Modeling Household Earthquake Hazard Adjustment Intentions: An Extension of the Protection Motivation Theory

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ABSTRACT

While existing literature has explored how hazard experience, salience, and demographics characteristics shape threat appraisal and hazard adjustment intentions, this study expands on past studies by exploring how additional factors such as qualitative characteristics of the hazard, political ideology, and oil entanglements shape threat appraisals, coping appraisals, and adjustment intentions in response to a techna hazard. This study builds on the Protection Motivation Theory (PMT) to explore factors that shape Oklahoman's intentions to adjust to induced seismicity using data collected from households (n=866) across 27 counties in Oklahoma that have experienced varying levels of seismic activity resulting from oil and gas exploration. Correlational analyses and structural equation modeling show that several variables not included in the original PMT, such as feelings of dread or negative emotions associated with earthquakes, are important predictors of intentions to adopt hazard adjustments. This study concludes with examining the effect of additional factors on adjustment intentions and risk perceptions that can help guide future earthquake risk management in identifying and taking appropriate actions that will stimulate precautionary behavior of private actors.

Keywords: Protection Motivation Theory, Techna, Earthquake Risk, Oklahoma, Hazard Adjustment

Practical Implication

This study builds on the Protection Motivation Theory (PMT) to explore factors that shape Oklahoman's intentions to adjust to induced seismicity using data collected from households (n=866) across 27 counties in Oklahoma that have experienced varying levels of seismic activity resulting from oil and gas exploration. While our results lend support to PMT hypotheses, we found that several variables not included in the original PMT, such as feelings of dread or negative emotions associated with earthquakes, are important predictors of intentions to adopt hazard adjustments. Results of this research can help guide future earthquake risk management in Oklahoma, providing insights that can be used to help residents identify and take appropriate actions to reduce their earthquake risk to reduce their risk. Local and state governments in Oklahoma should work to raise awareness of earthquake risk and use our research findings to emphasize adjustment measures that have low adoption intentions, high potential to reduce risk, and are relatively cheap and easy to install (e.g., installing secure cabinets). Likewise, stakeholders across the state should work to eliminate financial barriers by providing subsidies or government loans for costly adjustment measures (e.g., purchasing earthquake insurance) that protect individuals and property from future earthquake hazards. Local emergency managers should also work to increase households' familiarity and knowledge about earthquake risks and communicate the multi-use functions of many adjustment activities, which we find to be a strong predictor of adjustments.

1. Introduction

Wastewater disposal, or the process of injecting contaminated fluid underground after oil and gas extraction, has led to a dramatic increase in seismicity in Oklahoma since 2009 (Chen and Abercrombie 2020; Zhai et al. 2019). Seismicity in the state increased from averaging one M3 or greater earthquake per year pre-2009 to over 900 M3 or greater earthquakes in 2015 (Johann, Shapiro, and Dinske 2018). This period of increased seismicity has included some sizeable earthquakes, including a M5.6 in 2011 and a M5.8 in 2016, resulting in considerable damage for an area not built to withstand seismic shaking (Taylor et al. 2017; Jones 2016). Even with their rich history of hazards, earthquakes present a novel threat for Oklahomans. The induced seismicity in this case is a techna hazard, or an event where a technological hazard triggers what would be traditionally defined as a natural hazard (Gill and Ritchie 2018). In this paper, we explore how Oklahomans are understanding this techna hazard and how they intend to adjust to this threat.

Hazard risk adjustments are critical for individuals at risk to reduce their hazard exposure. Lindell and Perry (2000) define hazard risk adjustments as hazard mitigation, which provides passive protection at impact, emergency preparedness, which supports active post-impact responses, and the acquisition of insurance, which provides funds to recover when losses occur (Lindell and Perry 2000). When considering what leads individuals to consider adjusting to hazards, the Protection Motivation Theory (PMT) suggests that people's hazard adjustment intentions are shaped by threat appraisals and coping appraisals (Rogers 1975). While several researchers have used the PMT to explain adjustment intentions in response to natural hazards (Babcicky and Seebauer 2019; Bubeck et al. 2012; Westcott et al. 2017; Lindell and Prater 2002), the realm of hazards risk reduction for techna hazards has not been fully explored. Seismicity in Oklahoma is widely recognized as a techna hazard (Holland 2013; Ng'ombe and Boyer 2019; Office of The Secretary Of Energy & Environment 2018). The novelty of this hazard may result in deviations in households' hazard adjustment intentions and how the factors shape intentions.

This study uses data collected from households (n=866) across 27 counties in Oklahoma that have experienced varying levels of seismic activity (Petersen et al. 2018). Building on the original PMT and previous work by the authors (Murphy, Greer, and Wu 2018; Greer, Wu, and Murphy 2018; Greer, Wu, and Murphy 2020), we explore factors that shape both threat appraisals and adjustment intentions of Oklahomans, incorporating additional variables beyond the original PMT to advance the theory in the context of a techna threat (Rogers 1975). While the existing literature has explored how experiences, salience, and demographics characteristics shape threat appraisals and hazard adjustment intentions, this study expands on the literature by exploring the effects of qualitative characteristics of the hazard, ideology, and entanglement on threat appraisals. These factors are important because past research has shown that qualitative characteristics (Zwickle and Wilson 2014; Västfjäll, Peters, and Slovic 2008; Keller, Siegrist, and Gutscher 2006; Slovic et al. 2004), political ideology (Kahan et al. 2012; Choma et al. 2013; Kahan et al. 2007; The New York Times 2016), and benefits gained from hazardous activities (Starr 1969; Cole and Withey 1981; Fischhoff et al. 1978; Renn 1998; Slovic et al. 2004) all affect citizens' evaluation of threats and tolerance of risks. We analyzed these results in the context of both the original PMT and with adding these additional factors by correlational analyses and Structural Equation Modeling (SEM). We close this paper by discussing the implications of our findings and the utility of our identified additional factors for future studies.

2. Literature Review

2.1. Protection Motivation Theory

The Protection Motivation Theory (PMT), an expectancy-valence theory, attempts to capture the factors that influence intentions to adjust to risks (Rogers 1975). The theory relies on two cognitive mediating processes, threat and coping appraisals, to explain variations in protective responses to hazards (Figure 1). Threat appraisals (TA), often referred to as risk perceptions, captures perceived vulnerability to a threat. Coping appraisals (CA) measure perceived adaptive capacity to an event and is comprised of three variables: self-efficacy, response efficacy, and response costs. The two efficacy factors, self-efficacy and response efficacy, capture whether an individual thinks they can undertake adjustments and whether they believe the adjustments would effectively reduce the risk posed by said hazard to lives or property respectively. Response costs refers to perceptions of the effort, specialized knowledge, or funds required to adopt an adjustment (Bubeck, Botzen, and Aerts 2012).

[Figure 1 about here]

While this theory was originally designed to explain health-related behavior, several researchers have employed this theory and related theories to explain how individuals consider adjustments to disasters (Ong et al. 2021; Martin, Bender, and Raish 2007; Seebauer and Babcicky 2020; Greer, Wu, and Murphy 2020). When studying the adoption of adjustments in response to flooding risk in New York City, for example, Botzen et al. (2019) found that individuals with more risk exposure undertook more mitigation measures, and, in regards to coping appraisals, that both response- and self-efficacy correlated with adjustments undertaken while response costs did not. In a study of fire-prone communities in California, Ghasemi et al. (2020) found that perceived effectiveness of adjustments and risk perceptions related to fires drove adjustment intentions among homeowners. These studies generally find that both TA and CA drive intended hazard adjustments, but that CA accounts for more variability in adjustments than TA (Babcicky and Seebauer 2019; Bubeck et al. 2012; Greer et al. 2020; Lindell and Prater 2002).

As noted by Rogers (1975), the model was kept intentionally limited to increase generalizability. That said, Rogers suggested that future researchers should, as appropriate, consider including environmental, cognitive, and other factors that will likely improve the explanatory power of the PMT. Several researchers have expanded on the PMT in disaster research. For example, Grothmann and Reusswig (2006) added prior flood experience when exploring drivers of flooding adjustment, finding that personal experience correlated with protective response. When studying adjustment to floods, Oakley et al. (2020) included personal experience with flooding, emotional responses such as fear, and a variable capturing whether individuals thought adjusting was their responsibility. Lindell and Prater (2002), while exploring adjustment to earthquakes, added usefulness for other purposes, finding that this had a strong correlation with adjustment intentions. With this in mind, we explore other variables not traditionally included in the PMT that past literature has shown may shape adjustment intentions.

2.2. Additional Drivers of Adjustment Intentions and Risk Perceptions

2.2.1. Qualitative characteristics

As one of the most prominently cited drivers of hazard adjustment adoption (Becker et al. 2012; Dooley et al. 1992; Kunreuther and Slovic 1978; Lindell 2013; Lindell and Hwang 2008; Prater and Lindell 2000; Tierney 1993), there is value in considering risk perceptions beyond the perceived likelihood and severity of a given hazard, particularly in the context of techna earthquakes in Oklahoma. As noted by Slovic et al. (2004), risk perceptions cannot be reduced to how individuals *think* about a risk, but also how they *feel* about said risk. Studies have suggested that emotional responses, informed by perceived qualitative characteristics of risk sources, past experiences, and benefits associated with that risk source, create an affect heuristic that individuals use to quickly evaluate threats (Zwickle and Wilson 2014; Västfjäll, Peters, and Slovic 2008; Keller, Siegrist, and Gutscher 2006; Slovic et al. 2004). Such qualitative characteristics include whether hazards are controllable or uncontrollable, voluntarily undertaken or imposed by others, immediate or chronic, novel or familiar, known or unknown to the public, understood or not by experts, whether they are common or dreaded, their catastrophic potential, and equitable distribution of risks and benefits (Tierney 2014; Pidgeon 1998; Sjöberg 1998; Renn 1992; Boholm 1998; Slimak and Dietz 2006; Fischhoff et al. 1978; Renn 1998). These characteristics can be quite different when comparing technological hazards to natural hazards. In general, individuals tend to view risks associated with technological hazards as more controllable via policy, imposed upon them, unknown, less understood by both experts and the public, more dreaded, and with unequitable risk and benefit distribution (Fischhoff and Kadvany 2011; Kunreuther and Slovic 1996; van der Linden 2015; Renn 1992). Natural hazards, in contrast, are seen as less controllable, more voluntarily undertaken, and more understood by experts and the public (Brun 1992).

2.2.2. Experience and salience

Several prior studies have found that experience with natural hazards shapes risk perceptions (Palm 1998; Paton, Smith, and Johnston 2000; Asgary and Willis 1997; Kung and Chen 2012; Gotham et al. 2017; Nakayachi, Yokoyama, and Oki 2015; Tracy and Javernick-Will 2020; Whitmarsh 2008; Visschers and Siegrist 2013). Experience is important in the development of risk perceptions because what individuals remember about an event serves as an anchoring point for the likelihood and expected outcomes of a similar occurrence, often leading those with experience to see recurrence as more likely (Boholm 1998; Newman et al. 2014; Eiser et al. 2012; Tversky and Kahneman 1973). Likewise, there is a large body of research that suggests that previous experience with hazards is positively correlated with hazard adjustment adoption (Jackson 1981; Lindell and Hwang 2008; Perry and Lindell 2008; Prater and Lindell 2000). Several other studies, however, do not find these relationships. For example, past studies have shown that near misses, or experience with only minimal losses, can reduce the likelihood of individuals adopting protective measures (Blanchard-Boehm, Berry, and Showalter 2001; Dillon, Tinsley, and Cronin 2011; Tinsley, Dillon, and Cronin 2012). Some research suggests that this discrepancy may be due to mediating variables between experience and adjustments (Ge et al. 2011; Lindell and Hwang 2008), or that experience is inconsistently measured across the literature (Wu et al. 2015).

Hazard salience, or how often an individual thinks about an event, is another factor explored in studies as a driver of risk perceptions and hazard adjustments (Perry and Lindell 1990). Often highest in the immediate wake of an event (Dooley et al. 1992), findings relating salience to hazard adjustments and risk perceptions are mixed. While studies have found a positive correlation between hazard salience and hazard adjustment (Jackson 1981; O’Brien and Mileti 1992; Perry and Lindell 1990; Russell et al. 1995), other studies, such as Peers et al. (2021) and Greer et al. (2018), did not find this relationship. Prater and Lindell (2000) found that salience was correlated with risk perceptions, but more strongly correlated with hazard adjustments. Salience is also closely tied to hazard experience (Pennebaker and Harber 1993; Perry and Lindell 1990), with Lindell and Hwang (2008) finding that salience may act as a mediating variable between experience and risk perceptions, which then contribute both directly and indirectly to hazard adjustments.

2.2.3. Risk Perception

Recent work suggests that the risk perception is multidimensional, and affective responses play a dominating role of holistic judgments among affect, probability, and consequence dimensions, with studies finding that the dimensional structure does not vary across different hazard types (Wilson, Zwickle, and Walpole 2019; Walpole and Wilson 2021). While risk perceptions have been frequently used to predict protective behaviors, multidimensional measures are demonstrated to be more effective in predicting protective behavior than a unidimensional measure (Wilson, Zwickle, and Walpole 2019; Ferrer et al. 2016). To summarize, the existing literature provide rich sources on factors that affect risk perceptions, which in turn predict self-protective behaviors. However, few of them evaluated the risk perceptions drivers in the context of predicting protective behaviors with risk perceptions and coping appraisals, and specifically for techna hazard risks.

2.2.4. Demographics, Ideology and Entanglement

While demographics characteristics have shown impact on hazard adjustment intentions, findings from previous research are mixed. Studies have found that several factors, such as gender, age, race, and having children affect individuals' intentions of adopting adjustments (Duží et al. 2017; Kellens et al. 2011; Lindell et al. 2009; Lindell and Perry 2000; Prater and Lindell 2000; Stojanov et al. 2015). In terms of gender, women have been found to be positively correlated with adoption of adjustments (Kung and Chen 2012; Lindell and Prater 2000), but other research has found that women report higher risk perceptions and lower levels of adjustment intentions (Prater and Lindell 2000). Russell, Goltz, and Bourque (1995) found that household income, education level, owning a home, being married, and number of years in the neighborhood are all positively related to earthquake preparedness. In general, though, demographics characteristics tend to have small correlations with adjustment intentions (Lindell and Whitney 2000).

Two additional dimensions are likely complicating risk perceptions in Oklahoma: political ideology and perceived benefits gained from hazardous activities. First, research has found that individuals with a conservative ideology, as is the case for most Oklahomans, are less likely to support interventions to address collective hazards than their more liberal counterparts (Kahan et al. 2012; Choma et al. 2013; Kahan et al. 2007). Other research has found that individuals affiliating with a liberal political party are more likely to adopt hazard adjustments (Jenkins-Smith et al. 2017; Ripberger et al. 2017). Likewise, prior studies in Oklahoma indicate that when considering fracking, most individuals are more concerned about issues of water quality and availability than they are concerned about potential damages from earthquakes (Junod et al. 2018; Pollard and Rose 2019; Jackson et al. 2014; Porter et al. 2019). Second, findings suggest that individuals are more likely to tolerate risks that they derive a direct benefit from (Starr 1969; Cole and Withey 1981; Fischhoff et al. 1978; Slovic et al. 2004; Renn 1998). With the prevalence of oil and gas extraction in the state, we would expect to find that individuals who receive a direct benefit from resource extraction (via a job for themselves, a family member, or royalties from drilling on land they own) are more likely to tolerate increased risk than individuals who do not directly benefit from extraction.

2.3. Hypotheses

Given the ambiguous findings in the literature, this study seeks to advance the original PMT by including additional factors that affect risk perceptions and hazard adjustments and conducting a holistic examination using a range of hazard adjustment items (Greer et al. 2020; Wu et al. 2017). The original PMT considers the relationship between threat appraisals, coping appraisals, and hazard adjustment intentions (H6-H11), We propose additional drivers of adjustment intentions and risk perceptions based on the literature cited above where qualitative characteristics, salience, demographics characteristics, ideology, oil entanglement, and wastewater awareness shape households' risk perceptions, whereas the response cost variable of usefulness for other purposes (multiuse) and demographics characteristics affect adjustment intentions to earthquake hazards. We use the correlation results to further refine our hypothesized structural model.

Salience is predicted to positively affect the earthquake risk perceptions (H5), while salience itself is affected by the experience of property damage (H12) (Lindell and Hwang 2008; Prater and Lindell 2000). Qualitative characteristics including familiarity, self-knowledge, belief of scientists' knowledge, dreadfulness, and negative emotion also are predicted to shape households' risk perceptions (Keller, Siegrist, and Gutscher 2006; Västfjäll, Peters, and Slovic 2008; Slovic et al. 2004; Zwickle and Wilson 2014) (H1-H4). Political ideology, including party affiliation and conservativeness are also incorporated in our hypothesized model given past research suggests that ideology affects households' risk perceptions, particularly relating to technological hazards (Kahan et al. 2012; Choma et al. 2013; Kahan et al. 2007). Since the earthquakes in Oklahoma are triggered by wastewater disposal, oil entanglement, including mineral rights, oil industry employment, and wastewater awareness, are also used to predict households' risk perceptions (Cole and Withey 1981; Fischhoff et al. 1978; Renn 1998; Starr 1969; Slovic et al. 2004).

In addition, we also explore the effects of demographics characteristics on households' hazard adjustment intentions. As indicated previously, identifying as white (Lindell et al. 2009; Lindell and Perry 2000; Prater and Lindell 2000), women (Kung and Chen 2012; Lindell and Prater 2000), older (Lindell et al. 2009), married (Russell, Goltz, and Bourque 1995; Prater and Lindell 2000), homeowners (Lindell and Perry 2000; Russell et al. 1995), having dependents in the home (Lindell and Perry 2000; Russell et al. 1995), higher education level (Russell, Goltz, and Bourque 1995), years of tenure in an area (Lindell and Hwang 2008; Russell et al. 1995), and higher income (Lindell et al. 2009; Lindell and Perry 2000; Russell et al. 1995) are all expected to increase the intentions of hazard adjustments. In this study, we postulated that these demographics variables will have similar effects on households' hazard adjustment intentions for the techna earthquakes in Oklahoma. While many demographic variables may affect adjustment intentions, we only include those that are significantly correlated to adjustment intentions in the structural equation models. The structural model based on our hypotheses is shown in Figure 3.

3. Methods

3.1. Data Collection

Using the United States Geological Survey's 2018 One-Year Seismic Hazard Forecast map for the Central and Eastern US (Petersen et al. 2018), three earthquake risk areas were identified for collecting our household sample (high, moderate, and low) (Figure 2). Within each earthquake risk area, 480 household addresses were selected from each African American, Asian, Hispanic, and Native American, and White household group. In total, 7200 addresses were randomly selected from the study area from a household addressee list provided by *Experian Information Solutions Inc*. The mailing list was then used to match with the mailing address data provided by a survey company, *Oklahoma Direct*. Among these randomly selected households, 129 of them were removed from the original mailing list since they had moved to other areas. The questionnaires were sent by *Oklahoma Direct* from August to November of 2019. Following Dillman et al. (2014) survey procedures, each household was sent as many as three survey packages (waves 1, 3, and 4) and one reminder postcard (wave 2), with a pre-incentive (5-dollar Amazon gift codes) in one of their packages. In total, 866 complete surveys were returned, 44 households refused to participate, and 2179 survey packages were undeliverable. The final response rate was 17.86%, which is within the reasonable range according to studies conducted in recent years (Ju and You 2021; Meyer 2016; Steelman et al. 2015; Tracy, Javernick-Will, and Torres-Machi 2021; Wu, Greer, and Murphy 2020; Vásquez et al. 2018).

[Figure 2 about here]

3.2. Measures

Our survey instrument included 49 questions in total, building on previous surveys deployed in California, Washington, and Oklahoma (Lindell and Prater 2000; Murphy et al. 2018; Wu et al. 2017). Adjustment activities include purchasing earthquake insurance, installing cabinet latches (secure cabinets), learning where and how to shut off utilities, developing emergency plans, having a flashlight, having a fire extinguisher, having a first-aid kit, attending first-aid training, storing a three-day supply of food, and storing a three-day supply of water for each person in the family (Lindell and Whitney 2000). Additional variables capturing qualitative characteristics, political ideology, and oil entanglement were also added to the survey. The measures are summarized in Table 1.

3.3. Analyses

To test the hypothesized model, we first conducted correlation analyses using *Pearson's r* to examine the correlation of each path suggested by the original PMT model. Next, Structural Equation Modeling (SEM) models were built to examine the relationships among variables. SEM has become a popular methodology in analyzing the interplay among the PMT components due to its capability of fully uncovering the linkages between the PMT components (Babcicky and Seebauer 2019). To test the models, we built 10 basic models that only include original PMT variables. Subsequently, 10 separate SEM models were ran for each adjustment activity, with adding additional variables that can better explain household hazard adjustment behaviors.

All SEM models were built using SPSS AMOS 28 software with raw data using full information maximum likelihood (FIML) estimation. When evaluating the models, we used fit indexes to measure how well a model represents the observed data. This study employed the most frequently used model fit indexes: the comparative fit index (CFI), the normed fit index (NFI), and the root mean-square error of approximation (RMSEA) (Bentler 1990a 1990b; Bryne 2010). A model is considered acceptable if the CFI and NFI reach a minimum threshold of .90 (Hu and Bentler 1999; Marsh and Hocevar 1985). The common cut-off criterion for the RMSEA is .08 (Browne and Cudeck 1992) and the χ^2/df ratio should not exceed the range of 2–5 (Marsh and Hocevar 1985). Modification Indices were used in our models in identifying statistically significant covariances that would significantly improve the model's fit to the data (Peters, Burraston, and Mertz 2004).

4. Results

4.1. Descriptive Statistics

Descriptive statistics for the variables can be found in Table 2. Our respondents' average age is 55.2 years old, 65.1% of respondents identified as White, 50.3% as women, 82.4% are homeowners, and 64.5% are married. Regarding education and income, participating households mostly have at least some college or vocation school diploma; their income is roughly evenly laid out ranging from less than 30K to more than 130K. The mean value of tenure in the Oklahoma area is 38.4 years. Our sample demographics are consistent with Census data for the state (United States Census Bureau 2019). The data also shows most respondents identified as Republican (*46%*), followed by Democrats (*33%*) and Independents (18%). In addition, the political ideology variable shows that the mean value of the respondents' conservativeness is 3.35, suggesting that while most respondents identified as moderate (middle ground) we have more that lean conservative than liberal in the sample. Some respondents have received payments for the mineral rights underneath their property (*14.0%*) or have someone in their household who has been employed by an oil and gas company (*9%*).

4.2. Correlation Analyses

As indicated in Table 3, all the risk perception variables are significantly and positively correlated with intentions of purchasing earthquake insurance ($.21 \leq r \leq .26$, $p < .01$) and installing secure cabinets ($.18 \leq r \leq .22$, $p < .01$). The correlations among the risk perception variables and intentions of having a fire extinguisher, attending first-aid training, storing a three-day supply of food, and storing a three-day supply of water are also positive and significant ($p < .05$).

Some demographic variables are significantly correlated with risk perceptions and adjustment intentions (see Table 3). For risk perceptions, our results show that only age is positively correlated with most risk perception variables, and the correlation is not very strong. Overall being married, income level, and home ownership show significant correlations with most hazard adjustments ($p < .05$), but the correlations between demographics characteristics and adjustment intentions are mostly not significant. Therefore, only being married, income level, and home ownership were selected for SEM analyses, other demographics variables were dropped.

To identify factors that predict risk perceptions, Table 3 shows that both households' hazard salience and earthquake experience are positively and significantly correlated with all five measures for risk perceptions ($.18 \leq r \leq .35$, $p < .01$). The correlation between salience and experience is also positive and significant ($r=.23$, $p < .05$). The qualitative characteristics (dreadfulness and negative emotion) are also positively correlated with risk perception variables ($.27 \leq r \leq .46$, $p < .01$). While the correlation is relatively weak when comparing to other qualitative characteristics, self-knowledge is also significantly correlated with risk perceptions ($.10 \leq r \leq .15$, $p<.01$). Familiarity is only correlated with risk perceptions of family member injury, job disruption, and daily activity disruption and the correlations are also weak ($.08 \leq r \leq .11$, $p < .05$). On the other hand, households' beliefs in scientists' knowledge are not correlated with risk perceptions at all. Therefore, all qualitative characteristics are retained for further SEM analyses except for households' beliefs in scientists' knowledge.

Party affiliation and conservativeness are mostly not significantly correlated with risk perception variables; therefore, they are not included in SEM analyses. Mineral rights and oil industry employment are not significantly correlated with risk perception variables; thus, they are also not included in SEM analyses. Note that the variable of wastewater awareness is significantly correlated with mineral rights ($r = .19$, $p < .01$) and oil industry employment ($r = .18$, $p < .01$).

Table 4 shows the correlations between earthquake adjustment intentions and coping appraisal variables. In general, coping appraisal variables are significantly correlated with adjustment intentions. The response efficacy variable of protecting persons effectively is strongly and significantly correlated with all the adjustment intentions ($p < .01$). The other response efficacy variable, protecting property effectively, is correlated with all the adjustment intentions ($p < .01$) except having a flashlight and a first aid kit. Table 3 also shows that the self-efficacy variables only correlated with some adjustment intentions. On the other hand, the response cost variable, multi-use, is strongly correlated with all the adjustment intentions and cost money only correlates with three adjustment intentions. Noticeably, among all the adjustment intentions, the correlations between multi-use and adjustment intentions are especially strong, particularly intentions of secure cabinets ($r = 0.47, p < .01$), storing three-day supply of food ($r = 0.43, p < .01$) and water ($r = 0.41, p < .01$). Given the strong correlation between multi-use and adjustment intentions, we include this in the structural models.

4.3. SEM Analyses

Results for the intercorrelations of adjustment intentions are given in Table 3. Overall, low to moderate correlations were found among adjustment intentions. This indicates that the survey respondents believe these adjustments are implemented independently from each other (Babcicky and Seebauer 2019). Since the ten adjustments are conceptually distinct and feature good discriminant validity, we did not use the aggregation method that aggregates different variables into compound measures (Grothmann and Reusswig 2006). Instead, we estimated separate SEM models for all the adjustment intentions.

We first tested the relationships suggested by the original PMT model using the 10 earthquake hazard adjustment measures. Table 5 shows the results of the ten PMT models. These models set base values regarding model fit indexes and explained variances for our next analyses. These models have the same structure that only includes original PMT components (Figure 1). In Table 5, the upper five rows represent the paths as hypothesized by the original PMT. The columns are the earthquake hazard adjustment intentions. Each row contains one path between an appraisal variable and the earthquake adjustment items. For example, the row "Risk perception –> adjustment intention" shows the path coefficient for the effect of risk perceptions on the intention of adopting the corresponding adjustments. Note that self-efficacy is created as a latent variable in AMOS that is inferred from the three self-efficacy variables – requiring special knowledge, requiring efforts, and requiring cooperation. The model-specific fit indexes are provided at the bottom of the table. These fit indexes show that the qualities of the original PMT models are all acceptable. According to the squared multiple correlations (SMC), the original PMT models explain 3.9% (the model of having a flashlight) to 23.4% (the model of securing cabinets) of the variance in adjustment intentions.

Findings suggest that intentions of purchasing earthquake insurance and securing cabinets are highly predicted by risk perceptions in the original PMT. This is especially true for the earthquake insurance model. Risk perceptions are significant for the intentions of having a fire extinguisher, attending first-aid training, storing a three-day supply of food, and storing a three-day supply of water, while the effect sizes are small.

In terms of coping appraisals, we found response efficacy of protecting persons positively predicts all the adjustment intentions. Compared to other appraisals, protecting persons effectively plays a dominating role in predicting households' intentions to install secure cabinets, develop an emergency plan, store a three-day supply of food, and store a three-day supply of water. The response efficacy variable of protecting property strongly predicts the intentions of learning how to shut off utilities and having a fire extinguisher. Self-efficacy only significantly and negatively affects households' intentions of learning how to shut off utilities and having a flashlight. As for the response cost, it only significantly affects households' intentions of purchasing earthquake insurance.

Next, we will discuss our structural models that draw on the original PMT model by including qualitative characteristics of the hazard, two demographic variables, and the coping appraisal of multi-use. These variables were identified in the literature and found significant in our correlation analyses. The results of the new SEM models are reported in Table 6.

The new SEM models include perceptions of four qualitative characteristics of the hazard, including familiarity, self-knowledge, dreadfulness, and negative emotion, which predict risk perceptions. These relationships were identified in the literature and detailed in Table 3. Earthquake property damage experience significantly correlates with both salience and risk perceptions in the correlation analyses, but the significant relationship only remains between experience and salience in the SEM analysis. Additionally, our new structural models incorporated two demographic variables: homeownership and being married. This is based on its significant correlations with earthquake adjustment intentions.

The fit indexes show that the qualities of the new earthquake hazard adjustment intention models all range from good to excellent. According to the SMC, the new SEM models explain 12.7% to 29.1% of the variance in the adjustment intentions. Our structural models with incorporating additional factors increase the absolute explanatory power by 3.3% (first-aid training) to 9.9% (shut off utility) compared to the original PMT models. Comparing to the original PMT models, the explained variances of new structural models are all improved. The relative increase of the explained variance is extremely high for having a flashlight (from 3.9% in the original PMT model to 13.4% after adding additional variables) and having a first-aid kit (from 6.6% in the original PMT model to 13.2% after adding additional variables).

Similar to the basic PMT models, the intention of purchasing earthquake insurance is highly predicted by risk perceptions. Results show risk perceptions has a positive and stronger effect than all other coping appraisals and demographic variables on purchasing earthquake insurance. With incorporating additional factors, the new structural models also show that negative emotion has a strong effect on risk perceptions when compared to other qualitative characteristics across all the models. Dreadfulness and familiarity are also significant in shaping risk perceptions while self-knowledge only shows significant effects on the new fire extinguisher model. Hazard salience is significantly and positively affected by the experience of property damage. Finally, hazard salience shapes risk perceptions across all the adjustments.

As for the coping appraisals, the response efficacy variable of protecting persons effectively has a strong effect in predicting households' intentions of securing cabinets, developing an emergency plan, attending first-aid training, storing a three-day supply of food, and storing a three-day supply of water. On the other hand, the intention of purchasing earthquake insurance is better predicted by protecting property effectively when compared to protecting persons effectively. Self-efficacy, measured by how much special knowledge, effort, and cooperation are required, has a significant negative effect on households' intentions of learning to shut off utilities, developing an emergency plan, having a flashlight, and storing a three-day supply of food. These findings suggest households are less likely to adopt these adjustment activities if it requires higher levels of knowledge, effort, and cooperation. In terms of response cost, multi-use appraisal has a dominating role in predicting all the adjustment intentions in our new structural models except for the earthquake insurance model. Costing money only has a significant and negative impact on households' intentions of purchasing earthquake insurance, having a fire extinguisher, attending the first-aid training, and storing a three-day supply of food.

In addition, homeowners and married individuals both have a higher intention of purchasing earthquake insurance, learning how to shut off utilities, purchasing a fire extinguisher, and having a first-aid kit at home. Items unique to homeowners are that they are more likely to have a flashlight and store a three-day supply of food and water. Married individuals are likely to develop an emergency plan. Interestingly, both homeowners and married individuals show low interest in installing cabinet latches or attending the first-aid training. Overall, the demographic variables have a small effect size compared to other predictors.

5. Discussion

The results of the correlation analyses are somewhat aligned with the literature. Similar to Prater and Lindell (2000), Oklahoma households' earthquake hazard salience is correlated with five different earthquake hazard adjustment intentions including purchasing earthquake insurance, securing cabinets, having a fire extinguisher, having first-aid training, preparing three days of food, and preparing three-days of water. Noticeably, other than preparing three days of food and water, the other four hazard adjustments are considered intentions for hazard mitigation activities that provide passive protection during an earthquake.

Adding qualitative characteristics, salience, experience as risk perception drivers and multi-use and demographic variables as adjustment intention drivers give us a holistic view of the interactions among hazard salience, risk perceptions, and household adjustment intentions. Previous findings have suggested that both hazard salience and risk perceptions affect hazard adjustments (e.g., Perry and Lindell 1990; Russell et al. 1995; Huntsman et al. 2021; Wu et al. 2017). Our path analysis takes these findings a step further by clarifying these relationships. As indicated in Table 5, higher hazard salience always results in higher risk perceptions; however, risk perceptions do not always have a significant positive impact on hazard adjustment intentions. In fact, in most of the models, risk perceptions only affect hazard adjustment intentions when our correlation analyses show that hazard salience is positively correlated with that specific hazard adjustment intention. This finding suggests that hazard salience does not have a direct impact to hazard adjustment intentions; however, through risk perceptions, it is still an important variable that explains households' hazard adjustment intentions.

This study examines the correlations among five different risk perceptions measures and earthquake hazard adjustment intentions. This approach is different from some studies that use an aggregated risk perception index to examine the relationships (Huntsman et al. 2021; Lindell et al. 2009; Lindell and Perry 2000; Lindell and Whitney 2000). In addition, similar to Botzen et al. (2019), our findings also suggest that risk perception variables are mostly correlated with mitigation activities, especially the intentions of buying earthquake insurance and securing cabinets. Next, while the literature shows that risk perception variables are positively correlated with household size (Lindell et al. 2016), our further analyses showed that risk perceptions (damage to city, family injury, and home damage) are positively correlated with the numbers of elders (Over 65) in the household, and negatively correlated with the numbers of adults (18-65) and children (under 18) people in the household.

In terms of experience, this study captured the level of earthquake property damage experience and examined its correlations with other variables. As suggested in the literature (Palm 1998; Paton, Smith, and Johnston 2000; Asgary and Willis 1997; Kung and Chen 2012; Gotham et al. 2017; Dooley et al. 1992; E. L. Jackson 1981; van der Linden 2015; Prater and Lindell 2000), experience is strongly correlated with risk perception variables. However, our findings suggest that experience affects households' risk perceptions through hazard salience. While it is still aligned with the literature (Jackson 1981; Lindell and Hwang 2008; Perry and Lindell 2008; Prater and Lindell 2000), the correlations between experience and hazard adjustment intentions are significant but weak. As for the qualitative characteristics, similar to Oakley et al. (2020), people who feel stronger dread and negative emotions are more likely to have stronger intentions of adopting earthquake hazard adjustment activities.

Findings regarding demographic variables have some noticeable differences from the literature. While studies have found that women (Kung and Chen 2012; Lindell and Prater 2000) are more likely to adjust to hazards, our study provides more nuance to that finding. Our results suggest that women are more likely to intend to develop emergency plans and less likely to intend to learn how to shut off utilities. We found no relation between gender and intentions of adopting other types of adjustments. Similar to previous studies (Lindell et al. 2009; Lindell and Perry 2000; Prater and Lindell 2000), participants who identify as white ethnicity have stronger intentions of adopting a number of hazard adjustment activities, including having a flashlight, having a fire extinguisher, and having a first-aid kit at home. In contrast, participants who identify as white ethnicity haver a lower intention of installing secure cabinets. Other than the correlations between white ethnicity and hazard adjustment activities, other correlations between ethnicity and hazard adjustment activities' are considered low ($r < .20$) (Wright 2002). Future research is needed to explore this in more detail.

Some literature suggests homeownership (Lindell and Perry 2000; Russell et al. 1995), higher education level (Russell, Goltz, and Bourque 1995), years of tenure in an area (Lindell and Hwang 2008; Russell et al. 1995), and higher income (Lindell et al. 2009; Lindell and Perry 2000; Russell et al. 1995) are all positively correlated with hazard adjustments but our results do not mirror these findings. Most of the correlations regarding these demographic variables are either weak or with opposite effects. This is the same with the variables that measure participants' political views. For example, unlike previous studies (Jenkins-Smith et al. 2017; Ripberger et al. 2017), political ideology and party affiliations generally do not correlate with hazard adjustment intentions in our study. Another example would be household composition, which only matters in relation to household EM plan intention. We found that households with minors in the home and larger households are more likely to intend to make plans but homes with individuals 65+ are less likely to intend to make plans. As suggested by the literature, demographics are not good predictors of risk perceptions or hazard adjustment intentions, so that might explain these ambiguous findings (Lindell and Whitney 2000).

Finally, Table 3 shows the correlations among hazard adjustment intentions and coping appraisal variables. Note that some self-efficacy measures are positively correlated with hazard adjustment intentions. That means higher levels of requirements on knowledge, efforts, and cooperation are associated with higher levels of adjustment intentions. While these correlation results do not align with the PMT literature, the results of the SEM models show that the relationship between self-efficacy and hazard adjustment intention aligns more clearly with the literature after we control for other variables (Tables 4 and 5).

Regarding the findings of the SEMs, the basic PMT model suggests CA variables are better predictors than the TA variable. Different CA variables also predict specific hazard adjustment intentions differently. For example, protecting persons, one of the response efficacy variables, is good at predicting hazard adjustment intentions such as securing cabinets, developing emergency plans, first-aid kits, first-aid training, having a three-day of food, and having a three-day of water. Another response efficacy variable, protect property effectively, also has stronger predictive power on hazard adjustment intentions that are related to property protection such as earthquake insurance, learning how to shut off utility, and having fire extinguishers. As for the TA variable, risk perceptions is generally a weaker predictor in most of the models when compared to CA variables. This is quite similar to the literature (Babcicky and Seebauer 2019; Bubeck et al. 2012; Greer et al. 2020; Lindell and Prater 2002), with the exception of the earthquake insurance model. In this model, TA is a stronger predictor of intentions to purchase earthquake insurance when compared to other CA variables. While some literature suggests that when a hazard adjustment activity is more complex or difficult to do, threat appraisal is a dominant factor that shapes whether or not it is worth adopting (Huntsman, Wu, and Greer 2021), this finding deserves further inquiry, particularly given issues related to uptake of earthquake insurance across the state.

In terms of the new structural models, we included additional variables based on the existing literature and correlation analyses. Overall, the model fit indexes showed that adding additional variables provided more meaningful findings when compared to the basic PMT models. As Rogers (1975) indicated, there is a need to include other meaningful variables in the basic PMT model since our intention here is to explore hazard adjustment behaviors of a techna hazard, Oklahoma earthquakes. When examining the results of our models after incorporating additional factors, it is important to note that we found that TA, risk perceptions, can still predict hazard adjustment intentions in some models. TA is also strongly affected, however, by dreadfulness, negative emotions, and hazard salience, often not included in other PMT studies. While Oakley et al. (2020) suggest negative emotion can predict hazard adjustment, our findings suggest these relationships are more complicated than a direct relationship. In addition, the paths in the new structural models also showed that experience of property damage predicts hazard salience which, in turn, positively predicts risk perceptions and then hazard adjustment intentions.

When looking at the ways in which CA variables predict hazard adjustment intentions, the results show that the newly included CA variable, multi-use (Lindell and Prater 2002), is the most important predictor of adjustment intention when compared to all other variables that predict hazard adjustment intentions. This is true for all the models except the model of purchasing earthquake insurance. Like the basic PMT model, the best predictor of this model is risk perceptions. Noticeably, our model is better at predicting the intention of secure cabinets. Secure cabinets model has the most explained variances in both the basic PMT (23.4%) and our new structural models (29.1%). The next-best model in both basic PMT and our new structural model is three days of food.

Two additional demographic variables, homeownership and marital status, were also included in the new structural models. Table 5 shows that homeownership and being married can predict some hazard adjustment intentions but not all, while no demographic variables have shown strong correlation with risk perceptions in the correlation analyses or consistent and significant effects on households' risk perceptions in SEM models. The effect of demographic variables is generally small, but these two variables did increase the overall explained variances. In comparison to coping appraisals, the effect size of homeownership and being married only gets close to that of coping appraisals in predicting households' intentions of learning to shut off utilities. Interestingly, income level and homeownership show similar patterns in their correlations with adjustment intentions but dropped income level in SEM models because it lost significance while homeownership was included in the model.

6. Conclusion

Our findings have important implications for future research and future policymaking. This study provides insights regarding how households in Oklahoma are intending to adjust to their newfound seismic, techna risk, and what factors shape their adjustment intentions. Our findings in this study stretches beyond the original PMT to consider how additional factors shape threat appraisals, coping appraisals, and adjustment intentions (Figure 3). These new variables beyond the original PMT show how different types of qualitative characteristics, disaster experience, and hazard salience affect threat appraisal. We also included usefulness for other purposes in coping appraisals, which was found to be a critical variable in explaining adjustment intentions.

When considering the practical implications of this study, results of this research can help guide future earthquake risk management in Oklahoma in identifying and taking appropriate actions that will stimulate precautionary behavior of private actors. People often rely on the government to control and mitigate techna hazards (Kasperson and Pijawka 1985). The relaxed political response to techna earthquakes in Oklahoma, however, contrasts with policies in other states that experienced similar techna hazards (Campbell et al. 2020). Therefore, local governments in Oklahoma should work to raise awareness of earthquake risk and use our research findings to emphasize adjustment measures that have low adoption intentions but high potential to reduce risk and are relatively cheap and easy to install (e.g., installing secure cabinets), eliminate financial barriers like providing subsidies or government loans (Babcicky and Seebauer 2019) for costly adjustment measures (e.g., purchasing earthquake insurance), and protect individuals and property from future earthquake hazards. Based on our findings, emergency managers should also be communicating the multi-use function of many adjustment activities to increase adjustment intentions. Given that previous studies have found that individuals perceive information provided by scientists and federal government as more credible than state and local governments (Wu, Greer, and Murphy 2020; Tracy and

Javernick-Will 2020), emergency managers at federal agency level should also educate the public in terms of the earthquake risk and adjustment measures.

This study has several limitations to consider when considering study findings. First, we did not have a direct measure for the self-knowledge variable. Instead, we measure households' perception of their knowledge level on earthquakes, which could deviate from their actual level of knowledge and not accurately represent the relative knowledge level on earthquakes among the Oklahomans. Second, our respondents have a relatively older average age, in comparison to other studies in this area (Derakhshan et al. 2020; Greer et al. 2018; Ng'ombe and Boyer 2019; Wu et al. 2017), which may not sufficiently represent the whole targeted population. Third, most of our respondents identified as White, which could lead our data to have less representativeness on the minority groups. Fourth, some factors that we dropped, such as ideology, income level, the oil entanglement factors, and wastewater awareness, show a significant correlation in some cases but not in the SEM, can be evaluated in future studies for inclusion where appropriate. Lastly, we acknowledge that techna hazards may be unique in regard to the emotional response they produce, thereby limiting the generalizability of adding the identified additional factors to other types of hazards in different areas. Future work should examine the effectiveness of adding these additional variables to the original PMT in different contexts. In conclusion, future work should attempt to overcome the limitations of this research by using actual self-knowledge levels to predict risk perceptions, oversample younger age groups and minorities, and contrast the effect of these additional variables for techna and natural hazards.

7. Data Availability Statement

All data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

8. Acknowledgement

This work is fully supported by the National Science Foundation (CMMI 1827851). The opinions, findings, conclusions, and recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the funding agency.

9. References

Arnold, G., B. Farrer, and R. Holahan. 2017. “Measuring Environmental and Economic Opinions about Hydraulic Fracturing: A Survey of Landowners in Active or Planned Drilling Units.” *Review of Policy Research* 35 (2): 258-279. https://doi.org/10.1111/ropr.12276

Asgary, A., and K. G. Willis. 1997. “Household behaviour in response to earthquake risk: An assessment of alternative theories.” *Disasters* 21 (4): 354–65. https://doi.org/10.1111/1467-7717.00067.

Babcicky, P., and S. Seebauer. 2019. “Unpacking protection motivation theory: Evidence for a separate protective and non-protective route in private flood mitigation behavior.” *Journal of Risk Research* 22 (12): 1503–21. https://doi.org/10.1080/13669877.2018.1485175.

Becker, J. S., D. Paton, D. M. Johnston, and K. R. Ronan. 2012. “A model of household preparedness for earthquakes: How individuals make meaning of earthquake information and how this influences preparedness.” *Natural Hazards* 64 (1): 107–37. https://doi.org/10.1007/s11069-012-0238-x.

Bentler, P. M. 1990a. “Comparative fit indexes in structural models.” *Psychological Bulletin* 107 (2). https://doi.org/10.1037/0033-2909.107.2.238.

———. 1990b. “Fit indexes, lagrange multipliers, constraint changes and incomplete data in structural models.” *Multivariate Behavioral Research* 25 (2). https://doi.org/10.1207/s15327906mbr2502_3.

Blanchard-Boehm, R. D., K. A. Berry, and P. S. Showalter. 2001. “Should flood insurance be mandatory? Insights in the wake of the 1997 New Year’s Day flood in Reno–Sparks, Nevada.” *Applied Geography* 21 (3): 199–221. https://doi.org/10.1016/S0143-6228(01)00009-1.

Boholm, Åsa. 1998. “Comparative studies of risk perception: A review of twenty years of research.” *Journal of Risk Research* 1 (2): 135–63. https://doi.org/10.1080/136698798377231.

Botzen, W. J. W., H. Kunreuther, J. Czajkowski, and H. de Moel. 2019. “Adoption of individual flood damage mitigation measures in New York City: An extension of protection motivation theory.” *Risk Analysis* 39 (10): 2143–59. https://doi.org/10.1111/risa.13318.

Browne, M. W., and R. Cudeck. 1992. “Alternative ways of assessing model fit.” *Sociological Methods & Research* 21 (2). https://doi.org/10.1177/0049124192021002005.

Brun, W. 1992. “Cognitive components in risk perception: Natural versus manmade risks.” *Journal of Behavioral Decision Making* 5 (2): 117–32. https://doi.org/10.1002/bdm.3960050204.

Bryne, B. 2010. *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*. *Structural Equation Modeling*.

Bubeck, P., W. Botzen, and J. Aerts. 2012. “A Review of risk perceptions and other factors that influence flood mitigation behavior.” *Risk Analysis* 32 (9): 1481–95. https://doi.org/10.1111/j.1539-6924.2011.01783.x.

Campbell, N. M., M. Leon-Corwin, L. A. Ritchie, and J. Vickery. 2020. “Human-Induced seismicity: Risk perceptions in the state of Oklahoma.” *Extractive Industries and Society* 7 (1). https://doi.org/10.1016/j.exis.2020.01.005.

Chen, X., and R. E. Abercrombie. 2020. “Improved approach for stress drop estimation and its application to an induced earthquake sequence in Oklahoma.” *Geophysical Journal International* 223 (1). https://doi.org/10.1093/gji/ggaa316.

Choma, B. L., Y. Hanoch, M. Gummerum, and G. Hodson. 2013. “Relations between risk perceptions and socio-political ideology are domain- and ideology- dependent.” *Personality and Individual Differences* 54 (1): 29–34. https://doi.org/10.1016/j.paid.2012.07.028.

Cole, G. A., and S. B. Withey. 1981. “Perspectives on risk perceptions.” *Risk Analysis* 1 (2): 143–63. https://doi.org/10.1111/j.1539-6924.1981.tb01409.x.

Derakhshan, S., M. E. Hodgson, and S. L. Cutter. 2020. “Vulnerability of populations exposed to seismic risk in the state of Oklahoma.” *Applied Geography* 124. https://doi.org/10.1016/j.apgeog.2020.102295.

Dillon, R. L., C. H. Tinsley, and M. Cronin. 2011. “Why near-miss events can decrease an individual’s protective response to hurricanes.” *Risk Analysis* 31 (3): 440–49. https://doi.org/10.1111/j.1539-6924.2010.01506.x.

Dooley, D., R. Catalano, S. Mishra, and S. Serxner. 1992. “Earthquake preparedness: Predictors in a community survey.” *Journal of Applied Social Psychology* 22 (6): 451–70. https://doi.org/10.1111/j.1559-1816.1992.tb00984.x.

Duží, B., D. Vikhrov, I. Kelman, R. Stojanov, and D. Juřička. 2017. “Household measures for river flood risk reduction in the Czech Republic.” *Journal of Flood Risk Management* 10 (2). https://doi.org/10.1111/jfr3.12132.

Eiser, J. R., A. Bostrom, I. Burton, D. M. Johnston, J. McClure, D. Paton, J. van der Pligt, and M. P. White. 2012. “Risk interpretation and action: A conceptual framework for responses to natural hazards.” *International Journal of Disaster Risk Reduction* 1 (1): 5–16. https://doi.org/10.1016/j.ijdrr.2012.05.002.

Ferrer, R. A., W. M. P. Klein, A. Persoskie, A. Avishai-Yitshak, and P. Sheeran. 2016. "The tripartite model of risk perception (TRIRISK): Distinguishing deliberative, affective, and experiential components of perceived risk." *Annals of Behavioral Medicine* 50 (5). https://doi.org/10.1007/s12160-016-9790-z.

Finucane, M. L., P. Slovic, C. K. Mertz, J. Flynn, and T. A. Satterfield. 2000. "Gender, race, and perceived risk: The 'white male' effect." *Health, Risk and Society* 2 (2). https://doi.org/10.1080/713670162.

Fischhoff, B., and J. D. Kadvany. 2011. *Risk: A Very Short Introduction*. Oxford: Oxford University Press.

Fischhoff, B., P. Slovic, S. Lichtenstein, S. Read, and B. Combs. 1978. "How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits." *Policy Sciences* 9 (2): 127–52. https://doi.org/10.1007/BF00143739.

Ge, Y., W. G. Peacock, and M. K. Lindell. 2011. "Florida households' expected responses to hurricane hazard mitigation incentives." *Risk Analysis* 31 (10): 1676–91. https://doi.org/10.1111/j.1539-6924.2011.01606.x.

Ghasemi, B., G. T. Kyle, and J. D. Absher. 2020. "An examination of the social-psychological drivers of homeowner wildfire mitigation." *Journal of Environmental Psychology* 70 (August 2019): 101442. https://doi.org/10.1016/j.jenvp.2020.101442.

Gill, D. A., and L. A. Ritchie. 2018. "Contributions of technological and natech disaster research to the social science disaster paradigm." https://doi.org/10.1007/978-3-319-63254-4_3.

Gotham, K. F., R. Campanella, K. Lauve-Moon, and B. Powers. 2017. "Hazard experience, geophysical vulnerability, and flood risk perceptions in a postdisaster city, the case of New Orleans." *Risk Analysis*, June. https://doi.org/10.1111/risa.12830.

Greer, A., H. -C. Wu, and H. Murphy. 2018. "A serendipitous, quasi-natural experiment: Earthquake risk perceptions and hazard adjustments among college students." *Natural Hazards*. https://doi.org/10.1007/s11069-018-3337-5.

Greer, A., H. -C. Wu, and H. Murphy. 2020. "Household adjustment to seismicity in Oklahoma." *Earthquake Spectra*. https://doi.org/10.1177/8755293020919424.

Grothmann, T., and F. Reusswig. 2006. "People at risk of flooding: Why some residents take precautionary action while others do not." *Natural Hazards* 38 (1–2): 101–20. https://doi.org/10.1007/s11069-005-8604-6.

Holland, A. 2013. "Earthquakes triggered by hydraulic fracturing in south-central Oklahoma." *Bulletin of the Seismological Society of America* 103 (3): 1784–92.

Howard K., and P. Slovic. 1978. "Economics, psychology, and protective behavior." *The American Economic Review* 68 (2): 64–69.

Hu, L. T., and P. M. Bentler. 1999. "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives." *Structural Equation Modeling* 6 (1). https://doi.org/10.1080/10705519909540118.

Huntsman, D., H. -C. Wu, and A. Greer. 2021. "What matters? Exploring drivers of basic and complex adjustments to tornadoes among college students." *Weather, Climate, and Society* 13 (3). https://doi.org/10.1175/WCAS-D-21-0008.1.

Jackson, E. L. 1981. "Response to earthquake hazard: The west coast of North America." *Environment and Behavior*.

Jackson, R. B., A. Vengosh, J. W. Carey, R. J. Davies, T. H. Darrah, F. O'Sullivan, and G. Pétron. 2014. "The environmental costs and benefits of fracking." *Annual Review of Environment and Resources*. https://doi.org/10.1146/annurev-environ-031113-144051.

Jenkins-Smith, H., J. Ripberger, C. Silva, N. Carlson, K. Gupta, M. Henderson, A. Goodin, et al. 2017. "The Oklahoma meso-scale integrated socio-geographic network: A technical overview." *Journal of Atmospheric and Oceanic Technology* 34 (11): 2431–41. https://doi.org/10.1175/JTECH-D-17-0088.1.

Jigyasu, R. 2021. "Mainstreaming cultural heritage in disaster risk governance." *Strengthening Disaster Risk Governance to Manage Disaster Risk*. https://doi.org/10.1016/b978-0-12-818750-0.00003-9.

Johann, L., S. A. Shapiro, and Carsten Dinske. 2018. "The surge of earthquakes in central Oklahoma has features of reservoir-induced seismicity." *Scientific Reports* 8 (1): 1–14. https://doi.org/10.1038/s41598-018-29883-9.

Jones, C. 2016. "Insurers pay record $1.5 million in claims for prague earthquake, but overall approvals are few." *Tulsa World*, November 2016.

Ju, Y., and M. You. 2021. "It's politics, isn't it? Investigating direct and indirect influences of political orientation on risk perception of COVID-19." *Risk Analysis*. https://doi.org/10.1111/risa.13801.

Junod, A. N., J. B. Jacquet, F. Fernando, and L. Flage. 2018. "Life in the Goldilocks Zone: Perceptions of place disruption on the periphery of the Bakken Shale." *Society and Natural Resources* 31 (2). https://doi.org/10.1080/08941920.2017.1376138.

Kahan, D. M., D. Braman, J. Gastil, P. Slovic, and C. K. Mertz. 2007. “Culture and identity-protective cognition: Explaining the white-male effect in risk perception.” *Journal of Empirical Legal Studies* 4 (3): 465–505. https://doi.org/10.1111/j.1740-1461.2007.00097.x.

Kahan, D. M., E. Peters, M. Wittlin, P. Slovic, L. L. Ouellette, D. Braman, and G. Mandel. 2012. “The polarizing impact of science literacy and numeracy on perceived climate change risks.” *Nature Climate Change* 2 (10): 732–35. https://doi.org/10.1038/nclimate1547.

Kasperson, R. E., and K. D. Pijawka. 1985. “Societal response to hazards and major hazard events: Comparing natural and technological hazards.” *Public Administration Review* 45: 7. https://doi.org/10.2307/3134993.

Kellens, W., R. Zaalberg, T. Neutens, W. Vanneuville, and P. de Maeyer. 2011. “An analysis of the public perception of flood risk on the Belgian Coast.” *Risk Analysis* 31 (7). https://doi.org/10.1111/j.1539-6924.2010.01571.x.

Keller, C., M. Siegrist, and H. Gutscher. 2006. “The role of the affect and availability heuristics in risk communication.” *Risk Analysis* 26 (3): 631–39. https://doi.org/10.1111/j.1539-6924.2006.00773.x.

Kung, Y., and S. Chen. 2012. “Perception of earthquake risk in Taiwan: Effects of gender and past earthquake experience.” *Risk Analysis* 32 (9): 1535–46. https://doi.org/10.1111/j.1539-6924.2011.01760.x.

Kunreuther, H., and P. Slovic. 1996. “Science, values, and risk.” *The ANNALS of the American Academy of Political and Social Science* (May): 116–25.

Lindell, M. K., and C. Prater. 2002. “Risk area residents’ perceptions and adoption of seismic hazard adjustments.” *Journal of Applied Social Psychology* 32 (11): 2377–92.

Lindell, M. K. 2013. “Disaster studies.” *Current Sociology* 61 (5–6): 797–825. https://doi.org/10.1177/0011392113484456.

Lindell, M. K., S. Arlikatti, and C. S. Prater. 2009. “Why people do what they do to protect against earthquake risk: Perceptions of hazard adjustment attributes.” *Risk Analysis* 29 (8): 1072–88. https://doi.org/10.1111/j.1539-6924.2009.01243.x.

Lindell, M. K., and S. N. Hwang. 2008. “Households’ perceived personal risk and responses in a multihazard environment.” *Risk Analysis* 28 (2): 539–56. https://doi.org/10.1111/j.1539-6924.2008.01032.x.

Lindell, M. K., and R, W. Perry. 2000. “Household adjustment to earthquake hazard a review of research.” *Environment and Behavior* 32 (4): 461–501.

Lindell, M. K., C. S. Prater, H. -C. Wu, S. Huang, D. M. Johnston, J. S. Becker, and H. Shiroshita. 2016. “Immediate behavioural responses to earthquakes in Christchurch, New Zealand, and Hitachi, Japan.” *Disasters* 40 (1): 85–111. https://doi.org/10.1111/disa.12133.

Lindell, M. K., and D. J. Whitney. 2000. “Correlates of household seismic hazard adjustment adoption.” *Risk Analysis* 20 (1): 13–25. https://doi.org/10.1111/0272-4332.00002.

Lindell, M., and C. Prater. 2000. “Household adoption of seismic hazard adjustments: A comparison of residents in two states.” *International Journal of Mass Emergencies and Disasters* 18 (2): 317–38.

Marsh, H. W., and D. Hocevar. 1985. “Application of confirmatory factor analysis to the study of self-concept. First- and higher order factor models and their invariance across groups.” *Psychological Bulletin* 97 (3). https://doi.org/10.1037/0033-2909.97.3.562.

Martin, I. M., H. Bender, and C. Raish. 2007. “What motivates individuals to protect themselves from risks: The case of wildland fires.” *Risk Analysis* 27 (4): 887–900. https://doi.org/10.1111/j.1539-6924.2007.00930.x.

Meyer, M. A. 2016. “Elderly perceptions of social capital and age-related disaster vulnerability.” *Disaster Medicine and Public Health Preparedness* 2 (2): 1–8. https://doi.org/10.1017/dmp.2016.139.

Murphy, H., A. Greer, and H. -C. Wu. 2018. “Trusting government to mitigate a new hazard: The case of Oklahoma earthquakes.” *Risk, Hazards and Crisis in Public Policy* 9 (3). https://doi.org/10.1002/rhc3.12141.

Nakayachi, K., H. Yokoyama, and S. Oki. 2015. “Public anxiety after the 2011 Tohoku Earthquake: Fluctuations in hazard perception after catastrophe.” *Journal of Risk Research* 18 (2): 156–69. https://doi.org/10.1080/13669877.2013.875936.

Newman, S. M., M. S. Carroll, P. J. Jakes, D. R. Williams, and L. L. Higgins. 2014. “Earth, wind, and fire: Wildfire risk perceptions in a hurricane-prone environment.” *Society & Natural Resources* 27 (11): 1161–76. https://doi.org/10.1080/08941920.2014.918234.

Ng’ombe, J. N., and T. A. Boyer. 2019. “Determinants of earthquake damage liability assignment in Oklahoma: A Bayesian Tobit censored approach.” *Energy Policy* 131. https://doi.org/10.1016/j.enpol.2019.05.013.

Oakley, M., S. M. Himmelweit, P. Leinster, and M. R. Casado. 2020. “Protection motivation theory: A proposed theoretical extension and moving beyond rationality-the case of flooding.” *Water (Switzerland)* 12 (7). https://doi.org/10.3390/W12071848.

O'Brien, P., and D. S. Mileti. 1992. "Citizen participation in emergency response." *International Journal of Mass Emergencies and Disasters*.

Office Of The Secretary Of Energy & Environment. 2018. "What we know: Earthquakes in Oklahoma." 2018.

Ong, A. K. S., Y. T. Prasetyo, F. C. Lagura, R. N. Ramos, K. M. Sigua, J. A. Villas, M. N. Young, J. F. T. Diaz, S. F. Persada, and A. A. N. P. Redi. 2021. "Factors affecting intention to prepare for mitigation of 'the Big One' Earthquake in the Philippines: Integrating protection motivation theory and extended theory of planned behavior." *International Journal of Disaster Risk Reduction* 63 (July). https://doi.org/10.1016/j.ijdrr.2021.102467.

Palm, R. 1998. "Urban earthquake hazards: The impacts of culture on perceived risk and response in the USA and Japan." *Applied Geography* 18 (1): 35–46. https://doi.org/10.1016/S0143-6228(97)00044-1.

Paton, D., L. Smith, and D. Johnston. 2000. "Volcanic hazards: Risk perception and preparedness." *New Zealand Journal of Psychology* 29 (2): 86–91.

Peers, J. B., M.K. Lindell, C. E. Gregg, A. K. Reeves, A. T. Joyner, and D. M. Johnston. 2021. "Multi-hazard perceptions at Long Valley Caldera, California, USA." *International Journal of Disaster Risk Reduction* 51: 101955.

Pennebaker, J., and K. Harber. 1993. "A social stage model of collective coping: The Loma Prieta Earthquake and the Persian Gulf War." *Journal of Social Issues* 49 (4): 125–45.

Perry, R., and M. Lindell. 1990. "Predicting long-term adjustment to volcano hazard." *International Journal of Mass Emergencies & Disasters* 8 (2): 117–36.

Perry, R. W., and M. K. Lindell. 2008. "Volcanic risk perception and adjustment in a multi-hazard environment." *Journal of Volcanology and Geothermal Research* 172 (3): 170–78. https://doi.org/10.1016/j.jvolgeores.2007.12.006.

Peters, E. M., B. Burraston, and C. K. Mertz. 2004. "An emotion-based model of risk perception and stigma susceptibility: Cognitive appraisals of emotion, affective reactivity, worldviews, and risk perceptions in the generation of technological stigma." *Risk Analysis*. https://doi.org/10.1111/j.0272-4332.2004.00531.x.

Petersen, M. D., C. S. Mueller, M. P. Moschetti, S. M. Hoover, K. S. Rukstales, D. E. McNamara, R. A. Williams, et al. 2018. "2018 one-year seismic hazard forecast for the central and eastern United States from induced and natural earthquakes." *Seismological Research Letters* 89 (3): 1049–61. https://doi.org/10.3133/OFR20161035.

Pidgeon, N. 1998. "Risk assessment, risk values and the social science programme: Why we do need risk perception research." *Reliability Engineering & System Safety* 59: 5–15. https://doi.org/10.1016/S0951-8320(97)00114-2.

Pollard, J. A., and D. C. Rose. 2019. "Lightning rods, earthquakes, and regional identities: Towards a multi-scale framework of assessing fracking risk perception." *Risk Analysis* 39 (2). https://doi.org/10.1111/risa.13167.

Porter, R. T. J., A. Striolo, H. Mahgerefteh, and J. F. Walker. 2019. "Addressing the risks of induced seismicity in subsurface energy operations." *Wiley Interdisciplinary Reviews: Energy and Environment*. https://doi.org/10.1002/wene.324.

Prater, C. S., and M. K. Lindell. 2000. "Politics of hazard mitigation." *Natural Hazards Review* 1 (2): 73–82.

Renn, O. 1992. "Concepts of risk: A classification." *Social Theories of Risk*. https://doi.org/10.18419/opus-7248.

———. 1998. "Three decades of risk research." *Journal of Risk Research* 1 (1): 49–71. https://doi.org/10.1080/136698798377330.

Ritchie, L. A., M. A. Long, M. Leon-Corwin, and D. A. Gill. 2021. "Citizen perceptions of fracking-related earthquakes: Exploring the roles of institutional failures and resource loss in Oklahoma, United States". *Energy Research & Social Science* 90: 102235. https://doi.org/10.1016/j.erss.2021.102235

Ripberger, J. T., H. Jenkins-Smith, C. L. Silva, J. Czajkowski, H. Kunreuther, and K. M. Simmons. 2017. "Tornado damage mitigation: Homeowner support for enhanced building codes in Oklahoma." *Risk Analysis* 38 (11): 2300-2317. https://doi.org/10.1111/risa.13131

Rogers, R. 1975. "A protection motivation theory of fear appeals and attitude change." *Journal of Psychology: Interdisciplinary and Applied*. https://doi.org/10.1080/00223980.1975.9915803.

Russell, L., J. Goltz, and L. Bourque. 1995. "Preparedness and hazard mitigation actions before and after two earthquakes." *Environment and Behavior* 27 (6): 744–70.

Seebauer, S., and P. Babcicky. 2020. "(Almost) All quiet over one and a half years: A longitudinal study on causality between key determinants of private flood mitigation." *Risk Analysis*. https://doi.org/10.1111/risa.13598.

Sjöberg, L. 1998. "Worry and risk perception." *Risk Analysis* 18 (1): 85–93. https://doi.org/10.1111/j.1539-6924.1998.tb00918.x.

Slimak, M. W., and T. Dietz. 2006. "Personal values, beliefs, and ecological risk perception." *Risk Analysis* 26 (6): 1689–1705. https://doi.org/10.1111/j.1539-6924.2006.00832.x.

Slovic, P., M. L. Finucane, E. Peters, and D. G. MacGregor. 2004. “Risk as analysis and risk as feelings.” *Risk Analysis* 24 (2): 311–22.

Starr, C. 1969. “Social benefit versus technological risk.” In *Readings in Risk*, edited by Theodore Glickman and Michael Gough, 1st ed., 183–94. Washington D.C.: Resources for the Future.

Steelman, T. A., S. M. McCaffrey, A. K. Velez, and J. A. Briefel. 2015. “What information do people use, trust, and find useful during a disaster? Evidence from five large wildfires.” *Natural Hazards* 76 (1): 615–34. https://doi.org/10.1007/s11069-014-1512-x.

Stojanov, R., B. Duží, T. Danek, D. Nemec, and D. Procházka. 2015. “Adaptation to the impacts of climate extremes in central Europe: A case study in a rural area in the Czech Republic.” *Sustainability (Switzerland)* 7 (9). https://doi.org/10.3390/su70912758.

Sumy, D. F., E. S. Cochran, K. M. Keranen, M. Wei, and G. A. Abers. 2014. “Observations of static coulomb stress triggering of the November 2011 M5.7 Oklahoma Earthquake Sequence.” *Journal of Geophysical Research: Solid Earth* 119 (3). https://doi.org/10.1002/2013JB010612.

Taylor, J., M. Çelebi, A. Greer, E. Jampole, A. Masroor, S. Melton, D. Norton, N. Paul, E. Wilson, and Y. Xiao. 2017. “EERI Earthquake Reconnaissance Team Report: M5.0 Cushing, Oklahoma, USA Earthquake on November 7, 2016.” *EERI Learning From Earthquakes Program*, no. February: 1–25.

The New York Times. 2016. “Oklahoma Election Results 2016 – The New York Times.” The New York Times. 2016.

Tierney, K. J. 2014. *The Social Roots of Risk: Producing Disasters, Promoting Resilience*. Redwood City, CA: Stanford University Press.

Tierney, K. J. 1993. “Socio-Economic Aspects of Hazard Mitigation.” In *Research Seminar on Socio-Economic Aspects of Disasters in Central America*.

Tinsley, C. H., R. L. Dillon, and M. A. Cronin. 2012. “How near-miss events amplify or attenuate risky decision making.” *Management Science* 58 (9): 1596–1613. https://doi.org/10.1287/mnsc.1120.1517.

Tracy, A., and A. Javernick-Will. 2020. “Credible sources of information regarding induced seismicity.” *Sustainability (Switzerland)* 12 (6). https://doi.org/10.3390/su12062308.

Tracy, A., A. Javernick-Will, and C. Torres-Machi. 2021. “Human-induced or natural hazard? Factors influencing perceptions of actions to be taken in response to induced seismicity.” *International Journal of Disaster Risk Reduction* 57. https://doi.org/10.1016/j.ijdrr.2021.102186.

Tversky, A., and D. Kahneman. 1973. “Availability: A heuristic for judging frequency and probability.” *Cognitive Psychology* 5: 207–32.

United State Census Bureau. 2019. “U.S. Census Bureau QuickFacts: Oklahoma; United States”. Retrieved April 13, 2022, from https://www.census.gov/acs/www/data/data-tables-and-tools/data-profiles/2019/

USGS. n.d. “USGS Earthquakes Hazard Program.” Accessed December 15, 2021. https://earthquake.usgs.gov/earthquakes/.

van der Linden, S. 2015. “The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model.” *Journal of Environmental Psychology* 41: 112–24. https://doi.org/10.1016/j.jenvp.2014.11.012.

Vásquez W., T. Murray, S. Meng, P. Mozumder. 2018. “Risk perceptions of future hurricanes: Survey evidence from the northeastern and mid-Atlantic United States.” *Natural Hazards Review* 19 (1): 04017026.

Västfjäll, D., E. Peters, and P. Slovic. 2008. “Affect, risk perception and future optimism after the Tsunami Disaster.” *Judgement and Decision Making* 3 (1): 64–72. https://doi.org/10.4324/9781849776677.

Visschers, V. H. M., and M. Siegrist. 2013. “How a nuclear power plant accident influences acceptance of nuclear power: Results of a longitudinal study before and after the Fukushima Disaster.” *Risk Analysis* 33 (2): 333–47. https://doi.org/10.1111/j.1539-6924.2012.01861.x.

Walpole, H. D., and R. S. Wilson. 2021. “Extending a broadly applicable measure of risk perception: The case for susceptibility.” *Journal of Risk Research* 24 (2). https://doi.org/10.1080/13669877.2020.1749874.

Wertz, J. 2013. “Oklahoma’s response to man-made quakes is more passive than other states.” *StateImpact Oklahoma*, May 16, 2013.

Westcott, R., K. Ronan, H. Bambrick, and M. Taylor. 2017. “Expanding protection motivation theory: Investigating an application to animal owners and emergency responders in bushfire emergencies.” *BMC Psychology* 5 (1). https://doi.org/10.1186/s40359-017-0182-3.

Wright, D. B. 2002. *First Steps in Statistics*. London: SAGE.

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.” *Journal of Risk Research* 11 (3): 351–74. https://doi.org/10.1080/13669870701552235.

Wilson, R. S., A. Zwickle, and H. Walpole. 2019. “Developing a broadly applicable measure of risk perception.” *Risk Analysis* 39 (4). https://doi.org/10.1111/risa.13207.

Wu, H. -C., A. Greer, and H. Murphy. 2020. “Perceived stakeholder information credibility and hazard adjustments: A case of induced seismic activities in Oklahoma.” *Natural Hazards Review* 21 (3). https://doi.org/10.1061/(asce)nh.1527-6996.0000378.

Wu, H. -C., M. K. Lindell, and C. S. Prater. 2012. “Logistics of hurricane evacuation in hurricanes Katrina and Rita.” *Transportation Research Part F: Psychology and Behaviour* 15 (4): 445–61. https://doi.org/10.1016/j.trf.2012.03.005.

Wu, H. -C., M. K. Lindell, and C. S. Prater. 2015. “Process tracing analysis of hurricane information displays.” *Risk Analysis* 35 (12): 2202–20. https://doi.org/10.1111/risa.12423.

Wu, H. -C., M. Lindell, and C. Prater. 2013. “The logistics of household hurricane evacuation during Hurricane Ike.” In *Logistics: Perspectives, Approaches and Challenges*, edited by J. Cheung and H. Song, 127–40. Hauppauge, NY: Nova Science Publishers.

Wu, H. -C., A. Greer, and H. Murphy. 2017. “Perceived stakeholders’ trustworthiness of earthquake information: A case of induced seismic activities in Oklahoma.” In *Taiwan Urban and Regional Planning Conference*. Taipei, Taiwan.

Wu, H. -C., A. Greer, H. C. Murphy, and R. Chang. 2017. “Preparing for the new normal: Students and earthquake hazard adjustments in Oklahoma.” *International Journal of Disaster Risk Reduction* 25 (October): 312–23.

Zhai, G., M. Shirzaei, M. Manga, and X. Chen. 2019. “Pore-pressure diffusion, enhanced by poroelastic stresses, controls induced seismicity in Oklahoma.” *Proceedings of the National Academy of Sciences of the United States of America* 116 (33). https://doi.org/10.1073/pnas.1819225116.

Zwickle, A., and R. S. Wilson. 2014. “Construing risk: implications for risk communication.” In *Effective Risk Communication*, edited by Joseph Arvai and Louie III Rivers, 190–202. London: Routledge.

10. Tables

Table 1: Measurements of the Study

Variable	Measurement	Source
Hazard Salience	How often do you think about earthquakes (1=Never to 5=Daily)	(Lindell et al. 2016; Wu et al. 2012 2013; Wu et al. 2017)
Experience of property damage	In the last few years has your property had damage from a local earthquake (1=No damage to 5=Total collapse of home)	
Risk perceptions	Risk perceptions regarding potential damage to their homes or properties, injuries, job disruptions, and daily activity disruptions (1=Not at all likely to 5=Almost certain)	
Familiarity	Do you consider earthquakes new, novel risks or old, familiar ones (1=New, 5=Old)	(Fischhoff et al. 1978)
Perceived self-knowledge	How knowledgeable are you about earthquake hazards (1=Not at all to 5=Very great extent)	(Lindell and Whitney 2000)
Perceived scientists' knowledge	To what extent do you think scientists (Oklahoma Geological Survey, US Geological Survey, college professors) know about earthquake hazards (1=Known precisely to 5=Not known)	(Lindell and Whitney 2000)
Dreadfulness	Is earthquake risk a risk that people have learned to live with and can think about reasonably calmly, or is it one that people have great dread for (1=Common to 5=Dread)	(Fischhoff et al. 1978)
Negative emotions	Please rate how much negative emotion (i.e. anger, fear, disgust) you feel when you think about earthquakes and their impacts (1=No negative emotion to 5=High negative emotion)	
Adjustment intentions	The likelihood that they will adopt each of the ten hazard adjustment activities (1=Not at all to 5=Very great extent)	(Lindell and Whitney 2000)
Coping appraisals	The perceived attributes (efficacy, cost, and special knowledge, cooperation, and effort required) of adjustment activities (1=Not at all to 5=Very great extent)	
Demographic information	Age (Year)	(Lindell et al. 2016; Wu et al. 2012 2013; Wu et al. 2017)
	Women (Female=1, Non-female=0)	
	Race (White, African American, Native American, Asian, Hispanic)	
	Marital status (Married=1, Unmarried = 0)	
	Education level (Less than high school=1, High school graduate=2, Some college/vocational school=3, College graduate=4, Graduate school=5)	
	Household annual income level (Less than \$30K=1, \$30K-\$54,999=2, \$55K-\$79,999=3, \$80K-\$104,999=4, \$105K-\$129,999=5, More than \$130K=6)	
	Homeownership (Own=1, Rent=0)	
	The duration of time living in their current home (year), duration of living in the state of Oklahoma (Year)	
	Family composition in terms of age groups (How many members of your family (including yourself) are: under 18 years old, 18-65 years old, over 65 years old)	
Oil entanglement (mineral rights)	Have you received payments for the mineral rights underneath your property, either now or in the past (Yes=1, No=0)	(Arnold, Farrer, and Holahan 2017)
Oil entanglement	Have you or anyone in your household ever been employed by a hydraulic fracturing/oil and gas company, either now or in the past (Yes=1, No=0)	(Ritchie et al. 2021)

(family ties to the oil industry)		
Wastewater awareness	How would you rate your awareness on the subject of wastewater injection wells (1=Not at all knowledgeable to 5=Very knowledgeable)	(Lindell and Whitney 2000)

Table 2. Descriptive Statistics and Demographic Information Compared to 2019 Oklahoma Census

Variables	Mean	SD	Variables	Survey	Census
Hazard Salience	2.05	0.88	Age	55.2	36.6
Experience of Property Damage	1.47	0.75	Bachelor's degree or higher	57.4%	25.5%
Risk Perception - City Damage	2.36	1.12	Median household income	55K-80K	73k
Risk Perception - Home Damage	2.15	1.07	Homeownership	82.4%	57.5%
Risk Perception - Family Injury	1.79	0.95	Female	50.3%	50.4%
Risk Perception - Job Disruption	1.73	0.98	Married	64.5%	49.3%
Risk Perception - Activity Disruption	1.85	1.01	White	65.1%	72.3%
Familiarity	2.77	1.39	African American	4.7%	7.3%
Self-knowledge	2.89	1.08	Native American	11.0%	7.6%
Scientists Knowledge	3.56	1.00	Asian	9.6%	2.2%
Dreadfulness	2.90	1.13	Hispanic	8.7%	10.6%
Negative Emotion	2.51	1.27			
Intention – Earthquake Insurance (EQIns)	2.69	1.63			
Intention – Secure Cabinets (SecCabinets)	2.09	1.29			
Intention - Shut off Utility (ShutUti)	4.22	1.20			
Intention –Emergency Plan (EMPlan)	3.79	1.36			
Intention – Flashlight	4.75	0.80			
Intention – Fire Extinguisher (FireExt)	4.25	1.23			
Intention - First-aid Kit (FAKit)	4.49	1.05			
Intention - First-aid Training (FATraining)	3.89	1.36			
Intention - Three-day Food (TDFood)	3.67	1.43			
Intention - Three-day Water (TDWater)	3.84	1.40			
Mineral Right	0.14	0.35			
Oil Industry Employment	0.09	0.28			
Conservativeness	3.35	1.10			
Wastewater awareness	2.77	1.25			

Table 3. Intercorrelations Among Variables

Variables			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Hazard Salience	1	Hazard Salience	--																																											
Experience	2	Property Damage	.23**	--																																										
Risk Perceptions	3	City Damage	.35**	.29**	--																																									
	4	Home Damage	.32**	.36**	.86**	--																																								
	5	Family Injury	.29**	.25**	.71**	.80**	--																																							
	6	Job Disruption	.23**	.20**	.59**	.65**	.77**	--																																						
	7	Activity Disruption	.28**	.18**	.68**	.71**	.78**	.78**	--																																					
Qualitative Characteristics	8	Familiarity	-.03	-.06	.04	.05	.08*	.09**	.11**	--																																				
	9	Self-Knowledge	.17**	.06	.13**	.15**	.12**	.10**	.15**	.35**	--																																			
	10	Scientist Knowledge	.05	.00	.03	.01	.02	.01	.01	.03	.12**	--																																		
	11	Dreadfulness	.15**	.14**	.31**	.32**	.29**	.27**	.30**	-.06	-.02	.06	--																																	
	12	Negative Emotion	.33**	.23**	.44**	.46**	.38**	.33**	.38**	-.06	.09*	.09*	.43**	--																																
Adjustment Intentions	13	EQIns	.18**	.10**	.21**	.26**	.21**	.21**	.21**	.01	.10**	.02	.14**	.19**	--																															
	14	SecCabinets	.07*	.09*	.18**	.22**	.22**	.20**	.19**	.07*	.10**	.04	.15**	.20**	.23**	--																														
	15	ShutUti	.02	.04	.00	.00	-.06	-.05	-.06	-.06	.16**	.06	.02	-.03	.07	.15**	--																													
	16	EMPlan	.04	.03	.02	.06	.04	.06	.02	-.04	.09*	.09*	.08*	.04	.15**	.28**	.39**	--																												
	17	Flashlight	.01	.04	-.04	-.02	-.04	-.04	-.02	-.09**	.07*	.10**	.05	-.04	.09**	.06	.37**	.35**	--																											
	18	FireExt	.10**	.09*	.13**	.15**	.09*	.07	.11**	-.02	.13**	.03	.08*	.06	.14**	.18**	.34**	.30**	.36**	--																										
	19	FAKit	.01	.03	.04	.06	.00	.04	.04	-.01	.12**	.09*	.04	.03	.07*	.18**	.34**	.38**	.46**	.43**	--																									
	20	FATraining	.08*	.08*	.13**	.14**	.10**	.12**	.12**	.00	.09**	.03	.13**	.10**	.18**	.20**	.21**	.29**	.27**	.28**	.43**	--																								
	21	TDFood	.05	.07*	.10**	.14**	.09*	.09*	.08*	.05	.19**	.07*	.09**	.08*	.15**	.31**	.26**	.39**	.24**	.35**	.37**	.32**	--																							
	22	TDWater	.07*	.04	.10**	.13**	.09**	.10**	.08*	.05	.14**	.09*	.12**	.10**	.14**	.31**	.25**	.43**	.28**	.32**	.41**	.32**	.71**	--																						
Age	23	Age	.16**	.09*	.16**	.16**	.13**	-.01	.10**	.12**	.12**	.02	-.07*	.05	.01	-.10**	-.03	-.19**	-.07*	.02	-.06	-.09*	-.02	-.06	--																					
Oil Entanglement	24	Mineral Rights	.07	.07*	.03	.05	.01	-.04	.00	.08*	.06	-.07*	.00	-.03	-.06	-.09*	.01	-.09**	.00	.01	.02	-.01	.04	.01	.25**	--																				
	25	Oil Employment	.04	.09**	.01	.02	-.03	-.03	-.04	-.01	-.01	.03	-.05	-.03	.03	-.02	.00	.01	.05	.03	.01	.02	.02	.00	.00	.12**	--																			
Sex	26	Female	-.03	.07*	.09**	.08*	.07*	.09*	.06	.00	-.08*	.08*	.10**	.12**	.01	.07*	-.10**	.12**	.02	-.03	.02	.08*	-.02	.01	-.12**	-.02	.04	--																		
Race	27	White	.09**	.00	-.01	-.05	-.11**	-.12**	-.08*	-.06	.03	-.01	-.11**	-.12**	.00	-.20**	.02	.00	.12**	.13**	.08*	-.04	-.03	-.06	.22**	.16**	.06	-.01	--																	
	28	African American	.01	.07*	.06	.10**	.11**	.11**	.13**	.06	-.03	.01	.07	.10**	.09**	.17**	-.03	.04	-.02	.01	.00	.06	.07	.06	.01	-.09*	-.05	.04	-.30**	--																
	29	Native American	-.05	.05	.02	.03	.05	-.01	.03	-.04	-.06	.03	.11**	.02	-.04	.02	-.02	-.03	-.03	.00	-.03	.06	.01	.02	.00	.02	.03	.04	-.48**	-.08*	--															
	30	Asian	-.06	-.09**	.01	.02	.06	.11**	.05	.03	.07*	.01	.00	.07	.01	.12**	.01	-.03	-.07	-.09**	-.07*	-.07*	.01	.02	-.23**	-.10**	-.09*	-.08*	-.44**	-.07*	-.11**	--														
	31	Other	-.05	-.02	-.06	-.04	-.01	.01	-.05	.06	-.03	-.04	.01	.04	-.04	.06	.00	.03	-.07	-.12**	-.03	.03	-.02	.01	-.15**	-.12**	.00	.01	-.44**	-.07*	-.11**	-.11**	--													
	32	Hispanic	-.07	-.02	-.06	-.03	.00	.03	-.03	.05	-.05	-.03	.03	.05	-.02	.07	-.01	.03	-.09*	-.13**	-.05	.02	-.01	.01	-.16**	-.11**	-.04	.02	-.42**	-.07	-.11**	-.10**	.94**	--												
Marital Status	33	Married	.05	.03	-.02	-.02	-.07	-.04	-.04	-.12**	.01	-.04	-.07*	.01	.06	-.06	.19**	.09**	.09**	.12**	.11**	.00	-.03	-.03	-.03	.07*	.03	-.20**	.06	-.09*	-.12**	.11**	.00	-.01	--											
Education	34	Education	.10**	-.01	.03	.03	.00	.03	.03	-.04	.09**	.06	.03	.06	.07*	-.01	.09*	-.02	.04	.04	.05	.08*	-.02	.01	-.10**	-.04	-.01	-.06	.02	-.07*	-.13**	.22**	-.07	-.09*	.17**	--										
Income Level	35	Income Level	.05	-.02	-.04	-.04	-.11**	-.07	-.12**	-.13**	.03	.02	-.06	-.06	.14**	-.08*	.13**	.06	.11**	.09*	.09*	-.03	-.03	.00	-.04	.02	.07*	-.14**	.15**	-.13**	-.15**	.09**	-.09*	-.09*	.46**	.37**	--									
Homeownership	36	Own	.06	.06	.05	.09*	-.01	-.06	-.05	-.08*	.06	.03	-.08*	-.04	.12**	-.08*	.17**	.03	.12**	.10**	.09**	-.01	.04	.03	.29**	.14**	.03	-.10**	.15**	-.08*	-.08*	-.03	-.07	-.07*	.28**	.05	.36**	--								
Tenure	37	Tenure	.10**	.11**	.13**	.14**	.06	-.03	.04	-.01	-.04	.01	-.04	-.01	-.03	-.12**	.00	-.15**	.00	.01	-.06	-.06	-.04	-.08*	.61**	.32**	.02	-.02	.26**	-.03	.10**	-.31**	-.19**	-.19**	-.07*	-.21**	-.06	.27**	--							
Household Size	38	Under age of 18	-.11**	-.06	-.08*	-.07*	-.05	.00	-.04	-.04	-.07	-.03	.01	-.03	-.07	.07*	.06	.14**	-.01	.01	.07	.04	.07*	.06	-.34**	-.11**	.03	.09*	-.16**	-.02	.01	.07*	.19**	.20**	.10**	.05	.03	-.03	-.23**	--						
	39	Between 18-65	-.06	-.02	-.07*	-.07	-.07*	.00	-.04	-.13**	-.09*	-.06	.08*	-.01	-.02	-.03	.08*	.15**	.00	-.02	-.01	.04	.05	.05	-.37**	-.13**	.04	-.07	-.14**	.02	.07	.07*	.07*	.08*	.14**	.02	.13**	.01	-.21**	.37**	--					
	40	Over age 65	.10**	.05	.11**	.10**	.11**	-.03	.04	.08*	.07*	.04	-.07	.02	-.03	-.04	-.01	-.16**	-.02	.03	.05	-.05	-.03	-.05	.63**	.25**	.01	-.07	.15**	-.02	-.04	-.11**	-.06	-.08*	.07	-.02	-.05	.21**	.40**	-.21**	-.49**	--				
Politics	41	Democratic	.09*	.06	.05	.06	.07*	.03	.06	-.05	-.05	.07	.08*	.17**	.05	.12**	-.04	-.03	.02	-.02	.03	.02	-.02	-.03	.08*	-.01	-.04	.07*	-.12**	.21**	.07	-.04	.01	.01	-.08*	.05	-.11**	-.06	.06	-.05	-.10**	.10**	--			
	42	Republican	-.01	-.07	-.03	-.05	-.09*	-.10**	-.08*	.05	.03	-.10**	-.08*	-.16**	-.04	-.14**	.07	-.01	.06	.04	.00	-.01	.01	.00	.10**	.11**	.07*	-.07	.26**	-.13**	-.04	-.15**	-.12**	-.12**	.07	-.10**	.14**	.17**	.14**	-.07	.01	.05	-.66**	--		
	43	Independent	-.08*	.00	-.01	-.01	.02	.08*	.02	.01	.01	.03	.01	-.02	.01	.04	-.04	.03	-.11**	-.03	-.02	-.02	.01	.05	-.19**	-.11**	-.05	-.03	-.16**	-.07*	-.05	.21**	.15**	.13**	.00	.08*	-.03	-.12**	-.24**	.12**	.09*	-.15**	-.33**	-.43**	--	
	44	Conservativeness	-.06	.02	-.02	.00	-.01	-.03	.00	.09*	.00	-.07	-.03	-.19**	.03	-.09*	.07	.00	-.01	.04	-.05	-.05	.03	.00	.16**	.09*	.04	-.12**	.10**	.01	.02	-.14**	-.05	-.07	.10**	-.09*	.11**	.16**	.15**	-.04	.00	.06	-.50**	.60**	-.16**	--	
Wastewater	45	Wastewater Awareness	.18**	.11**	.12**	.10**	.02	.00	.03	-.02	.37**	.05	-.02	.08*	.07	-.01	.16**	.04	.08*	.12**	.07*	.10**	.13**	.06	.21**	.19**	.18**	-.15**	.16**	-.04	-.05	-.08*	-.10**	-.14**	.14**	.15**	.20**	.20**	.20**	-.10**	-.02	.11**	.00	.07	-.08*	.06	--

**Correlation is significant at the .01 level (2-tailed).

*Correlation is significant at the .05 level (2-tailed).

Table 4. Correlations among Coping Appraisal Variables and Adjustment Intentions

		Response Efficacy		Self-Efficacy			Response Cost	
		Protect Person Effectively	Protect Property Effectively	Require Special Knowledge	Require Efforts	Require Cooperation	Multi-use	Cost Money
Adjustment Intentions	EQIns	.25**	.26**	.07	.04	.11**	.22**	-.10**
	SecCabinets	.45**	.41**	.28**	.19**	.27**	.47**	.21**
	ShutUti	.25**	.30**	-.03	-.07*	-.11**	.33**	-.13**
	EMPlan	.41**	.23**	.08*	.03	.17**	.39**	-.02
	Flashlight	.12**	.01	-.13**	-.08*	-.11**	.31**	-.05
	FireExt	.24**	.25**	.02	-.03	.03	.26**	-.03
	FAKit	.24**	.02	.07	.01	.00	.30**	.02
	FATraining	.29**	.07*	.15**	.04	.10**	.28**	.01
	TDFood	.41**	.17**	.10**	-.05	.05	.43**	.01
	TDWater	.41**	.18**	.07*	.01	.07	.41**	.02

**Correlation is significant at the .01 level (2-tailed).
*Correlation is significant at the .05 level (2-tailed).

Table 5. SEM Results for the Original PMT Models (n=866)

PMT paths		Earthquake Hazard Adjustment Intentions				
		EQIns	SecCabinets	ShutUti	EMPlan	Flashlight
TA†	Risk perception –> adjustment intention (H6)	.22**	.15**	-.03	.02	-.04
CA†	Response efficacy (protect person) –> adjustment intention (H7)	.13**	.30**	.11*	.38**	.18**
	Response efficacy (protect property) –> adjustment intention (H8)	.20**	.14**	.24**	.13**	-.03
	Self-efficacy –> adjustment intention (H9)	.01	.07	-.14**	-.07	-.20**
	Response cost (cost money) –> adjustment intention (H10)	-.17**	.02	-.05	-.05	.09
$\chi^2(df)$		193.2 (44)	173.7 (44)	207.4 (46)	168.8 (44)	148.8 (44)
χ^2/df		4.390	3.948	4.508	3.836	3.383
CFI		.975	.981	.975	.979	.987
NFI		.969	.974	.969	.971	.982
RMSEA		.063	.058	.064	.057	.052
10%-CI RMSEA		.054-.072	.049-.068	.055-.073	.048-.067	.043-.062
SMC for the adjustment intention		.142	.234	.122	.185	.039
PMT paths		Earthquake Hazard Adjustment Intentions				
		FireExt	FAKit	FATraining	TDFood	TDWater
TA†	Risk perception –> adjustment intention (H6)	.14**	.02	.10**	.08*	.07*
CA†	Response efficacy (protect person) –> adjustment intention (H7)	.11*	.28**	.29**	.42**	.40**
	Response efficacy (protect property) –> adjustment intention (H8)	.17**	-.06	-.00	.11**	.12**
	Self-efficacy –> adjustment intention (H9)	-.06	-.05	.02	-.11	-.08
	Response cost (cost money) –> adjustment intention (H10)	-.08	.01	-.08	-.06	-.04
$\chi^2(df)$		179.1 (43)	135.9 (43)	122.9 (42)	170.5 (42)	129.4 (41)
χ^2/df		4.165	3.159	2.927	4.058	3.155
CFI		.980	.985	.986	.980	.987
NFI		.974	.978	.978	.973	.981
RMSEA		.060	.050	.047	.059	.050
10%-CI RMSEA		.051-.070	.041-.060	.038-.057	.050-.069	.040-.060
SMC for the adjustment intention		.091	.066	.092	.189	.180

†TA: Threat Appraisal; CA: Coping Appraisal

*p <.05; **p <.01; significance levels of standardized path coefficients and correlations.

Table 6. SEM Results for the New Structural Models (n=866)

PMT paths[†]		Earthquake Hazard Adjustment Intentions				
		EQIns	SecCabinets	ShutUti	EMPlan	Flashlight
QC[†]	Familiarity –> risk perception (H1)	.12**	.12**	.12**	.11**	.12**
	Self-knowledge –> risk perception (H2)	.05	.05	.05	.06	.05
	Dreadfulness –> risk perception (H3)	.18**	.18**	.18**	.18**	.18**
	Negative emotion –> risk perception (H4)	.32**	.32**	.32**	.33**	.32**
Experience of property damage –> hazard salience (H12)		.22**	.22**	.22**	.22**	.22**
Hazard salience –> risk perception (H5)		.20**	.19**	.20**	.20**	.20**
TA	Risk perception –> adjustment intention (H6)	.21**	.14**	-.02	.02	-.05
CA	Response efficacy (protect person) –> adjustment intention (H7)	.09*	.23**	.05	.27**	.11**
	Response efficacy (protect property) –> adjustment intention (H8)	.20**	.07	.18**	.12**	-.03
	Self-efficacy –> adjustment intention (H9)	-.01	.02	-.20**	-.15**	-.17**
	Response cost (multi-use) –> adjustment intention (H11)	.13**	.30**	.27**	.28**	.29**
	Response cost (cost money) –> adjustment intention (H10)	-.17**	.01	-.00	-.01	.07
DC[†]	Homeownership –> adjustment intention	.14**	.01	.13**	.05	.10**
	Being married –> adjustment intention	.06*	.00	.15**	.09**	.05
χ^2 (df)		607.1 (169)	562.4 (168)	628.7 (172)	512.1 (167)	519.2 (171)
χ^2/df		3.592	3.347	3.655	3.067	3.037
CFI		.942	.952	.943	.953	.962
NFI		.921	.933	.924	.932	.945
RMSEA		.055	.052	.055	.049	.049
10%-CI RMSEA		.050-.059	.047-.057	.051-.060	.044-.054	.044-.053
SMC for the adjustment intention		.193	.291	.221	.258	.134

[†]QC: qualitative characteristics; DC: Demographics

**p* <.05; ***p* <.01; significance level of standardized path coefficients and correlations.

Table 6. Cont

	PMT paths	Earthquake Hazard Adjustment Intentions				
		FireExt	FAKit	FATraining	TDFood	TDWater
QC†	Familiarity –> risk perception (H1)	.10**	.12**	.12**	.11**	.12**
	Self-knowledge –> risk perception (H2)	.07*	.05	.05	.05	.05
	Dreadfulness –> risk perception (H3)	.18**	.16**	.18**	.18**	.18**
	Negative emotion –> risk perception (H4)	.31**	.34**	.32**	.33**	.32**
Experience of property damage –> hazard salience (H12)		.22**	.22**	.22**	.22**	.22**
Hazard salience –> risk perception (H5)		.21**	.17**	.20**	.20**	.19**
TA	Risk perception –> adjustment intention (H6)	.13**	.02	.11**	.07*	.06*
CA	Response efficacy (protect person) –> adjustment intention (H7)	.08	.16**	.21**	.26**	.26**
	Response efficacy (protect property) –> adjustment intention (H8)	.11*	-.01	.03	.12**	.12**
	Self-efficacy –> adjustment intention (H9)	-.05	-.06	-.04	-.11*	-.08
	Response cost (multi-use) –> adjustment intention (H11)	.19**	.25**	.21**	.33**	.28**
	Response cost (cost money) –> adjustment intention (H10)	-.10*	-.01	-.08*	-.10*	-.06
DC†	Homeownership –> adjustment intention	.08*	.08*	.01	.08**	.06*
	Being married –> adjustment intention	.09**	.09**	-.01	-.03	-.04
χ^2 (df)		439.4 (162)	444.7 (166)	555.5 (170)	541.0 (166)	470.5 (165)
χ^2/df		2.713	2.679	3.268	3.259	2.852
CFI		.966	.963	.945	.951	.963
NFI		.948	.943	.923	.932	.945
RMSEA		.044	.044	.051	.051	.046
10%-CI RMSEA		.040-.050	.039-.049	.046-.056	.046-.056	.041-.051
SMC for the adjustment intention		.127	.132	.125	.275	.242

*p <.05; **p <.01; significance level of standardized path coefficients and correlations.

11. Figures

- **Fig. 1.** Protective Motivation Theory
- **Fig. 2.** Oklahoma Earthquake Risk Area Map (2018)
- **Fig. 3.** Hypothesized Structural Model