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LETTER

# Hurricane adaptation behaviors in Texas and Florida: exploring the roles of negative personal experience and subjective attribution to climate change

**Gabrielle Wong-Parodi**[1,2,*] **and Dana Rose Garfin**[3,4]

[1] Department of Earth System Science, Stanford University, Stanford, CA, United States of America
[2] Woods Institute for the Environment, Woods Institute for the Environment, Stanford University, Stanford, CA, United States of America
[3] Sue & Bill Gross School of Nursing, University of California, Irvine, CA, United States of America
[4] Program in Public Health, University of California, Irvine, CA, United States of America
[*] Author to whom any correspondence should be addressed.

**E-mail:** gwongpar@stanford.edu

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## Abstract

Understanding the motivation to adopt personal household adaptation behaviors in the face of climate change-related hazards is essential for developing and implementing behaviorally realistic interventions that promote well-being and health. Escalating extreme weather events increase the number of those directly exposed and adversely impacted by climate change. But do people attribute these negative events to climate change? Such subjective attribution may be a cognitive process whereby the experience of negative climate-change-related events may increase risk perceptions and motivate people to act. Here we surveyed a representative sample of 1846 residents of Florida and Texas, many of whom had been repeatedly exposed to hurricanes on the Gulf Coast, facing the 2020 Atlantic hurricane season. We assessed prior hurricane negative personal experiences, climate-change-related subjective attribution (for hurricanes), risk appraisal (perceived probability and severity of a hurricane threat), hurricane adaptation appraisal (perceived efficacy of adaptation measures and self-efficacy to address the threat of hurricanes), and self-reported hurricane personal household adaptation. Our findings suggest that prior hurricane negative personal experiences and subjective attribution are associated with greater hurricane risk appraisal. Hurricane subjective attribution moderated the relationship between hurricane negative personal experiences and risk appraisal; in turn, negative hurricane personal experiences, hurricane risk appraisal, and adaptation appraisal were positively associated with self-reported hurricane personal adaptation behaviors. Subjective attribution may be associated with elevated perceived risk for specific climate hazards. Communications that help people understand the link between their negative personal experiences (e.g. hurricanes) and climate change may help guide risk perceptions and motivate protective actions, particularly in areas with repeated exposure to threats.

## 1. Introduction

Understanding what motivates the public to adopt personal household adaptation behaviors (e.g. having an evacuation plan, purchasing flood insurance) in response to climate-change-related hazards (e.g. extreme weather events) is essential for developing and implementing behaviorally realistic interventions to improve collective well-being and health. The experience of extreme weather (e.g. hurricanes) and other climate-related events, which are predicted to increase over this century [1], may be signals that climate change presents direct personal risks and motivates adaptive behaviors. Indeed, such perceptions are important antecedents of behaviors that mitigate harm from climate-change-related hazards [2–7]. Subjective attribution [4], which research suggests is an important component of overall climate change

perceptions [8, 9], is an understudied but potentially important cognitive process that may guide risk appraisal and the adoption of personal household adaptation behavior.

In this study, we examine how negative personal experience with climate-change-related threats and subjective attribution are associated with appraisal processes and self-reported personal household adaptation behavior, expanding upon on Grothmann and Patt's (2005) process model of private proactive adaptation to climate change (MPPACC). We explored these relationships in the context of hurricanes, often associated with climate change in the media [10]. We focused on two self-reported personal household adaptation behaviors—anticipatory learning [11] and household protection—pertinent to hurricanes. These are actions that individuals can take in response to the impacts of climate change [12] and whose relationship to subjective attribution is understudied. At the time of our study, experts [13] projected four hurricanes would develop into major hurricanes—categories 3, 4 or 5—in the Atlantic with wind speeds of 111 mph or higher. There was also a 69% chance that one of these would make landfall along the US coast, imperiling the Gulf Coast and Atlantic states. In this context, we surveyed a longitudinal, representative sample of 1846 residents of Florida and Texas, many of whom had been repeatedly exposed to prior hurricanes on the Gulf Coast, facing the 2020 Atlantic hurricane season at the time of the survey.

## 2. Literature review

Climate change has contributed and will likely continue to contribute to the intensification of storm events like hurricanes due to warming temperatures [14–16]. Hence, experience with environmental extremes like a major hurricane or intense wildfire is one way individuals are exposed to the impacts of climate change [1]. Research suggests such experiences are often associated with climate change risk appraisals [7, 17–20] and adaptation intentions or self-reported adaptation behavior [6, 7, 21–24], but not always [25]. For those experiences to be related to climate change risk appraisals, and ultimately adaptation behavior, individuals may need to make a subjective attribution [4] that their experiences with environmental extremes are caused by or a signal of climate change. For example, in a survey of 845 private forest owners, Blennow *et al* (2012) found a positive association between extreme weather subjective attribution and self-reported adaptation of forest management measures in response to climate change [24]. Yet not all experiences with extremes are equal: some may suffer from property loss or injury while others remain relatively unscathed. Those who suffer from a greater number of [26] negative outcomes resulting from hazard exposure tend to express greater hazard risk perceptions [27–29]. Thus, it is likely that more negative experiences with major hurricanes will be associated with greater hurricane risk appraisal. Moreover, this pattern may be similar for subjective attribution; more negative experiences with major hurricanes may be positively associated with greater hurricane subjective attribution.

Emerging evidence suggests that climate change beliefs are positively associated with perceptions about the severity of weather-related extremes, with perceptions of severity a key component of overall hazard risk appraisal [30]. Hoogendoorn *et al* (2020) found the belief in anthropogenic climate change was positively associated with the perception that the impacts of the 2017 hurricane season in the United States were worse and caused more suffering than they would have in the absence of climate change [31]. As subjective attribution of extreme weather events to climate change reflects beliefs about climate change; it is likely that greater hurricane subjective attribution agreement will be associated with greater hurricane risk appraisal. In the context of flooding, Ogunbode *et al* (2019) found that subjective attribution modulated the association between personal flooding experience and risk appraisal [4]. Those who expressed high or moderate levels of flooding subjective attribution held greater climate risk perceptions than those who expressed low levels of subjective attribution. Thus, hurricane subjective attribution may moderate the association between hurricane negative personal experiences and hurricane risk appraisal.

Evidence suggests that negative personal experience with climate-change-related hazards is associated with adaptive behavior, such as household protection. For example, Bradford *et al* (2012) found flood experience and self-reported flood preparedness were positively associated [32]. Osberghaus (2015) found self-reported flood-related household protections such as moving valuables or installing water barriers increased with previous flood damage experience [33]. In the context of landscape planning, Blennow *et al* (2021) observed that negative, as well as positive, experiences with climate-change-related hazards were associated with climate adaptation [34]. Growing evidence also suggests that stronger risk appraisals (e.g. perceptions regarding the probability and severity [7, 30, 35] of a threat) and adaptation appraisals (e.g. perceptions regarding the efficacy of adaptation measures and self-efficacy [34, 36–38] to deal with a threat) are associated with stronger adaptation intentions and behaviors, especially those related to household protection across a range of environmental threats. As such, hurricane negative personal experiences, hurricane risk appraisal, and hurricane adaptation appraisal may be positively

associated with hurricane personal household adaptation. While subjective attribution has been previously associated with environmental views such as support for climate policy [39, 40], less is known about its relationship to personal household adaptation behaviors. Given the possible positive association between hurricane subjective attribution agreement and hurricane risk appraisal [8, 31], it is likely that greater subjective attribution agreement will be associated with greater self-reported hurricane personal household adaptation.

## 3. Research aims and hypotheses

This study aims to understand how hurricane negative personal experience relates to hurricane subjective attribution agreement and hurricane risk appraisal, and how these factors, along with hurricane adaptation appraisal, are associated with self-reported hurricane personal household adaptation. As shown in figure 1, we hypothesize:

H1: More hurricane negative personal experiences will be associated with greater hurricane subjective attribution agreement.

H2: Greater hurricane subjective attribution agreement will be associated with greater hurricane risk appraisal.

H3: (a) More hurricane negative personal experiences will be associated with greater hurricane risk appraisal. (b) Hurricane subjective attribution will moderate the positive relationship between negative hurricane personal experiences and hurricane risk appraisal.

H4: More hurricane (a) negative personal experiences, (b) subjective attribution agreement, (c) risk appraisal, and (d) adaptation appraisal will be associated with more self-reported hurricane personal household adaptation.

## 4. Methods

### 4.1. Sampling

Data were collected as part of an ongoing longitudinal study of Texas and Florida residents' responses to hurricanes and other extreme events [41]. Individuals were recruited from the Ipsos KnowledgePanel, a nationally representative panel of adults in the United States that employs address-based sampling methods. A total of 2507 current and former panelists who we surveyed in tandem with major extreme weather events (e.g. Hurricanes Harvey, Irma, and Michael) since 2017 were invited to participate; 1846 completed the survey between 14 and 27 May 2020 (pre-2020 Atlantic hurricane season) for a response rate of 73.6%. The median completion time of the survey was 17 min. Qualified active panelists received a cash-equivalent incentive of $15 ($n = 1760$) and qualified withdrawn panelists received a cash-equivalent incentive of $20 ($n = 86$).

### 4.2. Protection of human subjects

The Institutional Review Boards of Stanford University and the University of California, Irvine approved all procedures.

### 4.3. Variables

#### *4.3.1. Self-reported hurricane personal household adaptation*

Two types of self-reported personal household adaptation behaviors were assessed using an 11-item checklist adapted from Wong-Parodi and Feygina (2018) [42]: anticipatory learning and household protection. Learning was assessed through one option: 'learn about the risks from hurricanes and how to prepare for them.' Household protection was assessed through ten options: 'make a plan for safe places to move vehicle(s) in the event of a hurricane,' 'put together an emergency kit (e.g. food, medical supplies, flashlight),' 'develop and practice an emergency plan,' 'identify shelter locations in the event of an evacuation,' 'copy important documents,' 'consider hurricane forecasts when making travel plans,' 'get a row boat or inflatable raft,' 'make my home more hurricane proof (e.g. install hurricane shutters, sand bags),' 'have flood insurance,' and 'other, please specify.' For each item, participants indicated whether they had taken that action to prepare for the 2020 Atlantic hurricane season. Responses were summed to create an overall count measure of self-reported hurricane personal household adaptation behaviors.

#### *4.3.2. Hurricane negative personal experiences*

Prior to May 2020, hurricane negative experiences were assessed using a six-item checklist, which included: 'I lost property in a hurricane or its aftermath,' 'My home was totally destroyed in the hurricane or its aftermath,' 'I was injured in the hurricane or its aftermath,' 'I lost a pet in the hurricane or its aftermath,' 'I knew someone who was injured in a hurricane or its aftermath', and 'I knew someone who was killed in a hurricane or its aftermath,' (0 = did not occur, 1 = occurred). Responses were summed.

#### *4.3.3. Subjective attribution*

Hurricane subjective attribution was assessed by asking respondents to rate their agreement with the statement: 'Climate change will make the 2020 hurricane season worse.' Endpoints were 1=strongly disagree, 5=strongly agree.

#### *4.3.4. Hurricane risk appraisal*

Respondents reported (a) how likely they think it is that their well-being (health, financial, emotional, social, etc) will be impacted by a major hurricane this year (perceived probability) (endpoints were 1 = not at all likely, 5 = extremely likely) and (b) how much they think their well-being would be harmed if a major hurricane were to occur in their community (perceived severity) (endpoints were 1 = not at all,

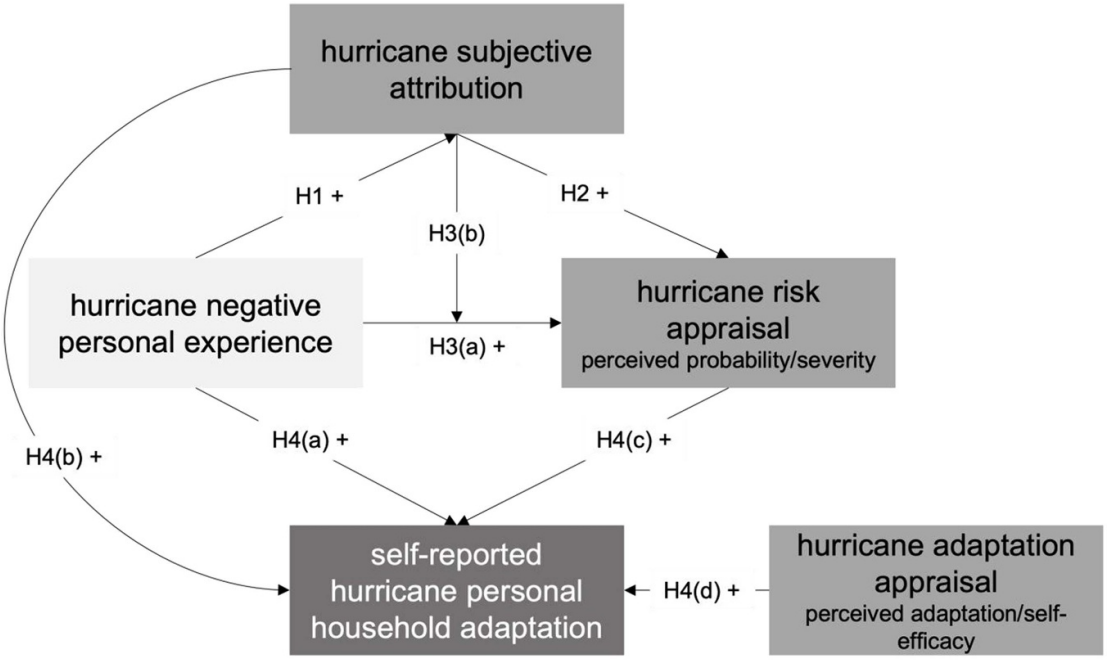



**Figure 1.** Simplified conceptual model based on Grothmann and Patt's (2005) process MMPACC demonstrating the hypothesized relationships and made specific to hurricanes.

5 = a great deal). Items 1 and 2 were averaged following the conceptualization of the construct of 'risk appraisal' as described by the Extended Parallel Process Model [37, 38, 43], and internal consistency was 'moderate' (Cronbach's $\alpha = 0.75$) [44].

*4.3.5. Hurricane adaptation appraisal*

To assess self-efficacy, respondents reported how well they thought they could perform actions to prepare for the 2020 Atlantic hurricane season (endpoints: 1 = not well at all, 5 = extremely well). To assess response efficacy, respondents reported how much they thought adopting hurricane mitigation behaviors would prepare them for the 2020 Atlantic hurricane season (endpoints: 1 = not at all, 5 = completely). Items 1 and 2 were averaged following the conceptualization of the construct of 'adaptation appraisal' as described by the Extended Parallel Process Model [37, 38, 43] and internal consistency was marginal (Cronbach's $\alpha = 0.68$) [44]. Higher Cronbach's $\alpha$ indicates that participants' individual responses were correlated, signaling that items measure an overarching construct (e.g. adaptation appraisal), although not necessarily an identical component of that construct (e.g. self and response efficacy) [45]. Despite the lower than ideal alpha, based on theory and for parsimony, we combined these two items into a single measure.

*4.3.6. Demographics*

Prior to the start of the study, upon entry into the KnowledgePanel, respondents provided information about their demographics including age, education, gender, income, ethnicity, and political party identification. These demographics are updated by Ipsos regularly.

See the supplemental materials section (available online at stacks.iop.org/ERL/17/034033/mmedia) for the exact wording of the survey questions.

### 4.4. Weighting

Post-stratification weights were constructed iteratively, adjusting for factors from Ipsos's initial sampling strategy, forms of non-response and non-coverage, and panel attrition, using probability estimates based on location of residence, demographic characteristics (gender, age, race/ethnicity, household income, metro/non-metro area, and education), and access to the Internet. Weights were constructed in several steps. First, panel design weights were computed that reflected unequal selection probabilities for different respondents (e.g. some demographic groups are more likely to agree to be on the KnowledgePanel than others). These design weights were then calculated for the panel according to active panel members. Each panel member was assigned a design weight reflecting in part the sampling procedures used to recruit that individual onto the panel. In the second phase of weighting, study design weights were constructed for use in study-specific datasets such as the one used in our analyses; these study design weights included information from the initial weighting procedure, sample attrition, and discrepancies between the final obtained sample and US Census Bureau's March 2020 Current Population Survey (CPS) [46] benchmarks for Florida and Texas,

allowing for population-based inferences. Thus, the weighted sample used for this study closely matched the US Census Bureau's CPS for Florida and Texas. Unless otherwise indicated, all descriptive and inferential statistics were weighted using study-specific post-stratification weights.

### 4.5. Data analytic plan

Analyses were conducted using Stata (version 15.1; StataCorp). Descriptive statistics for key study variables were conducted. To test H1 we conducted an ordinary least squares (OLS) regression with hurricane negative personal experiences predicting hurricane subjective attribution. To test H2 we conducted an OLS regression with hurricane subjective attribution predicting hurricane risk appraisal. To test H3(a) we conducted an OLS regression with hurricane subjective attribution predicting hurricane risk appraisal, and to test H3(b) we conducted an OLS regression with hurricane negative personal experiences interacting with hurricane subjective attribution predicting hurricane risk appraisal. To test H4 we conducted a Poisson regression with hurricane (a) negative personal experiences, (b) subjective attribution, (c) risk appraisal, and (d) adaptation appraisal predicting hurricane personal household adaptation. All models were estimated using multiple imputation by chained equations to account for missing data. Missing data were extremely low in the sample. The following measures had some missing responses: negative personal experiences ($n = 4$, 0.22%), risk appraisal ($n = 2$, 0.11%), adaptation appraisal ($n = 13$, 0.70%), subjective attribution ($n = 6$, 0.33%), and political party identification ($n = 120$, 6.50%), with no other measures having missing responses. All analyses controlled for gender, age, income, education, ethnicity, and political party identification. Analyses for H2 and H4(b) were pre-registered at the Center for Open Science, and the rest were not explicitly stated in our preregistration plan.

### 4.6. Participants

Our respondents were 53.2% female, with a median age of 51.0 years old; 56.9% of households reported annual incomes less than $75 000. About 1/3 reported having earned a Bachelor's degree or higher (29.5%). Of our sample, 54.8% were White/non-Hispanic, 28.1% were Hispanic, 11.9% were Black/non-Hispanic, and 5.2% were Other, non-Hispanic, or 2+ races. A little fewer than half of our participants reported leaning toward being strong Republicans (48.1%), 47.1% reported leaning toward being strong Democrats, and 4.9% reported being undecided/independent. For more details on demographics by state and comparison to US Census and Pew Research Center data, see supplemental material table 1.

## 5. Results

### 5.1. Descriptive statistics

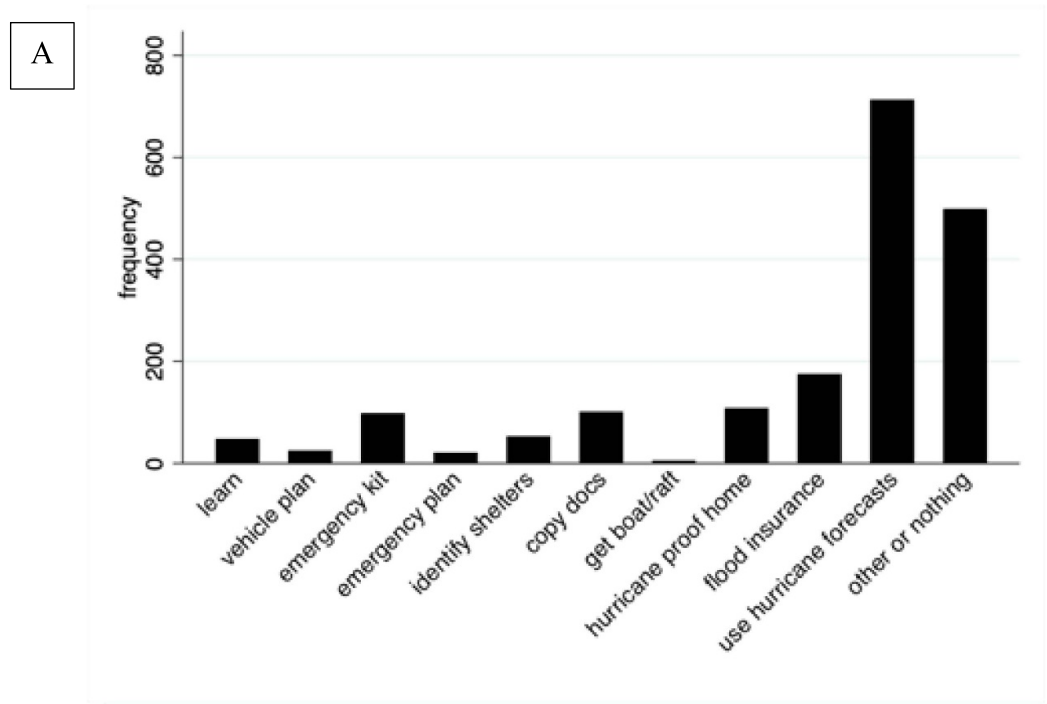
As shown in figure 2(A), the top five most common self-reported adaptation behaviors were using hurricane forecasts when making travel plans ($n = 713$, 38.60%), followed by having flood insurance ($n = 108$, 5.90%), copying important documents ($n = 101$, 5.50%), putting together an emergency kit ($n = 98$, 5.30%), and identifying shelters ($n = 53$, 2.90%). As shown in figure 2(B), the majority ($n = 1347$, 73.00%) of our participants self-reported having performed at least one adaptation behavior to prepare for the 2020 Atlantic hurricane season. Close to 1/3 (29.00%) of our participants reported having had at least one hurricane negative personal experience. On average, participants expressed a moderate level of hurricane subjective attribution agreement ($M = 3.09$, SD = 1.10). They also expressed a small-to-moderate level of hurricane risk appraisal ($M = 2.49$, SD = 0.98) and moderate level of hurricane adaptation appraisal ($M = 3.31$, SD = 0.95). For more details on differences in key measures of self-reported adaptation behaviors (no adaptation versus at least one adaptation behavior), see supplemental material figures 1–6 and table 2.

### 5.2. Hurricane personal negative experiences, subjective attribution, and risk appraisal

Support was observed for H2 and H3(a) and (b). As shown in table 1 and figure 3, more hurricane negative personal experiences and greater hurricane subjective attribution agreement were associated with greater hurricane risk appraisal. The positive relationship between hurricane negative personal experiences and hurricane risk appraisal was moderated by hurricane subjective attribution. More specifically, hurricane subjective attribution agreement was associated with increasing levels of hurricane risk appraisal among those with no hurricane negative personal experience (figure 4). However, no support was found for H1, as no association between hurricane negative personal experiences and hurricane subjective attribution agreement was observed (table 1 and figure 3).

### 5.3. Hurricane personal household adaptation

Support was observed for H4(a), (c) and (d). As shown in table 2 and figure 3, hurricane negative personal experiences, hurricane risk appraisal, and hurricane adaptation appraisal were positively associated with more hurricane personal household adaptation. However, when controlling for hurricane negative personal experiences, risk appraisal and adaptation appraisal, no association between hurricane subjective attribution and hurricane personal household adaptation was observed.



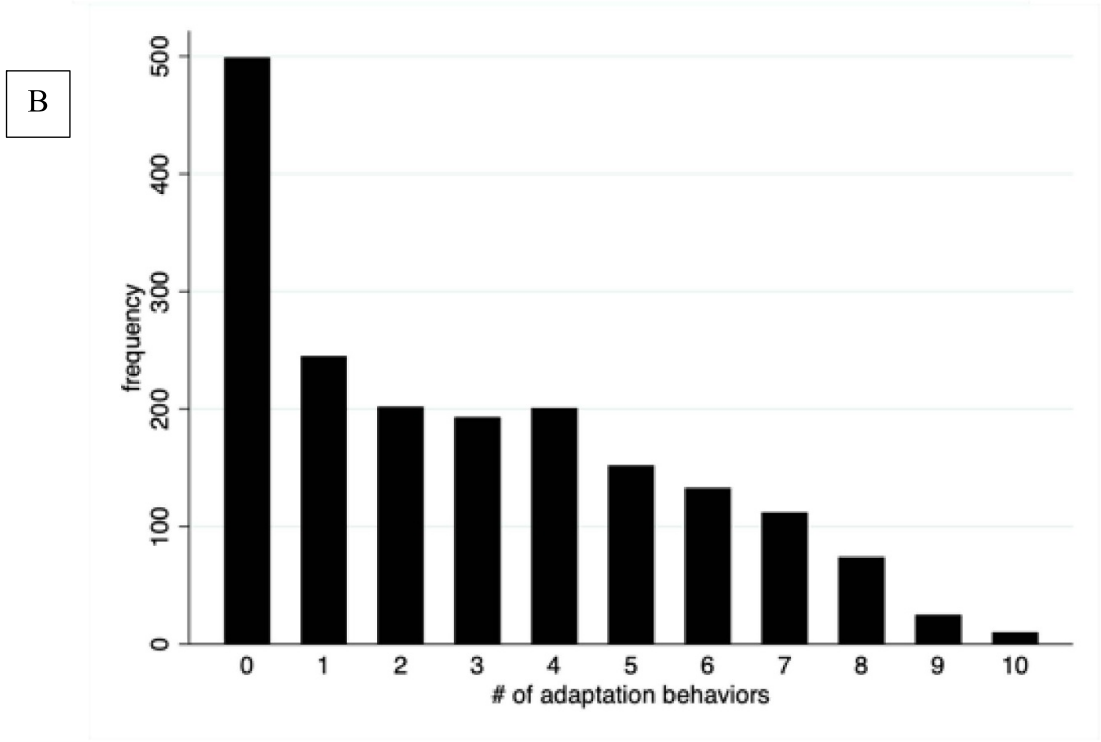




**Figure 2.** Panel (A) shows the frequency of each of the self-reported adoption of personal household protection adaptation behavior. Panel (B) shows the frequency of the number of total self-reported adopted personal household adaptation behaviors.

## 6. Discussion

Overall, our results indicate that, in a sample exposed to repeated hurricanes, prior hurricane negative personal experiences and hurricane subjective attribution agreement were associated with greater hurricane risk appraisal prior to an impending above-normal hurricane season. Hurricane subjective attribution agreement moderated the relationship between hurricane negative personal experiences and hurricane risk appraisal. In turn, hurricane negative experiences, hurricane risk appraisal, and hurricane adaptation appraisal were positively associated with self-reported hurricane personal household adaptation behaviors.

In support of H3(a) and H2 (section 5.2), higher levels of hurricane negative personal experiences and hurricane subjective attribution agreement were associated with higher levels of hurricane risk appraisal. This aligns with mounting evidence that negative

**Table 1.** OLS regressions with hurricane negative personal experience predicting hurricane subjective attribution, and hurricane negative experience and subjective attribution and their interaction predicting hurricane risk appraisal ($N = 1846$).

| | Hurricane subjective attribution | | | | Hurricane risk appraisal | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (1) | | | | (2) | | | |
| Variables | *B* | *p* | 95% CI | | *B* | *p* | 95% CI | | *B* | *p* | 95% CI | |
| Hurricane negative personal experiences | 0.04 | 0.28 | −0.03 | 0.11 | **0.23** | **<0.001** | **0.12** | **0.34** | **0.62** | **<0.001** | **0.30** | **0.94** |
| Hurricane subjective attribution | | | | | **0.10** | **0.02** | **0.01** | **0.18** | **0.15** | **0.001** | **0.06** | **0.25** |
| Experiences × attribution | | | | | | | | | **−0.12** | **0.01** | **−0.20** | **−0.03** |
| Gender (ref = female) | −0.09 | 0.15 | −0.22 | 0.03 | −0.19 | 0.02 | −0.34 | −0.03 | −0.17 | 0.02 | −0.32 | −0.02 |
| Age | −0.01 | 0.01 | −0.01 | −0.001 | 0.00 | 0.11 | −0.001 | 0.01 | 0.00 | 0.12 | 0.00 | 0.01 |
| Income | 0.00 | 0.97 | −0.04 | 0.04 | −0.02 | 0.36 | −0.06 | 0.02 | −0.02 | 0.29 | −0.07 | 0.02 |
| Education (ref = no college) | 0.16 | 0.04 | 0.01 | 0.30 | −0.11 | 0.17 | −0.27 | 0.05 | −0.11 | 0.16 | −0.27 | 0.04 |
| Ethnicity (ref = White) | | | | | | | | | | | | |
| Black, non-Hispanic | −0.28 | 0.03 | −0.54 | −0.03 | 0.10 | 0.45 | −0.16 | 0.35 | 0.11 | 0.41 | −0.14 | 0.36 |
| Other, non-Hispanic, 2+ races | 0.30 | 0.04 | 0.01 | 0.59 | 0.38 | 0.03 | 0.04 | 0.72 | 0.40 | 0.02 | 0.05 | 0.74 |
| Hispanic | 0.05 | 0.58 | −0.13 | 0.23 | 0.04 | 0.71 | −0.16 | 0.23 | 0.03 | 0.73 | −0.16 | 0.23 |
| Political party (1 = strong Republican, 7 = strong Democrat) | 0.23 | <0.001 | 0.19 | 0.26 | 0.00 | 0.90 | −0.04 | 0.05 | 0.00 | 0.91 | −0.04 | 0.05 |
| Constant | 2.48 | <0.001 | 2.14 | 2.83 | 2.05 | <0.001 | 1.59 | 2.50 | 1.88 | <0.001 | 1.42 | 2.35 |
| Model statistics | $F(9,1780.7) = 29.30; p < 0.001$ | | | | $F(10,1811.9) = 5.93; p < 0.001$ | | | | $F(11,1816.1) = 6.34; p < 0.001$ | | | |
| *R*-square | 0.24 | | | | 0.08 | | | | 0.09 | | | |

Note. Model (1) shows the main effect of hurricane negative personal experiences and subjective attribution on hurricane risk appraisal, and model (2) shows the interaction between hurricane negative personal experiences and subjective attribution on hurricane risk appraisal. Bolded values are significant at $p < 0.05$ and are thus interpreted. The variance inflation factor for each model was under 2, suggesting no meaningful collinearity among the independent variables.

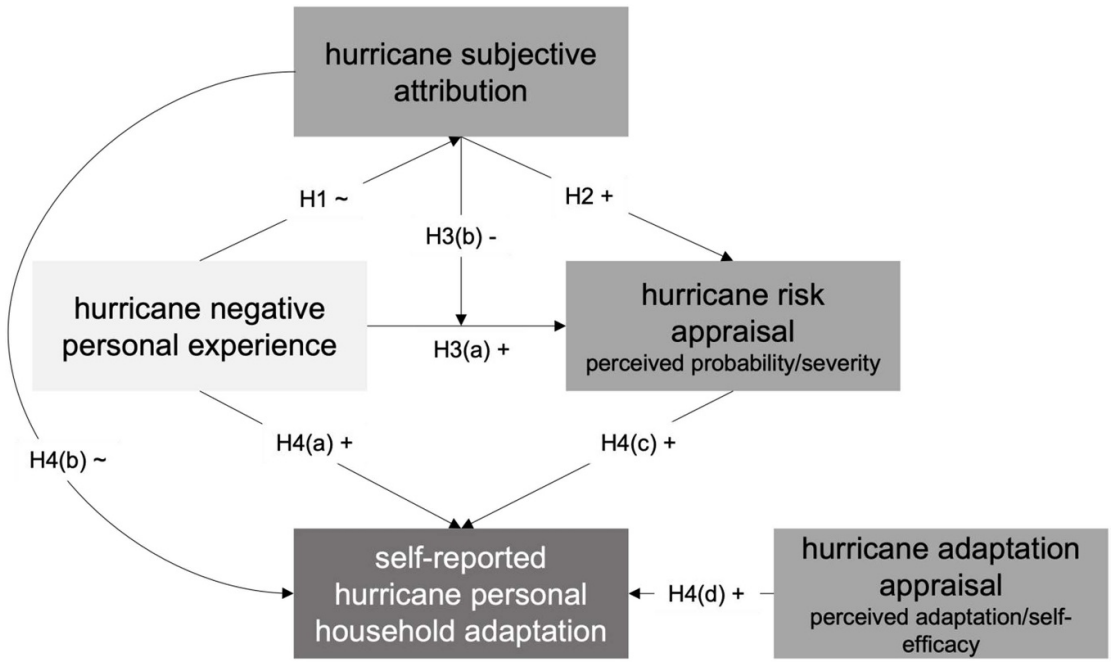



**Figure 3.** Conceptual model showing the observed relationships for each hypothesis (∼ indicates no association, + indicates a positive association, and − indicates a negative association).

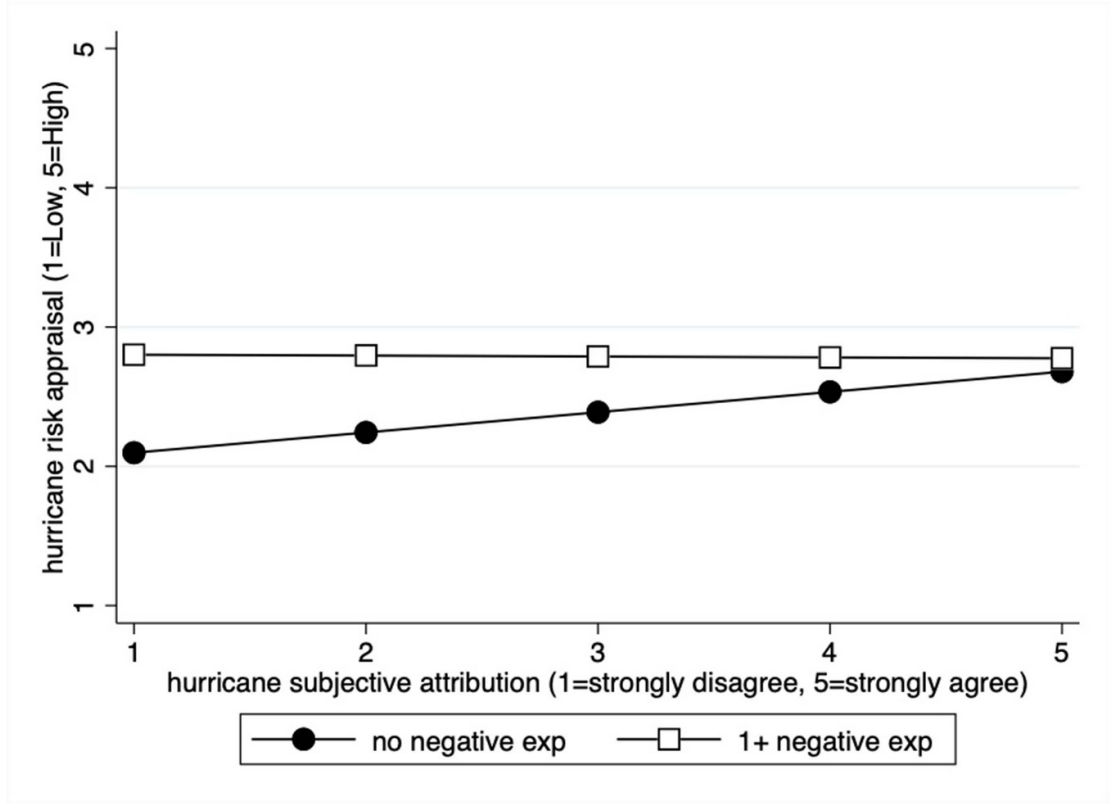



**Figure 4.** Hurricane subjective attribution moderates negative personal experiences on hurricane risk appraisal. 1+ negative experience means having had one or more previous negative hurricane experiences.

personal experiences with extreme weather (e.g. hurricanes, flooding) and other collective trauma (e.g., COVID-19) are associated with greater risk perceptions [7, 17–20, 47]. Prior research shows that even for those repeatedly exposed to hurricanes, nearly half of homeowners have never engaged in any protective action against future storms [47]. Our findings suggest that subjective attribution and perceptions of risk

**Table 2.** Poisson regression with hurricane negative personal experience, subjective attribution, risk appraisal, and adaptation appraisal predicting hurricane personal household adaptation ($N = 1{,}846$).

| Variables | *B* | *p* | 95% CI | |
|---|---|---|---|---|
| Hurricane negative personal experiences | **0.17** | **<0.001** | **0.12** | **0.21** |
| Hurricane subjective attribution | 0.03 | 0.27 | −0.02 | 0.08 |
| Hurricane risk appraisal | **0.16** | **<0.001** | **0.11** | **0.22** |
| Hurricane adaptation appraisal | **0.49** | **<0.001** | **0.43** | **0.55** |
| Gender (ref = female) | −0.01 | 0.87 | −0.13 | 0.11 |
| Age | 0.01 | <0.001 | 0.01 | 0.01 |
| Income | 0.04 | 0.03 | 0.00 | 0.07 |
| Education (ref = no college) | −0.04 | 0.48 | −0.17 | 0.08 |
| Ethnicity (ref = White) | | | | |
| Black, non-Hispanic | 0.09 | 0.38 | −0.11 | 0.30 |
| Other, non-Hispanic, 2+ races | 0.16 | 0.23 | −0.10 | 0.41 |
| Hispanic | −0.05 | 0.53 | −0.20 | 0.11 |
| Political party (1 = strong Republican, 7 = strong Democrat) | 0.00 | 0.84 | −0.03 | 0.03 |
| Constant | −2.10 | <0.001 | −2.50 | −1.70 |
| Model statistics | $F(12{,}1200\,000.0) = 50.96$; $p < 0.001$ | | | |
| Pseudo *R*-square | 0.15 | | | |

Note. Bolded values are significant at $p < 0.05$ and are thus interpreted. The variance inflation factor for the model was under 2, suggesting no meaningful collinearity among the independent variables. The pseudo *R*-square was calculated with the original data.

are explanatory mechanisms that help explain variability in preparation behavior. Importantly, these findings support the suggestion of Ogunbode *et al* [4, 48] that subjective attribution agreement is also associated with greater risk perceptions in the context of hurricanes. In contradiction to H1 (section 5.2), we did not observe a relationship between hurricane negative personal experiences and hurricane subjective attribution agreement. Taken together, these results suggest that hurricane negative personal experiences and hurricane subjective attribution agreement are independently associated with hurricane risk appraisal.

In support of H3(b) (section 5.2), hurricane subjective attribution moderated the relationship between hurricane negative experiences and hurricane risk appraisal. Among those who strongly disagree that hurricanes are attributable to climate change, having no hurricane negative personal experience was associated with lower levels of hurricane risk appraisal compared to those with at least one prior hurricane negative personal experience. However, among those who strongly agree that hurricanes are attributable to climate change, no differences in hurricane risk appraisal between those with or without at least one prior hurricane negative personal experience were observed. This aligns with Ogunbode *et al* who found that flood subjective attribution moderated an observed positive association between personal experience with flooding and perceived threat from climate change [4], with higher levels of subjective attribution being associated with greater perceived threat. Our findings build upon and extend the work of Ogunbode *et al* [4] on flooding by demonstrating that subjective attributions may modulate positive relationships between negative personal experiences and risk appraisal in the context of hurricanes. These results reinforce the hypothesis that subjective attributions may be an important precursor for perceptions about climate change, but also about the impacts of climate change on such weather extremes. Future study may examine subjective attribution for other hazards such as climate-related infectious disease spread and hazard-specific risk appraisals, as well as with respect to climate change more generally.

We also found support for H4(a), (c) and (d) (section 5.3), where more hurricane negative personal experiences, hurricane risk appraisal, and hurricane adaptation appraisal were associated with the self-reported adoption of more hurricane personal household adaptation behaviors. Our results align with previous work in finding that greater flood experience is associated with more self-reported household protective adaptation behavior [32, 33]; having had greater reported experience with the impacts of climate change predicts greater adaptation to climate change in forest management [24]; and further support previous work in finding that negative experience such as severe loss during a flood may motivate the adoption of measures such as obtaining more information or making structural changes, and may be mediated by factors such as fear [49]. Our results also expand on previous findings regarding positive associations between risk appraisal [7, 30, 35] and adaptation appraisal [36–38] with self-reported or observed adaptation behaviors. Similarly, we expand on work suggesting that subjective attributions may be associated with how risks are appraised [4]. One possible explanation for a lack of association between subjective attribution and personal household adaptation (H4(b)) could have to do with 'decision-maker tipping point behavior' [34]. Blennow and Persson (2021) describe 'tipping point behavior' as the belief

that any adaptation behavior adopted would not make a difference, resulting in behavioral abstinence. Future study may further examine the relationships of adaptation appraisals (i.e. response efficacy) [30, 37, 38], in the context of personal household adaptation to hurricanes.

Overall, these results provide support for Grothmann and Patt's process MPPACC [30], with our findings showing a positive association of risk and adaptation appraisal with self-reported adaptation behaviors. They also underscore the potential for including key factors such as negative personal experiences and subjective attribution in conceptual models of climate adaptation behaviors (e.g. MPPACC) to better understand processes of individual decision making, informing potential interventions to promote adaptation.

### 6.1. Limitations

There are several strengths of this study including its large sample size ($N = 1846$), representative sample of Gulf Coast residents, fielding in the weeks leading up to the start of the 2020 Atlantic hurricane season, and prior hurricane negative experiences data. We acknowledge some limitations. First, we focused only on a subset of self-reported adaptation behaviors (anticipatory learning and household protection). While not the focus of the study, it would have been informative to assess whether in the context of hurricanes, subjective attribution modulates the relationship between negative personal experiences and other self-reported adaptation behavior or civic engagement. Second, previous studies have found that subjective attributions may be important for how people perceive climate change risks more generally. Again, while not the focus of this study, it would have been informative to assess whether, in the context of hurricanes, subjective attribution modulates the association between negative personal experiences and climate change risk appraisal. Future study should examine the relationships of subjective attribution across domain areas with risk appraisals and self-reported or observed adaptation behaviors to specific hazards and to climate change more broadly. Third, internal consistency for the two questions comprising 'hurricane adaptation appraisal' was marginal (Cronbach's $\alpha = 0.68$). While lower than ideal alpha, we combined these questions based on theory and parsimony; however, future study should include revising and/or adding questions to assess the overall construct of adaptation appraisal.

## 7. Conclusions

Our findings demonstrate that hurricane subjective attribution and hurricane negative personal experiences are positively associated with hurricane risk appraisal. Importantly, hurricane subjective attribution moderated the positive relationship between hurricane negative personal experiences and hurricane risk appraisal. Our findings suggest that connecting personal experiences with climate-related events like hurricanes to climate change, and communications that enhance understanding of climate change impacts [34], may help promote personal household adaptation behaviors. Such messaging may be useful for science communicators and practitioners engaging with the public.

## Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: www.icpsr.umich.edu/web/pages/. Data will be available from 15 June 2022.

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## Conflict of interest

The authors declare that they have no conflicts of interest.

## Ethics statement

The authors confirm that this original manuscript has not been previously published and is not currently under consideration by any other journal. Additionally, the authors have approved the contents of this paper and have agreed to Environmental Research Letters' submission policies. The Institutional Review Boards of Stanford University (IRB-52533) and the University of California, Irvine (IRB-2016-2827) approved all procedures, and informed consent was obtained.

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## Contributions

Gabrielle Wong-Parodi: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, visualization, writing—original draft, and writing—review and editing. Dana Rose Garfin: Conceptualization, funding acquisition, investigation, methodology, project administration, resources, and writing—review and editing.

## ORCID iDs

Gabrielle Wong-Parodi https://orcid.org/0000-0001-5207-7489
Dana Rose Garfin https://orcid.org/0000-0002-0435-9307

## References

[1] IPCC 2014 *IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* ed R K Pachauri and L A Meyer (Core Writing Team) (Geneva: IPCC) p 151
[2] Howe P D, Marlon J R, Mildenberger M and Shield B S 2019 How will climate change shape climate opinion? *Environ. Res. Lett.* **14** 113001
[3] Zanocco C, Boudet H, Nilson R and Flora J 2019 Personal harm and support for climate change mitigation policies: evidence from 10 US communities impacted by extreme weather *Glob. Environ. Change* **59** 101984
[4] Ogunbode C A, Demski C, Capstick S B and Sposato R G 2019 Attribution matters: revisiting the link between extreme weather experience and climate change mitigation responses *Glob. Environ. Change* **54** 31–9
[5] Lee G-E, Loveridge S and Winkler J A 2018 The influence of an extreme warm spell on public support for government involvement in climate change adaptation *Ann. Am. Assoc. Geogr.* **108** 718–38
[6] Demski C, Capstick S, Pidgeon N, Sposato R G and Spence A 2017 Experience of extreme weather affects climate change mitigation and adaptation responses *Clim. Change* **140** 149–64
[7] van der Linden S 2015 The social-psychological determinants of climate change risk perceptions: towards a comprehensive model *J. Environ. Psychol.* **41** 112–24
[8] van Valkengoed A M and Steg L 2019 Meta-analyses of factors motivating climate change adaptation behaviour *Nat. Clim. Change* **9** 158–63
[9] Deng Y, Wang M and Yousefpour R 2017 How do people's perceptions and climatic disaster experiences influence their daily behaviors regarding adaptation to climate change?—A case study among young generations *Sci. Total Environ.* **581–582** 840–7
[10] Weiner R *et al* 2021 Climate change coverage in the United States media during the 2017 hurricane season: implications for climate change communication *Clim. Change* **164** 1–19
[11] Tschakert P and Dietrich K A 2010 Anticipatory learning for climate change adaptation and resilience *Ecol. Soc.* **15** 11
[12] Carman J P and Zint M T 2020 Defining and classifying personal and household climate change adaptation behaviors *Glob. Environ. Change* **61** 102062
[13] Klotzbach P J, Bell M and Jones J 2020 Extended range forecast of Atlantic seasonal hurricane activity and landfall strike probability for 2020 *Tropical Meteorology Project* (Boulder, CO: Colorado State University) (available at: https://tropical.colostate.edu/Forecast/2020-07.pdf (Accessed 26 August 2021)
[14] Sobel A H, Camargo S J, Hall T M, Lee C Y, Tippett M K and Wing A A 2016 Human influence on tropical cyclone intensity *Science* **353** 242–6
[15] Emanuel K 2020 Evidence that hurricanes are getting stronger *Proc. Natl Acad. Sci.* **117** 13194–5
[16] Kossin J P, Knapp K R, Olander T L and Velden C S 2020 Global increase in major tropical cyclone exceedance probability over the past four decades *Proc. Natl Acad. Sci. USA* **117** 11975–80
[17] Spence A, Poortinga W, Butler C and Pidgeon N F 2011 Perceptions of climate change and willingness to save energy related to flood experience *Nat. Clim. Change* **1** 46–9
[18] Akerlof K, Maibach E W, Fitzgerald D, Cedeno A Y and Neuman A 2013 Do people 'personally experience' global warming, and if so how, and does it matter? *Glob. Environ. Change* **23** 81–91
[19] Brody S D, Zahran S, Vedlitz A and Grover H 2008 Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States *Environ. Behav.* **40** 72–95
[20] Reser J P, Bradley G L, Glendon A I, Ellul M C and Gallaghan R 2012 *Public risk perceptions, understandings and responses to climate change in Australia and Great Britain.* Gold Coast, Qld: Griffith Climate Change Response Adaptation Facility, p 298
[21] Broomell S B, Budescu D V and Por H H 2015 Personal experience with climate change predicts intentions to act *Glob. Environ. Change* **32** 67–73
[22] Taylor A, de Bruin W B and Dessai S 2014 Climate change beliefs and perceptions of weather-related changes in the United Kingdom *Risk Anal.* **34** 1995–2004
[23] Lujala P, Lein H and Rød J K 2015 Climate change, natural hazards, and risk perception: the role of proximity and personal experience *Local Environ.* **20** 489–509
[24] Blennow K, Persson J, Tomé M and Hanewinkel M 2012 Climate change: believing and seeing implies adapting *PLoS One* **7** e50182
[25] Whitmarsh L 2008 Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response *J. Risk Res.* **11** 351–74
[26] Cutter S L 2018 Compound, cascading, or complex disasters: what's in a name? *Environ. Sci. Pol. Sustainable Dev.* **60** 16–25
[27] Kellens W, Terpstra T and de Maeyer P 2013 Perception and communication of flood risks: a systematic review of empirical research *Risk Anal.* **33** 24–49
[28] Ho M C, Shaw D, Lin S and Chiu Y C 2008 How do disaster characteristics influence risk perception? *Risk Anal.* **28** 635–43
[29] Keller C, Siegrist M and Gutscher H 2006 The role of the affect and availability heuristics in risk communication *Risk Anal.* **26** 631–9
[30] Grothmann T and Patt A 2005 Adaptive capacity and human cognition: the process of individual adaptation to climate change *Glob. Environ. Change* **15** 199–213
[31] Hoogendoorn G, Sütterlin B and Siegrist M 2020 The climate change beliefs fallacy: the influence of climate change beliefs on the perceived consequences of climate change *J. Risk Res.* **23** 1577–89
[32] Bradford R A, O'Sullivan J J, van der Craats I M, Krywkow J, Rotko P, Aaltonen J, Bonaiuto M, de Dominicis S, Waylen K and Schelfaut K 2012 Risk perception—issues for flood management in Europe *Nat. Hazards Earth Syst. Sci.* **12** 2299–309
[33] Osberghaus D 2015 The determinants of private flood mitigation measures in Germany—evidence from a nationwide survey *Ecol. Econ.* **110** 36–50

[34] Blennow K, Persson E and Persson J 2021 DeveLoP—a rationale and toolbox for democratic landscape planning *Sustainability* **13** 12055
[35] Shi J, Visschers V H M, Siegrist M and Arvai J 2016 Knowledge as a driver of public perceptions about climate change reassessed *Nat. Clim. Change* **6** 759–62
[36] Janz N K and Becker M H 1984 The health belief model: a decade later *Health Educ. Q.* **11** 1–47
[37] Popova L 2012 The extended parallel process model: illuminating the gaps in research *Health Educ. Behav.* **39** 455–73
[38] Witte K 1996 Fear as motivator, fear as inhibitor: using the extended parallel process model to explain fear appeal successes and failures *The Handbook of Communication and Emotion* (NY: Academic) pp 423–50
[39] Thaker J and Cook C 2021 Experience or attribution? Exploring the relationship between personal experience, political affiliation, and subjective attributions with mitigation behavioural intentions and COVID-19 recovery policy support *J. Environ. Psychol.* **77** 101685
[40] Wong-Parodi G and Berlin Rubin N 2022 Exploring how climate change subjective attribution, personal experience with extremes, concern, and subjective knowledge relate to pro-environmental attitudes and behavioral intentions in the United States *J. Environ. Psychol.* **79** 101728
[41] Thompson R R, Holman E Alison and Silver R Cohen 2019 Media Coverage, Forecasted Posttraumatic Stress Symptoms, and Psychological Responses Before and After an Approaching Hurricane JAMA Netw Open **2** e186228
[42] Wong-Parodi G and Feygina I 2018 How psychosocial factors influence (mal)adaptive responses to Hurricane Matthew *Weather Clim. Soc.* **10** 747–68
[43] Maloney E K, Lapinski M K and Witte K 2011 Fear appeals and persuasion: a review and update of the extended parallel process model *Soc. Personal. Psychol. Compass* **5** 206–19
[44] Gliem J A and Gliem R 2003 Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales *The Ohio State University Conference, Columbus, OH* 2003
[45] Taber K S 2018 The use of Cronbach's alpha when developing and reporting research instruments in science education *Res. Sci. Educ.* **48** 1273–96
[46] US Census Bureau Current population survey data tables (available at: www.census.gov/programs-surveys/cps/data/tables.html) (Accessed 26 August 2021)
[47] Stock A, Davidson R A, Trainor J E, Slotter R, Nozick L K and Kruse J B 2021 What makes homeowners consider protective actions to reduce disaster risk? An application of the precaution adoption process model and life course theory *Int. J. Disaster Risk Sci.* **12** 312–25
[48] Ogunbode C A, Böhm G, Capstick S B, Demski C, Spence A and Tausch N 2019 The resilience paradox: flooding experience, coping and climate change mitigation intentions *Clim. Policy* **19** 703–15
[49] Siegrist M and Gutscher H 2008 Natural hazards and motivation for mitigation behavior: people cannot predict the affect evoked by a severe flood *Risk Anal.* **28** 771–8