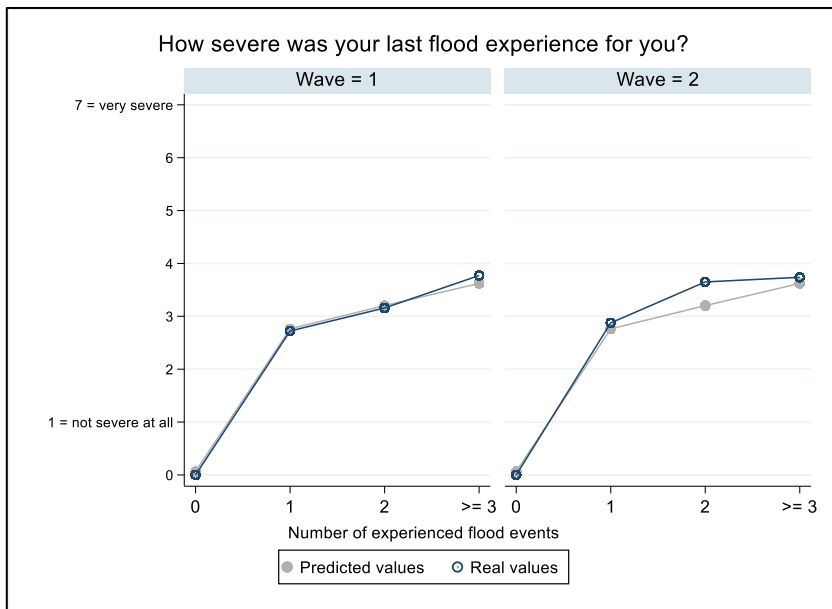
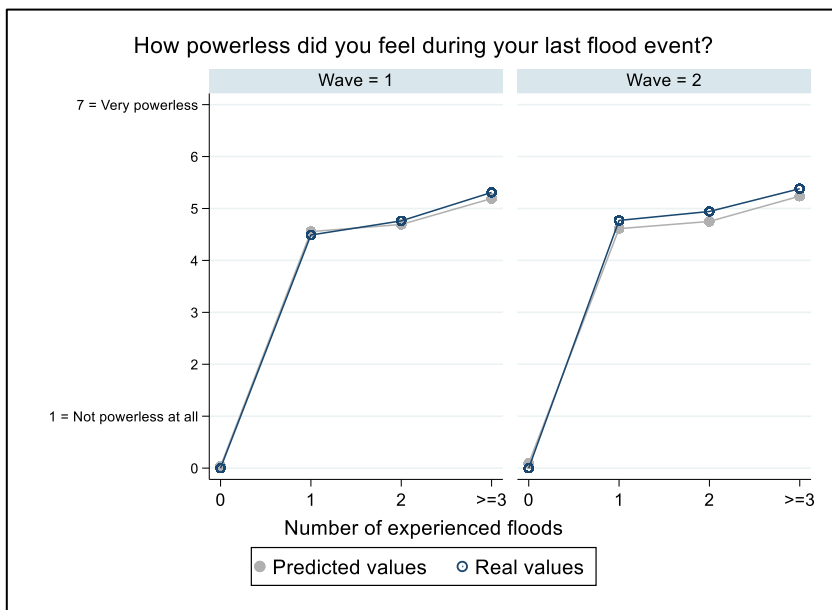



Figure B1. Comparison mean outcomes of the fitted model and real data: severity of last flood event

 Figure B2. Comparison mean outcomes of the fitted model and real data: felt powerlessness during the last flood

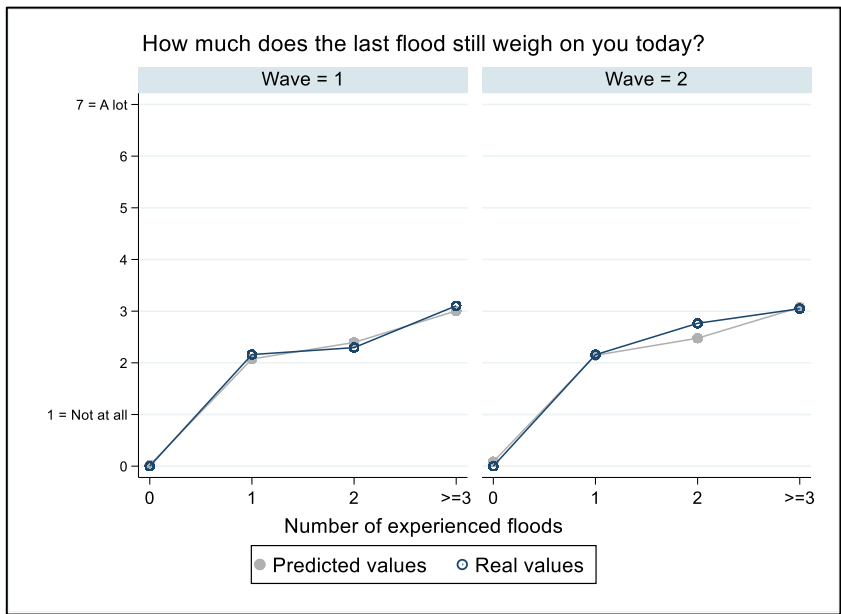



Figure B3. Comparison mean outcomes of the fitted model and real data: still existing burden from the last flood

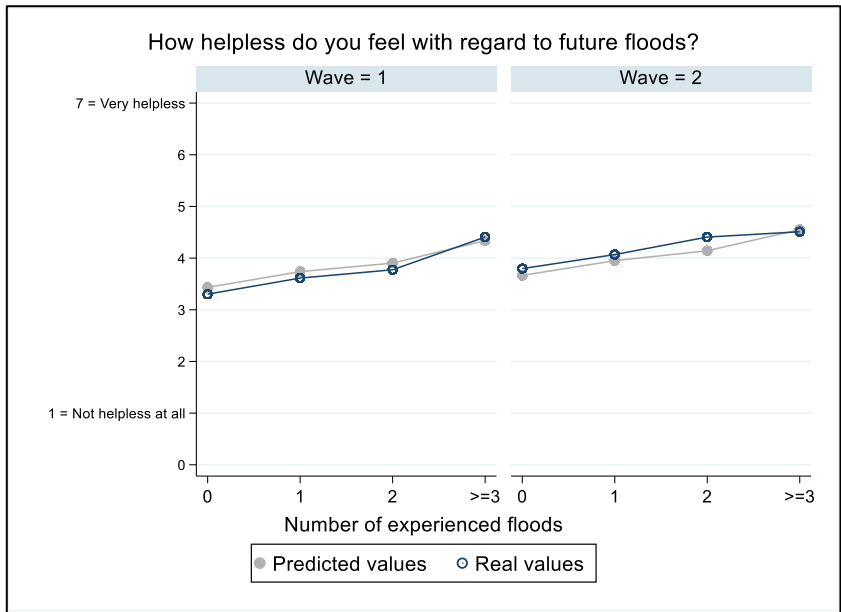



Figure B4. Comparison of mean outcomes of the fitted model and real data: felt helplessness with regard to future floods

Appendix C: Regression output table: adaptive behavior

Table C1. Regression output table: adaptive behavior, including odds ratios

	Adaptation actions general	**Safe storage**	**Property-level adaptation**	**Insurance**
Model	Binary logistic	Binary logistic	Binary logistic	Binary logistic
Age	0.99	1.02**	1	1.01
Tenure (0 = tenant, 1 = owner)	1.13	1.21	1.3	1.24
Building_single	4.97**	1.53	2.6**	3.2**
Building_semidetached	2.32*	1.34	0.71	0.8
Building_apartment	0.79	0.8	0.39**	0.17**
Building_double double	3.06**	1.26	2.3	1.58
Experience	1.88**	1.57**	1.8**	1.61**
Flood21	1.44	0.92	0.95	1.15
Constant	1.73	0.25	0.02	0.66
N	2844	2719	2668	2710

*p<0.05; **p<0.01

Table C2. Regression output table: adaptive behavior, including odds ratios and non-linear forms of experience variable

	Adaptation actions general	Safe storage	Property-level adaptation	Insurance
Model	Binary logistic	Binary logistic	Binary logistic	Binary logistic
Age	0.99	1.02**	1	1.01
Tenure (0 = tenant, 1 = owner)	1.12	1.21	1.31	1.24
Building_single	4.97**	1.54	2.61**	3.18**
Building_semidetached	2.31*	1.36	0.73	0.84
Building_apartment	0.79	0.81	0.39**	0.17**
Building_double	3.05**	1.27	2.39*	1.56
Experience	2**	1.77**	1.82*	1.95*
Experience^2	1.01	1.13	1.23	1.05
Experience^3	0.97	0.92	0.95	0.91
Flood21	1.44	0.92	0.95	1.16
Constant	3.03	0.3**	0.02**	0.83
N	2238	2143	2105	2140

*p<0.05; **p<0.01

Appendix D: AIC and BIC values, depending on the inclusion of experience variables

Table D1. AIC values depending on the inclusion of squared and cubic forms of the experience variable

AIC/ BIC	With curvilinearity	Without curvilinearity
Adapted any action	2693.77 / 2765.21	2689.87 / 2749.4
Safe storage	3427.01 / 3497.91	3424.04 / 3483.12
Insurance	3078.39 / 3149.24	3075.19 / 3134.24
Property-level adaptation	2809.4 / 2880.07	2808.28 / 2867.17

Data and code availability: Data used for this study and codes for the analyses can be made available for scientific use upon request to the author.

Author contributions: LK, SK, TM, and CK conceptualized this study. SK, TM and CK have collected data. LK and TM developed the model. LK performed the formal analysis and prepared the results. The original draft was written by LK and reviewed and edited by the co-authors. LK prepared the final manuscript for submission.

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