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ORIGINAL ARTICLE

Residents' information seeking behavior and protective action for earthquake hazards in The Portland Oregon Metropolitan Area

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Abstract
Though significant research exists on earthquake hazard adjustment adoption more generally, research focused on how information seeking influences planned or actual preparedness behavior is rare, limiting our understanding of how information seeking translates into preparedness. To address this gap, our study tests a proposed model of household seismic hazard adjustment using questionnaire responses of roughly 400 households living in the Portland, OR metropolitan region. The proposed model includes components of the Protective Action Decision Model (PADM) with specific emphasis on past information seeking behavior, preparedness behavior, intentions to seek information, and intentions to take protective action. Other components include risk perception, earthquake experience, affective response, seismic risk zone residency, and demographics. Consistent with previous research, this study finds information seeking behavior to be the strongest influence on preparedness with other important influences being risk perception, affective response, and intentions to prepare. We find weak ties between risk zone residency and earthquake risk perception, though this may be because our sample has little experience with earthquakes and the majority live in the same earthquake risk zones. Importantly, longitudinal studies are needed to determine whether information seeking and intentions to prepare eventually result in household protective action.

KEYWORDS
Information seeking, protective action, risk perception, seismic hazard

1 | INTRODUCTION

As populations grow into hazard zones and the impacts of a changing climate are felt around the globe, the need to understand how to reduce disaster impacts becomes paramount. The responsibility for taking action to reduce disaster risk spans all levels of involvement, from the individual citizen through national governments (Aerts et al., 2018; Kuhlicke et al., 2020; Lindell, 2020a). In addition to legislation to reduce risks and improved building standards, preparedness at the household level is an important aspect of disaster readiness, yet the majority of households remain underprepared (Ablah et al., 2009; Bourque et al., 2012). Additionally, attempts by the Federal Emergency Management Agency (FEMA) over the last decade to increase household preparedness have shown "little to no sign of improvement" (FEMA, 2019). Thus, the need to better understand what motivates household preparedness and mitigation actions has never been more relevant.

Over the past 50 years, disaster researchers focused on identifying to what degree certain factors influence households' strategies for coping with hazards, also referred to as *hazard adjustments* (Burton et al., 1993); despite this effort, variability and gaps in knowledge remain. A collection of review articles summarizing past research on household hazard adjustment adoption helps to clarify how measures were assessed and characterize which ones appear to consistently correlate with household preparedness for floods (Bubeck et al., 2012; Lindell, 2013b; Lindell & Perry, 2000; Solberg et al., 2010), earthquakes (Lindell & Perry, 2000; Solberg et al., 2010), and other hazards (Lindell, 2013a). These summary articles suggest that a major impediment to the scientific understanding of hazard adjustment adoption is the variety of ways in which relevant variables, such as risk perception and preparedness, are measured, thus making comparisons across studies difficult. To remedy this issue, they recommend that future studies replicate existing measures across different locations and over time. In addition, these authors advise using theoretical frameworks to organize and understand variable relationships with respect to protective action decision making. In doing so, existing theoretical frameworks can be tested and refined to uncover the main drivers of household hazard adjustment adoption.

One such theoretical framework is the Protective Action Decision Model (PADM), which synthesizes research on risk communication, disaster sociology, persuasion, and attitude–behavior relationships. This framework identifies the context needed to test how well-known variables such as hazard experience and risk perception impact peoples' decision to prepare for and respond to hazard threats. The PADM was proposed by Lindell and Perry (1992) and later revised (Lindell & Perry, 2004, 2012) to reflect available research findings and address unresolved issues. Since then, components of the PADM have been either well tested and supported (e.g., the relationship between female gender and risk perception), tested with mixed findings (e.g., the relationship between hazard experience and protective action adoption), or acknowledged to be unexamined (Lindell, 2018). One significant limitation of PADM studies to date is the relative neglect of research on information seeking at times other than imminent threats, also called the "continuing hazard phase" (Lindell & Perry, 2012). Thus, more study is needed to confirm or challenge the PADM's propositions regarding the role of information seeking in predisaster preparedness.

To address the research gaps outlined above, this paper aims to test components of the PADM and their influence on seismic hazard adjustment adoption, investigate the influence of information-seeking behavior on seismic preparedness, and use previously implemented measures of preparedness and risk perception. By doing so, we aim to advance our understanding of the role key factors play in influencing household preparedness and provide recommendations to make risk communication strategies more effective.

2 | BACKGROUND

This study investigates PADM components that include information seeking behavior, threat/risk perception, risk zone residency, and demographic characteristics to understand their influences on adoption of seismic hazard adjustments. The following sections first discuss why we selected the PADM as opposed to other theoretical models and then summarize the research on the variables of interest and existing knowledge gaps. Since our study focuses on information seeking and preparedness in the Cascadia Subduction Zone (CSZ), we predominantly include references to research focused on earthquake hazards and actions. That being said, the majority of the adjustments for seismic hazards are relevant for other hazards (e.g., storing water) and where appropriate, we include reference to studies on other hazard types.

2.1 | Selection of Protective Action Decision Model

Unlike other models of protective behaviors, such as protection motivation theory (PMT; Rogers, 1975, 1983) and the theory of planned behavior (TPB; Ajzen, 1991; Fishbein & Ajzen, 1975), which are purely cognitive/behavioral models addressing threat and protective action perceptions and their effects on behavioral responses, the PADM (Lindell & Perry, 2004, 2012) is a social psychological model that incorporates elements of persuasion, such as information sources and channels as well as behavioral responses (Lindell, 2018). The PADM also corresponds with models of information seeking such as the risk information seeking and processing model (RISP; Griffin et al., 1999) and the planned risk information seeking model (PRISM; Kahlor, 2010) in terms of some of the variables measured (e.g., hazard experience, risk/hazard perception, stakeholder perceptions/channel beliefs), which are described in more detail in Section 2.3. Yet, unlike these models, the PADM was developed specifically in the context of environmental hazards and includes behaviors beyond information seeking such as emotion focused coping and protective response. It is for the above reasons that we selected the PADM to examine information seeking and seismic hazard adjustment for this study.

2.2 | Earthquake hazard adjustments

Following Burton et al. (1993), Lindell and Perry (2000) defined hazard adjustments as protective actions that intentionally or unintentionally reduce risk from extreme events in the natural environment. To be consistent with FEMA's typology of disaster phases, Lindell and Perry (2000, see also Lindell et al., 2006) further categorized household hazard adjustments as comprising actions associated with hazard mitigation, emergency preparedness, and recovery preparedness. They defined *hazard mitigation* as resources or actions that provide passive protection when a hazard occurs (e.g., strapping heavy objects down), whereas *emergency and recovery preparedness* support active response at the time of hazard impact (e.g., having emergency supplies ready) and response following the event (e.g., purchasing hazard insurance), respectively. Practically, the more hazard adjustments a household implements, the more prepared they are likely to be when a hazard occurs.

2.3 | Earthquake information seeking

The concept of information seeking is a key component of many models that investigate decision making and behavior change in response to risk, such as the RISP model (Griffin et al., 1999), PRISM (Kahlor, 2010), and PADM (Dunwoody & Griffin, 2014; Kahlor, 2010; Lindell & Perry, 2012). Irrespective of the type of risk, which can include health or environmental hazard, information seeking is a process that individuals go through when they perceive a risk but lack enough information to decide whether or how to respond. Research suggests people remain in this "milling" phase (Wood et al., 2018) until they feel they have enough information to move forward with a protective action, although they may return to this phase when circumstances change (Lindell & Perry, 2012).

The above models suggest that information seeking behavior depends upon a combination of variables that include, but are not restricted to, *individuals' characteristics* (e.g., hazard experience, hazard knowledge, risk perception, affective responses, personal values, attitudes toward information seeking, perceived information insufficiency, information seeking subjective norms, information seeking control, and demographic characteristics), *perceived ability to collect information*, *perceptions of information source*, and *perceptions of channel characteristics*. In addition, information search is influenced by the relative importance of people's concern about accuracy versus consistency with existing beliefs (Hart et al., 2009). The search for accurate information is more important when people are uncertain about a threat than when they are uncertain about the efficacy of protective actions (Goodall & Reed, 2013; Howell & Shepperd, 2012). Additionally, expectations about the outcome of information seeking, whether it is increased knowledge or risk awareness, can influence intentions to seek information (Li & Guo, 2016).

Though significant research exists on earthquake hazard adjustment adoption more generally, research on the influence of information seeking is less robust. Despite findings showing a strong correlation between preparedness and information seeking behavior (Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1992), many studies focus on earthquake information seeking without examining planned or actual preparedness behaviors (Kahlor et al., 2019; Li & Guo, 2016; Tekeli-Yesil et al., 2020). This limits the understanding of how information seeking translates into preparedness. The PADM helps to bridge this gap by including information seeking as one of the three behavioral responses along with protective response and emotion-focused coping. In concert with existing studies that examine factors associated with information seeking, additional research can begin to link these factors and better decipher which are most important for protective action.

2.4 | Earthquake risk perception

Across studies, risk perception appears to play an important, though complicated, role in hazard adjustment adoption. Consistent with findings from flood studies, seismic risk perception is frequently correlated with hazard adjustment adoption, but some studies fail to find this relationship (Lindell, 2013a; Lindell & Perry, 2000; Solberg et al., 2010). Several reasons can explain the inconsistent findings.

First, studies differ in their measures of risk perception, making comparisons difficult (Kirschenbaum, 2005). For example, Peers et al. (2021) recently noted that some researchers define risk perception in terms of dread and unknown risk (Slovic, 1987), while many others use an expectancy value (EV) model. EV formulations, which date at least to Withey (1962), define risk perception by the perceived probability and consequences of an event (for a review of EV models, see (Kruglanski & Stroebe, 2005). EV models of risk perception have been operationalized in PMT by severity and vulnerability (Rogers, 1975) and in the PADM by the probability of consequences such as death, injury, property damage, and disruption to daily activities within a defined period of time (Lindell & Perry, 1992).

Second, an individual's risk perception can change over the course of the two stages of the hazard adjustment adoption process (Bubeck et al., 2012; Weinstein & Nicolich, 1993). Stage one occurs between when someone becomes aware of a hazard and when they adopt one or more hazard adjustments, whereas stage two happens after they adopt hazard adjustments. Specifically, having an elevated risk perception in the first stage of the process may motivate increased preparedness which, in turn, would then lower risk perception in the second stage. Cross-sectional surveys that only ask which hazard adjustments respondents have adopted without also asking which adjustments they intend to adopt may find nonsignificant correlations of risk perception with hazard adjustment adoption if the sample comprises roughly equal numbers of respondents in each stage of the hazard adjustment adoption process.

Third, it is also possible that increased risk perception will not lead to increased preparedness if people see the costs of preparing to be greater than their perceived risk or if they do not feel personally responsible for reducing those risks (Wachinger et al., 2013). If the caveats above are considered, measures of risk perception can still provide valuable insight into the process of preparedness.

Fourth, following Fishbein and Ajzen's (1975) distinction between an attitude toward an object and an attitude toward a behavior related to that object, Lindell and Perry (2004, 2012) noted that risk perception motivates the adoption of hazard adjustments but does not specify which hazard adjustment to adopt. Thus, risk perception is more likely to predict the number of hazard adjustments, whereas perceptions of the attributes of a hazard adjustment will be the best predictors of that hazard adjustment's adoption (for a more recent statement, see Ajzen & Fishbein, 2005).

In addition to its effect on hazard adjustment adoption, risk perception is also thought to influence information seeking. In the information seeking models described above, authors suggest that the motivation to seek additional information is influenced, in part, by the perceived risk (Dunwoody & Griffin, 2014; Griffin et al., 1999; Kahlor, 2010). For example, if people perceive a significant earthquake risk but are uncertain about how to reduce it, they may seek information about the hazard or hazard adjustments before taking protective actions. However, additional information may or may not increase people's risk perceptions (Kasperson et al., 1988). Of course, tests of the information seeking process are subject to the same causal ambiguity as preparedness actions.

Finally, there is some evidence that risk perception, defined as expected personal consequences of hazard impact, is correlated with affective responses (Wei & Lindell, 2017). In turn, affective responses are correlated with people's responses during earthquakes (for a review, see (Goltz, Park, Nakano et al., 2020), as well as their information seeking and hazard adjustment adoption before and in anticipation of an earthquake (Becker et al., 2012; Dooley et al., 1992; Doyle et al., 2018; Heller et al., 2005; Sun & Xue, 2020; Turner et al., 1986). In summary, risk perception and affective responses are important to examine as components of the household hazard adjustment process. Future research is needed to uncover why some studies find strong relationships between risk perception and hazards adjustment adoption, whereas others do not.

2.5 | Earthquake risk zone residence, personal experience, and hazard awareness

The influence of risk zone residency (i.e., living on or near a hazard source) on information seeking and hazard adjustment adoption is ambiguous. Some studies report that risk zone residency leads to higher risk perceptions and levels of hazard adjustment adoption, whereas others suggest the opposite (Lindell & Perry, 2000). One explanation for the inconsistent results is that prior experience with hazards and the severity of impacts, rather than merely living in a risk zone, influence risk perception and hazard adjustment adoption (McGee et al., 2009). Lindell and Perry (2000) and Solberg et al. (2010) conclude that earthquake experience consistently increases risk perception and, somewhat less consistently, hazard adjustment adoption. More recently, Demuth (2018) drew similar conclusions about the relationship between experience of severe weather and risk perception. These findings can be explained by the results from Lindell and Hwang (2008), which indicate that personal experience mediates the relationship of hazard proximity with risk perception and hazard adjustment adoption. Indeed, following the 2011 M9.0 Tohoku earthquake and tsunami, Japanese residents had higher earthquake anxiety levels (Nakayachi & Nagaya, 2016) and increased preparedness levels (Onuma et al., 2017). This relationship also implies that individuals who experience a mild event—or none at all, as is the case with Oregonians and a major earthquake—may form risk perceptions that underestimate the threat and, thus, fail to motivate protective action. This misalignment, which has been found in studies focused on both hurricane (Hasan et al., 2011) and wildfire (McGee et al., 2009) hazards, can be explained by the ways in which people interpret their experience (Baker, 1991; Demuth et al., 2016; Lindell & Perry, 2000). Additionally, Becker et al. (2017) note that different types of experience (direct, indirect, and vicarious) influence preparedness outcomes.

Research has also found that, despite residing in hazardous areas, people are inconsistently aware of their risk, which may be a result of nonexistent, inconsistent, or ineffective hazard education programs. Emergency management agencies employ hazard education programs to help people develop hazard awareness and motivate preparedness, but, the effectiveness and prevalence of these programs are not well known since few hazard awareness programs are evaluated (Lindell et al., 1997, 2022). One exception to this is the evaluation of ShakeOut earthquake drills, which are widespread and aimed at educating people about what to do when earthquake shaking starts. Studies show that drill participation increases participant knowledge of what to do during an earthquake and general preparedness (Jones & Benthien, 2011; Vinnell et al., 2020), but other studies find that most people in the United States do not take this action during real earthquakes (Goltz, Park, Nakano et al., 2020; Goltz, Park, Quitoriano et al., 2020). This suggests further investigation is needed in terms of assessing the effectiveness of these kinds of education campaigns and others at reducing future impacts.

In the absence of comprehensive hazard awareness programs, many communities have hazard maps that are available through local government agency websites. However, these sites may not be well known to local residents and their contents might be difficult to understand (Hwang et al., 2001; Lindell, 2020b; MacPherson-Krutsky et al., 2020). Even with access to hazard maps, residents seem to have trouble correctly identifying their risk zone. Arlikatti et al. (2006) and Zhang et al. (2004) found that, when presented with a map of hurricane hazard zones, between one- and two-thirds of residents could not correctly identify their hazard zone. These findings are supported by a study of tsunami evacuation maps in three Pacific Coast communities, which found that only 41% of those *who lived outside* the tsunami zone correctly interpreted their risk zone, whereas 29% thought they were inside, and 30% did not know (Lindell et al., 2019). By contrast, 84% of those *who were inside* the tsunami zone correctly interpreted their risk zone, while 10% thought they were outside, and 6% did not know. There were notable differences across the three communities, which might be due to differences in local tsunami hazard awareness programs. Another study investigating perceived disaster risk across the United States showed that people living in so called "Hurricane states" correctly judged their hurricane risk to be higher than those in neighboring states (Viscusi & Zeckhauser, 2006), but that these perceptions were also mediated by hazard experience. Similarly, in a study examining risk perceptions before and after the Christchurch earthquake in 2011, prior expectations and experiences with the earthquake influenced peoples' judgement of future earthquake likelihoods for specific locations (McClure et al., 2015). Following the earthquake, perceived risk increased more for Christchurch relative to other locations despite people perceiving earthquakes as more likely in other regions prior to the earthquake. In summary, these studies suggest that residence in a hazard zone might have only a modest correlation with hazard adjustment, given that people may have preconceived notions of where risk is high or may not be aware of their risk especially when a hazard rarely occurs.

Though links between risk zone residency, hazard experience, and perceived risk zone appear relevant, the extent to which they influence hazard adjustment adoption requires more study.

2.6 | Individual and household characteristics

Research shows that household and individual characteristics have small and inconsistent influences on overall seismic hazard preparedness (Lindell, 2013a; Lindell & Perry, 2000; Solberg et al., 2010). Specifically, Lindell's (2013b) review of North American studies on hazard adjustment adoption found that characteristics such as female gender, education, income, age, and White ethnicity had weak and inconsistent relationships both in terms of significance and direction. Other demographic characteristics, such as marital status, children in home, and homeownership, had too few results to make reliable classifications. These findings suggest that *audience segmentation*, the use of specific characteristics to target underprepared populations, may not be an effective tactic for emergency management programs. However, review studies do show that certain demographic characteristics consistently correlate with variables that are associated with hazard adoption, such as female gender and risk perception. Thus, further research is needed to identify the role demographic characteristics play in the hazard adjustment adoption process.

3 | STUDY HYPOTHESES

The influence of risk zone residency, hazard experience, risk perception, and affective reactions on information seeking and hazard adjustment adoption are illustrated in Figure 1, which extends Lindell and Hwang's (2008) model of hazard adjustment adoption and yields four research hypotheses.

H1: Residence in a severe earthquake shaking zone or liquefaction zone, or having earthquake experience, will be significantly correlated with past information seeking and past hazard adjustment adoption.

H2: Past information seeking and past hazard adjustment adoption will be significantly correlated with higher risk perceptions, affective responses, and knowledge of what to do during an earthquake.

H3: Risk perception, affective responses, and earthquake response knowledge will be significantly correlated with intentions to search for earthquake information and intentions to adopt hazard adjustments.

H4: Past information seeking will be significantly correlated with past hazard adjustment adoption and information seeking intentions will be correlated with hazard adjustment adoption intentions.

4 | METHODS

4.1 | Study area

The Portland Metropolitan Area (PDX) is home to more than 2.5 million people and includes both urban and rural areas. Environmental hazards in the region include extreme summer and winter weather, flooding, and landslides, but most destructive of all is the potential for CSZ earthquakes (State Interagency Hazard Mitigation Team; SIMT, 2020a). Stretching from southern Canada to northern California, the CSZ can produce an M8.0 or greater earthquake, the likes of which has not been felt since 1700. Simulations suggest that such an earthquake would cause significant shaking, liquefaction, and landslides across western Oregon (Bauer et al., 2018), and cost tens of billions of dollars in damage (SIMT, 2020b).

Despite their proximity to this major fault system, Oregonians have experienced fewer damaging earthquakes than their Washington neighbors to the north and California neighbors to the south (Hake, 1976; United States Geological Survey, 2020). Local emergency management agencies responded to this and other hazards by developing the Regional Disaster Preparedness Organization (RDPO), a collaborative group that spans the five counties comprising PDX, to proactively plan across jurisdictions. In addition, the Oregon Public Broadcasting news service created an entire section devoted to articles highlighting the CSZ earthquake potential and areas for improvement. The section is aptly termed "Unprepared." Given the hazard potential and efforts across the region, PDX is an excellent place to better understand residents' current hazard adjustment adoption levels and how to improve them before "the Big One" happens.

4.2 | Sample

During September and October 2019, we mailed questionnaires to a random sample of 2415 addresses that the Marketing Systems Group provided in Oregon's Columbia, Clackamas, Multnomah, and Washington counties. After 159 packets were returned as undeliverable, the sample included 2257 valid addresses. To participate in the survey, individuals had to be 18 years of age or older and living in one of the four counties. As an incentive to participate, we offered entry into a drawing to win two $50 Amazon gift cards. Questionnaire packets included a web link so participants could choose to take the questionnaire electronically. A total of 403 people responded to the survey for a response rate of 17.8%, 88.6% of whom returned the questionnaire by mail and 11.4 % completed it online. A comparison of the sample demographics with census information for the region is in Table 1. The sample is reasonably representative of the four counties and Oregon State with respect to race, household size, and sex. However, the respondents are older, have higher income, and are more educated than the region as a whole, which is consistent with other recent studies on environmental hazards (Brody et al., 2017; Lindell et al., 2017; Peers et al., 2021).

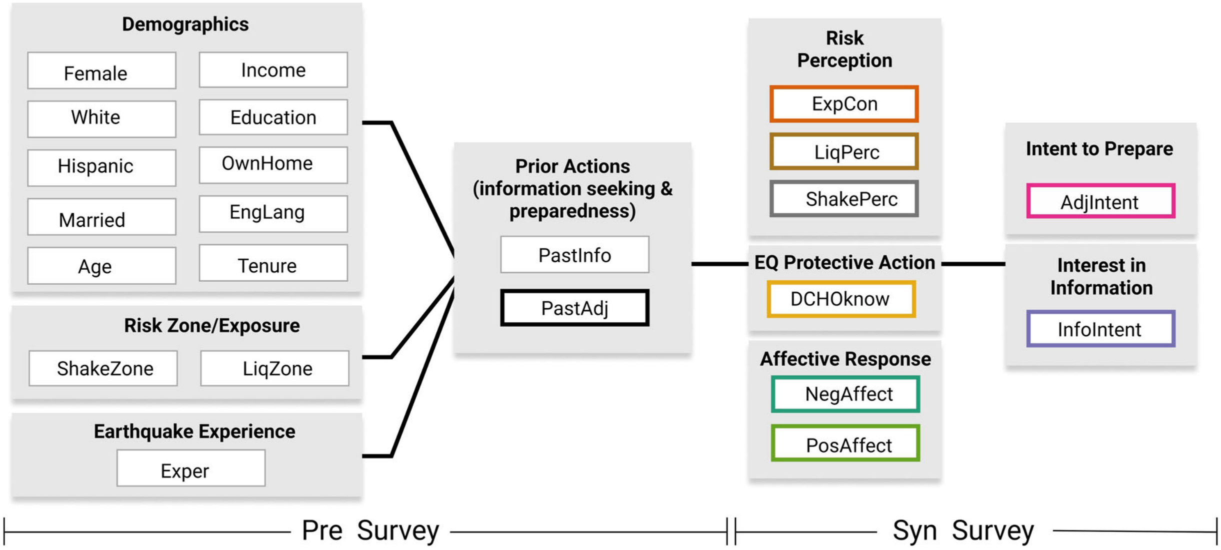

FIGURE 1 Hypothesized model relationships for information seeking and hazard adjustment variables. Variable codes: Female, female gender 1, else 0; White, White ethnicity 1 else, 0; Hispanic, Hispanic Ethnicity 1, else 0; Married, married 1, else 0; Age, age in years; Income, income categories; Education, education categories; OwnHome, home owners 1, else 0; EngLang, English is the first language 1, else 0; Tenure, time in community; ShakeZone, Mercalli Intensity shaking zone; LiqZone, liquefaction susceptibility zone; Exper, earthquake experience; PastInfo, past information seeking actions; PastAdj, past hazard adjustments; ExpCon, risk perception; LiqPerc, perceived liquefaction zone; ShakePercep, perceived shaking zone; DCHOKnow, selection of drop, cover, and hold on as recommended protective action; NegAffect, negative emotional response earthquake potential; PosAffect, positive emotional response earthquake potential; AdjIntent, intentions to adopt hazard adjustments; InfoIntent, intentions to see additional information. See Table 2 for in-depth variable descriptions

TABLE 1 Demographic comparisons between sample and region

	Sample	Four metro counties[a]	Oregon State[a]
65 years or older (%)	31.9	15.9	17.6
Female (%)	57.6	50.4	50.4
White (%)	84.8	85.2	86.8
Home ownership (%)	75.4	65.0	61.9
Education, bachelor's degree or higher (%)	71.6	35.7	32.9
Household size (number of people)	2.4	2.6	2.5
Median Income	$82,813	$69,665	$59,393

[a]Regional data are from U.S. Census Bureau, 2018.

4.3 | Survey instrument

The questionnaire included 30 items measuring demographics, hazard zone location, earthquake experience and knowledge, risk perception and affective response, past hazard adjustment adoption, hazard adjustment adoption intentions, past information search, and information search intentions (Table 2; see Supporting Information Appendix for questionnaire). In an effort to replicate measures, four questions with sub-items were incorporated from the Lindell and Prater (2000) Six City study. We used three styles of questions formats including five-point Likert type items, multiple choice, and text entry. Fourteen questions were five-point Likert type items rated from *not at all* (= 1) to *very great extent* (= 5), 12 were multiple choice, and four were text entry.

Earthquake experience was measured by asking respondents if they had experienced an earthquake that caused damage to property in their city, deaths or injuries to people in their city, damage to their home, injury or deaths to their family, or disruption to utilities. They could answer *No* = 1 *or Yes* = 2. We generated the experience variable, Exper (α = 0.70), by computing the average rating across all five items. We opted not to separate types of earthquake experience because few people had experiences beyond damage to property in their city and utility disruption. For example, of the 385 people who responded to the experience question, 37.0% experienced damage to property in their city, 19.8% experienced disruption to utilities, 16.2% experienced death/injuries in their city, 10.1% experienced damage to their home, and 0.3% experienced deaths or

TABLE 2 Measures

Abbreviation	Description	Values
Demographics		
Female	Gender	Female = 1, Male = 0
White	White ethnicity	White = 1, non-White = 0
Hispanic	Hispanic ethnicity	Hispanic = 1, non-Hispanic = 0
Married	Marital Status	Married = 1, nonmarried = 0
Age	Age	22–94
Income	Income	Below $25K = 1 to above $100K = 5
Educ	Education	Elementary = 1 to Graduate Degree = 6
HomeOwn	Home Ownership	Own home = 1, else = 0
EngLang	Language	English is primary = 1, else = 0
Tenure	Community tenure (time in a community)	0 (less than 1) to 76 years
Actual risk zone		
ShakeZone	In severe earthquake shaking zone	Strong = 1, Very strong = 2, Severe = 3
LiqZone	In liquefaction zone	inside zone = 1, outside = 0
Earthquake experience		
Exper	Experienced earthquake impacts (damage to city/property, death or injuries to people in your city/family, disruption to services)	No experience = 1 to Experienced all = 2
Prior actions (information seeking and preparedness)		
PastInfo	Received/searched for earthquake risk information across sources (print media, broadcast media, internet, social media, peers, community groups, local emergency mgmt. groups)	Not at all = 1 to Very great extent = 5
PastAdj	Hazard adjustments adopted at time of survey	Have done = 1, else = 0
Affective Response & DCHO knowledge		
PosAff	Feeling optimistic, energetic, and alert toward the possibility of an earthquake	Not at all = 1 to very great extent = 5
NegAff	Feeling depressed, nervous, and fearful toward the possibility of an earthquake	Not at all = 1 to very great extent = 5
DCHOknow	Correct intended action during an earthquake	DCHO selected = 1, other = 0
Risk perception		
ExpCon	Expected earthquake consequences (damage to city/property, death or injuries to ppl. in own city/family, disruption to services) in next 10 years	Low expectations = 1 to High expectation = 5
ShakePerc	Perceived earthquake risk zone	Inside = 2, Unsure = 1, Outside = 0
LiqPerc	Perceived liquefaction zone	Inside = 2, Unsure = 1, Outside = 0
Intentions (information seeking and preparedness)		
InfoIntent	Interest in receiving information about: earthquakes and hazards science, actions to take before, during and after an earthquake, how to get involved in disaster prep.	Not at all = 1 to Very great extent = 5
	Planned hazard adjustments	Haven't done, but plan to = 1, else = 0

injuries to their family. The experience variable we generated provides a "general" estimate of earthquake experience with higher values representing a broader set of earthquake impacts.

To measure knowledge of the recommended "Drop, cover, and hold on" (DCHO) earthquake response action, respondents were asked to select one of five possible actions they would take if earthquake shaking started while they were at home. We generated the variable, DCHOknow, by recoding the responses into two categories, the recommended action of "Drop, cover, and hold on" (= 1) and all other responses (= 0).

To assess risk perception, we asked respondents to estimate how likely it was that an earthquake would occur in the next 10 years that would cause damage to property in their city, deaths or injuries to people in their city, damage to their home, injury or deaths to their family, and disruption to utilities. This question and phrasing were taken directly from the Lindell and Prater (2000) questionnaire. We computed the average rating across the five sub-items in this question to generate the, "expected consequences" or ExpCon variable ($\alpha = 0.92$). A second risk perception question asked respondents to answer whether they thought their home was in a severe earthquake shaking zone (ShakePerc) or a liquefaction zone (LiqPerc). They could answer risk perception question asked respondents to answer whether they thought their home was in a severe earthquake shaking zone (ShakePerc) or a liquefaction zone (LiqPerc). They could answer No (= 1), Unsure (= 2), or Yes (= 3). Affective responses were measured by three positive (optimistic, energetic, alert; PosAff $\alpha = 0.58$) and three negative (depressed, nervous, fearful; NegAff $\alpha = 0.89$) items. The three measures of risk perception and two measures of affective response were kept separate for analyses.

We determined respondents' actual risk zones by using ArcMap to overlay the latitude and longitude of the respondents' addresses onto the Oregon Department of Geology and Mineral Industries Cascadia earthquake shaking layer (Bauer et al., 2018; Madin & Burns, 2013) and liquefaction susceptibility layer (Madin & Burns, 2013). The Cascadia shaking layer is the modeled ground shaking measured as peak ground acceleration during a CSZ earthquake. We converted peak ground acceleration values to Modified Mercalli Intensities (MMI) using the Wald et al. (1999) conversion table. The MMI values in the study area are strong (MMI 6), very strong (MMI 7), and severe (MMI 8) shaking and were coded as 1, 2, and 3 for the ShakeZone variable, respectively. We coded liquefaction susceptibility categories for the LiqZone variable into none (= 0) and liquefaction possible (= 1; low, moderate, and high susceptibility).

To assess hazard adjustment adoption, we asked respondents whether they had adopted each of 16 emergency preparedness (e.g., wrenches to shut off utilities) and hazard mitigation measures (e.g., installed latches to keep cabinets closed; See Supporting Information Appendix). They could select *no* (= 0), *have not, but plan to do/get* (= 1), or *yes* (= 2). All these items, which are used for basic survival, planning, or hazard mitigation, were selected from the Lindell and Prater (2000) study and amended based on feedback from local emergency managers. For the preparedness items, we added a 1-week supply of medicines, flashlight with batteries, nonelectric can opener and increased 4-day to 2-week supply of food. For the mitigation measures, we omitted purchased hazard insurance, joined a community organization, and wrote a letter supporting action about earthquake hazards since Lindell and Prater (2000) reported low levels of adoption for these items.

From these items, we developed two hazard adjustment scales. The first scale, PastAdj ($\alpha = 0.71$), represents hazard adjustments people had already completed at the time of the survey. The responses to the 16 items were coded as 1 if an adjustment had been completed and 0 if the respondent either had not done it but planned to do it or did not plan to do it. The PastAdj measure is the average across all items. The second scale, AdjIntent ($\alpha = 0.74$), represents people's intentions to perform hazard adjustments. The responses to the 16 items were coded as 1 if respondents had not done it but planned to do so, and 0 otherwise. We then calculated an average across all items to measure AdjIntent.

We also asked participants to what extent (*not at all* = 1 *to very great extent* = 5) they had received or searched for risk and preparedness information from a list of seven sources (see Table 2). We calculated an average score, PastInfo ($\alpha = 0.77$), across all seven sources. To assess interest in further earthquake risk and preparedness information, we asked participants to what extent they wanted to receive five types of risk and preparedness information (see Table 2). The average value of these items became the InfoIntent variable ($\alpha = 0.88$).

4.4 | Procedure and analyses

We sent as many as four waves of survey materials until we received a response. Waves one and three consisted of full packets containing a cover letter, a letter of support from the Portland Metro RDPO, a questionnaire, a card to request additional hazard educational materials, and a stamped return envelope. Waves two and four were postcards reminding participants to fill out and return their questionnaires. We sent each wave within 7–12 days of the previous one.

Pearson correlations, ordinary least squares (OLS) regression analysis, and multivariate analysis of variance (MANOVA) are used to test the four research hypotheses. In the analyses that follow, there are 210 statistical tests on correlation coefficients and 127 on regression coefficients, so experiment-wise error rate is a concern (Ott & Longnecker, 2016). Specifically, the expected number of false positive tests would be $FP = \alpha \times n$, where FP is the number of false positive test results, α is the Type I error rate, and n is the number of statistical tests. If $\alpha = 0.05$ and $n = 337$, then FP = 34. Benjamini and Hochberg (1995) (see Glickman et al., 2014 for a more recent discussion) advocated that researchers (1) specify a false discovery rate d for the entire study, (2) sort the pi significance values for the individual tests in ascending order $1 \leq i \leq n$, and (3) classify each $pi \leq d \times i/n$ as statistically significant. Thus, only $p < 0.01$ is considered statistically significant.

5 | RESULTS

5.1 | Correlational analysis

As indicated in Table 3, there is no support for H1: Residence in a severe earthquake shaking zone or liquefaction zone or having earthquake experience will be significantly correlated with past information seeking and past hazard adjustment adoption. Specifically, shake zone, liquefaction zone, and experience had nonsignificant correlations with PastInfo and PastAdj ($\bar{r} = 0.06$). Although not hypothesized, shake zone, liquefaction zone, and experience also had nonsignificant correlations with the two affective response variables ($\bar{r} = -0.02$), DCHOknow ($r = 0.07$), the three risk

TABLE 3 Means, standard deviations, and Pearson correlations

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Female	0.58	0.49	1																					
2. White	0.85	0.36	0.03	1																				
3. Hispanic	0.03	0.17	−0.01	−0.41*	1																			
4. Married	0.61	0.49	−0.20*	0.06	−0.02	1																		
5. Age	54.6	16.6	−0.05	0.13	−0.01	0.04	1																	
6. Income	3.6	1.37	−0.22*	0.01	−0.06	0.48*	−0.16*	1																
7. Education	4.9	0.93	−0.05	−0.01	0.00	0.09	−0.14*	0.38*	1															
8. OwnHome	0.75	0.43	−0.11	0.09	−0.15*	0.34*	0.35*	0.35*	0.11	1														
9. EngLang	0.99	0.12	0.05	0.26*	−0.53*	0.05	−0.04	0.16*	−0.01	0.14	1													
10. Tenure	19.2	17.56	−0.09	0.13	−0.08	0.04	0.50*	−0.04	−0.17*	0.36*	0.06	1												
11. ShakeZone	2.02	0.30	−0.06	0.00	0.04	−0.05	−0.06	0.01	0.04	−0.05	−0.07	−0.05	1											
12. LiqZone	0.53	0.50	−0.07	−0.02	0.10	−0.07	0.08	−0.07	−0.04	−0.15*	−0.11*	−0.07	0.18*	1										
13. Exper	1.17	0.24	−0.01	−0.10	0.07	−0.06	0.12	−0.03	0.04	0.01	0.06	0.01	0.06	−0.01	1									
14. PastInfo	2.26	0.81	0.10	−0.02	−0.05	0.02	0.12	−0.05	0.10	0.07	−0.05	−0.04	0.05	0.03	0.11	1								
15. PastAdj	0.54	0.18	−0.08	0.05	0.01	0.29*	0.24*	0.21*	0.12	0.33*	0.07	0.15*	0.05	−0.02	0.11	0.35*	1							
16. PosAff	2.03	0.73	0.02	−0.18*	0.09	−0.03	0.15*	−0.10	−0.10	−0.03	−0.03	0.10	−0.01	0.01	0.10	0.25*	0.05	1						
17. NegAff	2.40	1.07	0.25*	−0.15*	0.00	−0.02	−0.22*	0.04	0.09	−0.05	0.00	−0.13	−0.08	−0.10	−0.06	0.20*	−0.14*	0.25*	1					
18. DCHOknow	.37	0.48	0.14*	0.02	−0.03	0.01	−0.04	−0.02	0.03	−0.02	0.04	0.01	0.05	0.08	0.07	0.24*	0.11	0.10	0.20*	1				
19. ExpCon	2.96	0.88	0.28*	−003	−0.05	0.01	0.01	−0.18*	−0.16*	0.00	0.03	−0.07	0.01	−0.01	0.03	0.23*	0.05	0.19*	0.29*	0.08	1			
20. ShakePerc	1.45	0.68	−0.01	0.08	0.00	0.12	−0.11	0.17*	0.14*	0.11	0.05	0.04	0.11	−0.03	0.13	0.07	0.12	−0.11	0.05	0.13	0.10	1		
21. LiqPerc	1.71	0.58	0.10	−0.04	0.12	−0.10	−0.12	−0.04	−0.05	−0.10	−0.10	−0.08	−0.09	0.17*	−0.10	−0.06	−0.10	0.00	0.15*	−0.01	0.09	0.21*	1	
22. InfoIntent	3.59	1.05	0.07	−0.06	0.07	0.01	−0.07	−0.08	−0.05	−0.06	−0.03	−0.01	−0.07	−0.07	0.02	0.16*	−0.07	0.19*	0.32*	0.03	0.31*	0.07	0.09	1
23. AdjIntent	0.11	0.14	0.10*	−0.19*	0.08	−0.13	−0.04	−0.16*	0.06	−0.10	−0.12	−0.13	−0.08	−0.07	−0.03	0.17*	−0.28*	0.16*	0.26*	0.02	0.13	0.09	0.15*	.20*

*Correlation is significant at the 0.01 level (2-tailed).

perception variables ($\bar{r}$ = 0.02), InfoIntent (r = −0.04), and AdjIntent (r = −0.06). However, it is important to note that the overwhelming majority of the respondents were located in the very strong (91%) shaking zone and very few of them were located in the strong (4%) or severe (5%) zones. Thus, it is possible that true correlations of ShakeZone with other variables were obscured by variance restriction in the shaking zone variable (Nunnally & Bernstein, 1994). The fact that the respondents reported very low levels of earthquake experience (58% had no direct experience) suggests that correlations of this variable with other variables might also have been obscured by variance restriction.

Table 3 indicates that there was some mixed support for H2: *Past information seeking and past hazard adjustment adoption will be significantly correlated with higher risk perceptions, affective responses, and knowledge of what to do during an earthquake*.

The average correlation of PastInfo with the two affective response variables and DCHOknow was significant ($\bar{r}$ = 0.23), as was the correlation with ExpCon (r = −0.23), but not the risk zone perception variables ($\bar{r}$ = 0.01). In contrast, the average correlation of PastAdj with the two affective response variables and DCHOknow was not significant ($\bar{r}$ = 0.01), nor was the correlation with ExpCon (r = 0.05) or with the risk zone perception variables ($\bar{r}$ = 0.01).

There was also mixed support for H3: *Risk perception, affective responses, and earthquake response knowledge will be significantly correlated with* intentions to search for earthquake information and intentions to adopt hazard adjustments. InfoIntent was significantly correlated with the affective response variables ($\bar{r}$ = 0.26) and ExpCon (r = 0.31), but not DCHOknow (r = 0.03), or the risk zone perception variables ($\bar{r}$ = 0.08). Moreover, AdjIntent was significantly correlated with the affective response variables ($\bar{r}$ = 0.21) and LiqPerc (r = 0.15), but not DCHOknow (r = 0.02), ExpCon (r = 0.13), or ShakePerc (r = 0.09).

We found stronger support for H4: Past information seeking will be significantly correlated with past hazard adjustment adoption and information seeking intentions will be significantly correlated with hazard adjustment adoption intentions. Table 3 shows that PastInfo is correlated r = 0.35 with PastAdj and InfoIntent is correlated r = 0.20 with AdjIntent. Although not hypothesized, PastInfo is correlated r = 0.16 with InfoIntent and r = 0.17 with AdjIntent, but PastAdj is correlated r = −0.07 with InfoIntent and r = −0.28 with AdjIntent.

5.2 | Regression analysis

The regression analyses presented in Table 4 and Figure 2 show a modest degree of support for the model in Figure 1. In Stage 1 of the model we investigated the prediction of PastInfo and PastAdj. Since the temporal ordering of PastInfo and PastAdj is ambiguous, we tested a series of combinations for predicting PastAdj and PastInfo to find the best model fit. First, we regressed PastAdj onto all the demographic variables and PastInfo and found three demographic variables (Married, Age, and OwnHome) and PastInfo to be significant predictors (Adj R^2 = 0.24, see Table 4). Second, we performed the same regression analysis, but excluded PastInfo. The demographic variables remained statistically significant predictors (Adj R^2 = 0.16, $F_{3,399}$ = 25.93, p = 0.00). Next, we regressed PastInfo onto all the demographic variables and PastAdj, which was the only significant predictor (Adj R^2 = 0.11, $F_{1,399}$ = 25.34, p = 0.00). Finally, we performed the same analysis, but excluded PastAdj (Adj R^2 = 0.04, $F_{13,389}$ = 2.29, p = 0.01). Contrary to H1, none of the demographic variables were significant predictors of PastInfo.

Nonetheless, in Stage 2, PastInfo significantly predicts ExpCon (Adj R^2 = 0.13), DCHOknow (Adj R^2 = 0.05), PosAff (Adj R^2 = 0.07), and NegAff (Adj R^2 = 0.14). LiqZone is the only significant predictor of LiqPerc (Adj R^2 = 0.03). Moreover, although not predicted by H2, female gender also has significant regression coefficients in the prediction of ExpCon and NegAff. Education also significantly predicts ExpCon and White significantly predicts PosAff. Additionally, contrary to the model, there were no significant predictors for ShakePerc. Finally, the analysis of Stage 3 shows that ExpCon, and NegAff are the only significant predictors of InfoIntent (Adj R^2 = 0.14) and PastInfo and PastAdj are the only significant predictors of AdjIntent (Adj R^2 = 0.14).

6 | DISCUSSION

6.1 | The influence of risk zone residency and experience on information seeking and hazard adjustment adoption

The lack of support for H1 is due, in part, to nonsignificant relationships of the two risk zone variables and earthquake experience with past information seeking, which is consistent with findings by Mileti and Darlington (1997). Moreover, neither of the two risk zone variables nor earthquake experience predicts past hazard adjustment adoption. These results for the risk zone variables are not completely surprising given the inconsistency of relationship between hazard proximity and hazard adjustment adoption in the studies reviewed by Lindell and Perry (2000) and Lindell (2013b), perhaps due to an indirect relationship that hazard proximity has with hazard adjustment adoption (Lindell & Hwang, 2008). In addition, the absence of a significant correlation of experience with hazard adjustment adoption is consistent with the findings of reviews reporting inconsistent effects (Lindell, 2013b; Lindell & Perry, 2000).

The lack of support for this hypothesis could be due to issues with the distribution of the risk zone residency and experience measures. Specifically, the majority of people were located in one of the three shaking zones and experience with earthquake hazards is low in our sample, restricting the variance of both the shaking zone and experience

TABLE 4 Regression models for PastAdj, AdjIntent, and associated intermediary variables

	Stage 1			Stage 2[b]									Stage 3					
	1.DV: PastAdj			2.DV: ExpCon			2. DV: PosAff			2. DV: NegAff			3. DV: InfoIntent			3. DV: AdjIntent		
	b	SE (*b*)	*β*	*b*	SE(*b*)	*β*	*b*	SE(*b*)	*β*	*b*	SE(*b*)	*β*	*b*	SE(*b*)	*β*	*b*	SE(*b*)	*β*
(Constant)	0.19	0.04		2.90	0.25		1.85	0.14		2.57	0.23		2.19	0.19		0.15	0.02	
Female				0.42	0.08	0.24				0.39	0.10	0.19						
White							−0.30	0.10	−0.20									
Married	0.08	0.02	0.22															
Age	0.00	0.00	0.14							0.00	0.00	−0.20						
Education				−0.10	0.04	−0.20												
OwnHome	0.08	0.02	0.18															
PastInfo	0.07	0.01	0.30	0.23	0.05	0.21	0.20	0.04	0.22	0.31	0.07	0.24				0.05	0.01	0.28
PastAdj										−0.90	0.29	−0.20				−0.30	0.04	−0.40
NegAffect													0.23	0.05	0.23			
ExpCon													0.28	0.06	0.24			
	Adj $R^2 = 0.24$			Adj $R^2 = 0.13$			Adj $R^2 = 0.07$			Adj $R^2 = 0.14$			Adj $R^2 = 0.14$			Adj $R^2 = 0.14$		
	$F_{4,398} = 33.18$			$F_{3,394} = 20.34$			$F_{2,397} = 16.24$			$F_{4,398} = 16.70$			$F_{2,390} = 32.12$			$F_{2,398} = 34.20$		
	$p = 0.00$			$p = 0.00$			$p = 0.00$			$p = 0.00$			$p = 0.00$			$p = -0.00$		

[a]Values are significant at $p = 0.01$.
[b]The models for LiqPerc, ShakePerc, and DCHOknow had only one significant predictor each, so multiple regression is unnecessary. See the correlation coefficients in Table 3 for specific values.

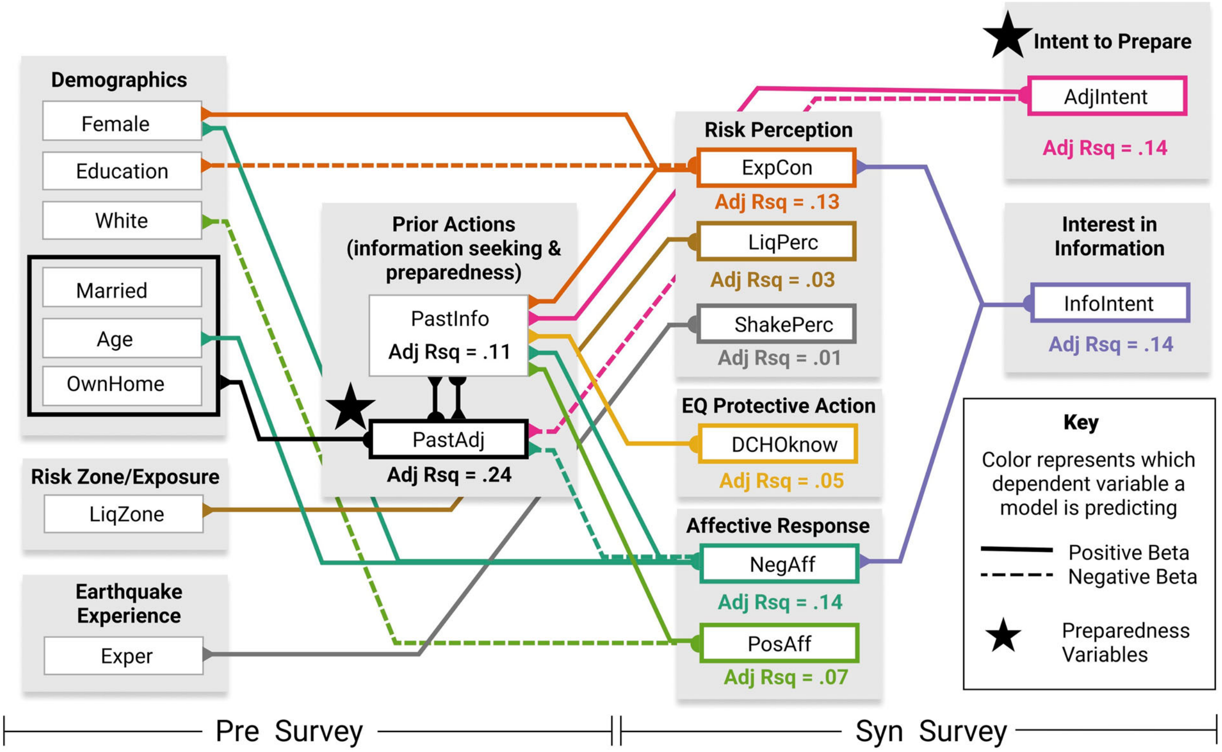

FIGURE 2 Revised model relationships for information seeking and hazard adjustment variables. The ShakePerc model is not significant at $p = 0.01$. See Table 2 for variable descriptions

variables. This makes the PDX sample quite different from those in recent New Zealand studies that found significant effects of experience on hazard adjustment adoption shortly after earthquakes (Doyle et al., 2018; McClure et al., 2016). Future studies could begin to address these issues by surveying respondents with a greater diversity in hazard zone location, but the issue of hazard experience is more challenging because there is a need—both scientific and practical—to identify ways to increase risk area residents' information seeking in communities such as PDX where people lack personal experience precisely because hazard impact is rare. In addition, future research could continue the work of Demuth (2018; Demuth et al., 2016) and Becker et al. (2017) by examining more differentiated measures of experience and, possibly including experience with other hazards. Assessing experience with multiple hazards might be especially useful in predicting the adoption of hazard adjustments that are useful in a variety of hazards (e.g., a 3-day supply of food and water). This would provide greater variation in experience in places that have little personal experience with earthquakes impacts, like the PDX region.

Although neither risk zone nor experience significantly predicts past adjustment adoption, other variables do. Specifically, past information, married, age, and homeownership (β = 0.30 0.22, 0.14, and 0.18, respectively) all have significant regression coefficients. The small effects of the demographic variables on past adjustment adoption are consistent with previous research reviews which has found that these tend to be small and inconsistent across studies (Lindell & Perry, 2000). Finally, the significant correlation of past information with past adjustment adoption, which is consistent with other studies on earthquakes (e.g., Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1992), is more difficult to interpret because as we discussed above, it is not possible for a cross-sectional study to determine whether past information caused past adjustment adoption, past adjustment adoption caused past information, a third variable caused both of them, or there is a reciprocal relationship between these two variables over time (Lindell, 2008). However, including past information in the prediction of past adjustment adoption resulted in the best model fit. Thus, the results of the regression of past adjustment adoption onto past information, married, age, and homeownership can be interpreted to mean that past adjustment adoption retains a significant relationship with past information seeking even after controlling for married, age, and homeownership.

6.2 | The influence of past actions (information seeking and preparedness) on hazard awareness (risk perception, affective response, and knowledge of what to do in an earthquake)

The regression analysis for expected consequences (risk perception) indicates that past information seeking, female gender, and education have significant coefficients (β = 0.21, 0.24, and −0.20, respectively; adj R^2 = 0.13). The effect of past information seeking on expected consequences is broadly consistent with Mileti and Fitzpatrick (1992) and Mileti and Darlington (1997), although their measures of past information and expected consequences are somewhat different from those in the present study. However, this finding conflicts with Wei and Lindell (2017), who reported a nonsignificant effect. The effect of female gender is well documented, but the effect of education appears to be inconsistent (Solberg et al., 2010). Although not hypothesized, there is a nonsignificant correlation of experience with expected consequences. This result conflicts with the findings of Doyle et al. (2018) and some of the references cited therein, but it is unclear whether the differing results are due to differences in the ways the variables are measured, true differences in the populations studied, or some other reasons.

By contrast, the regression analysis of shake zone perception reveals that experience is the strongest predictor, but the equation is not significant ($\beta = 0.13$; adj $R^2 = 0.01$). This result might seem puzzling, given that income and education have significant correlations with shake zone perception ($r = 0.17$ and 0.14, respectively) but these two predictors are significantly correlated ($r = 0.38$), so their shared variance with the dependent variable is also shared with each other—making both nonsignificant. By contrast, the regression model for liquefaction zone perception has a single predictor, liquefaction zone that is significant ($\beta = 0.17$; adj $R^2 = 0.03$). Since both risk zone perception variables are very poorly predicted by the variables measured in this study, further research is needed to identify better predictors. However, the underlying problem might be that people's responses to these items were little more than guesses, which would be consistent with other studies showing that people demonstrate poor performance in interpreting hazard zone maps (Lindell, 2020b). If that is the case, there might be no better predictors to be found. Consequently, local authorities will need to find better ways to communicate risk zone information and explain unfamiliar terms like "liquefaction."

Both positive and negative affective response have significant positive correlations with past information seeking ($r = 0.25$ and 0.20, respectively), and these effects are maintained in significant regression coefficients when other variables are controlled. One possible explanation for the apparent conflict between the increase in both positive and negative affective responses to past information is that those who have sought information may feel more positive about their level of hazard awareness and ability to reduce risk while simultaneously feeling fearful that the hazard adjustments they adopted have only reduced, rather than eliminated, the probability of significant earthquake impacts. This result may also represent coinciding information processing styles where, according to Griffin et al. (1999), *heuristic* processing is linked with positive affective states while *systematic* processing is linked with negative affective states. More study is needed to understand this curious result and how information seeking and the risk information itself influences affective states and vice versa.

It is also noteworthy that negative affect has a significant correlation with past hazard adjustment adoption ($r = -0.14$), but positive affect does not. With other variables controlled, past hazard adjustment retains a significant regression coefficient ($\beta = -0.20$) in predicting negative affect along with female gender, age, and past information seeking ($\beta = 0.19$, -0.20, and 0.24). This finding suggests that prior hazard adjustment along with information seeking behavior can influence negative affective response to a hazard and not just the other way around as is typically proposed in information seeking models (Dunwoody & Griffin, 2014; Griffin et al., 1999). Indeed, the negative correlation and regression coefficients for the relationship between past hazard adjustment and negative affect are consistent with the relationship that would be expected in the second stage of the hazard adjustment adoption process—higher levels of past hazard adjustment adoption lead to lower levels of current negative affect. However, it is unclear why higher levels of past hazard adjustment adoption do not also lead to lower levels of current expected consequences. These results provide an impetus for future studies to assess both prior and intended actions with respect to information seeking and hazard adjustment.

Finally, the regression analysis for knowledge of earthquake protective actions (DCHOknow) shows that past information seeking is the only variable to have a significant coefficient ($\beta = 0.24$; adj $R^2 = 0.05$). This appears to be a new finding because there do not appear to be any previous studies that have identified predictors of people's knowledge of what to do during an earthquake.

6.3 | The influence of hazard awareness (risk perception, affective response, and knowledge of what to do in an earthquake) on intentions to seek information and adopt hazard adjustments

The partial support for H3 is due to the significant correlations of information search intention with expected consequences, as well as positive and negative affective responses ($r = 0.31$, 0.19, and 0.32, respectively) while the other risk perception variables (perceived shaking zone and perceived liquefaction zone) are not significantly related. However, only expected consequences and negative affect had significant regression coefficients ($\beta = 0.24$ and 0.23, respectively; adj $R^2 = 0.14$). These results are important because they indicate that, although expected consequences and negative affect are significantly correlated in this study ($r = 0.29$) as they were previously ($r = 0.34$) in Wei & Lindell (2017), both variables make essentially equal and independent contributions to the prediction of information search intention. This finding is especially notable because expected consequences and negative affect have two common predictors, female gender and past information seeking (see Table 4). Despite their significant correlation and common antecedents, expected consequences and negative affect are distinctly different constructs. Specifically, the disattenuated correlation between expected consequences and negative affect is $r_d = r_{12} / \sqrt{r_{11} r_{22}} = 0.29 / \sqrt{(0.96 \times}$

0.89) = 0.31. where r_d is correlation corrected for unreliability in the variables, r_{12} is the observed correlation, and r_{11} and r_{22} are the reliabilities of the two variables (Nunnally & Bernstein, 1994). The finding that r_d is much less than 1.0 supports a conclusion that the two variables are measuring distinctly different constructs. Thus, a challenge for future research is to identify the aspects of past information that influence expected consequences and negative affect and to explain why the demographic variables have different patterns of correlations with them.

Overall, the significant correlation and regression coefficients for expected consequences with information search intention are consistent with previous earthquake hazard adjustment research (e.g., Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1992). This suggests other factors mentioned in the literature, such as individual characteristics, perceived ability to acquire information, community participation, and social norms, may have a greater influence on information seeking-behavior (Becker et al., 2012; Dunwoody & Griffin, 2014; Kahlor, 2010).

Finally, hazard adjustment adoption intentions has a significant correlation with liquefaction zone perception ($r = 0.15$), but none of the other risk perception variables. However, this variable does not retain a significant regression coefficient when controlling for other variables. Instead, as discussed below, only past information seeking and past adjustment adoption have significant regression coefficients.

6.4 | The influence of information seeking on hazard adjustment adoption and the relationship between intentions and actions

There is partial support for H4, with past information seeking behavior predicting past hazard adjustment adoption ($r = 0.35$, $\beta = 0.30$) and information seeking intention correlating with, but not predicting hazard adjustment adoption intentions ($r = 0.20$). These results are consistent with previous research that found information seeking to be highly predictive of seismic hazard adjustment adoption (Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1992). In addition, there are also significant correlations of past information seeking with information seeking intentions and hazard adjustment adoption intentions ($r = 0.16$ and 0.17, respectively), as well as of past hazard adjustment adoption with hazard adjustment adoption intentions but not information seeking intentions and ($r = -0.28$ and -0.07, respectively).

One explanation for a correlation of information seeking with hazard adjustment adoption is that information on earthquake hazard and earthquake hazard adjustments from credible sources such as emergency managers and emergency management websites encourages people to adopt earthquake hazard adjustments. Moreover, some people who are motivated to seek information are also likely to be motivated to act on that information once they obtain it. However, the finding that past information seeking has a nonsignificant regression coefficient in the prediction of information seeking intentions when controlling for the affective response variables suggests that the explanation is more complex. Specifically, there appears to be an indirect effect of past information on information seeking intentions that is due to past information increasing the (negative) expected consequences of earthquake impact and, thus, increasing negative affect. This result does not conflict with previous seismic hazard adjustment studies because these studies did not include affective responses as predictors. Thus, the prediction of who engages in information seeking and why they do so requires further study.

By contrast, there is a negative correlation of past hazard adjustment adoption with hazard adjustment adoption intention. One explanation for this finding would be that respondents view adoption of additional hazards adjustments as having a diminishing return on investment (Wachinger et al., 2013). However, Lindell et al. (2009) reported that most earthquake hazard adjustments are perceived to have relatively high efficacy in protecting persons and property but relatively low resource requirements. Consequently, a “rational” benefit/cost analysis does not appear to provide a completely satisfactory explanation for negative influence of past hazard adjustment adoption on hazard adjustment adoption intention.

It is important to note that past hazard adjustment adoption is only moderately high ($M = 0.54$) and hazard adjustment adoption intention only adds a small increment ($M = 0.11$), so only about two-thirds of the hazard adjustments will be adopted even if the respondents’ reports of their past adjustment adoption are accurate and they follow through on their intentions. This might be an overestimate because people’s self-reports of their hazard adjustment adoption are poorly correlated with independent assessments (Joffe et al., 2016). However, even a zero correlation between self-reports and independent assessments does not necessarily mean that the former are overestimated, so further research is needed to assess the accuracy of self-reports. Moreover, the correspondence between intentions and actual behavior can vary substantially as a function of many different conditions that emergency managers cannot influence (Ajzen & Fishbein, 2005), such as lack of, or more immediate demands for, a household’s financial resources. Nonetheless, Kang et al. (2007) and Paton et al. (2005) found significant correlations between intentions and later behavior. Moreover, even if an upward bias in respondents’ self-reports of their hazard adjustment adoption overstates community preparedness for future disasters, it has no effect on model fit as long as it is not so severe as to produce a “ceiling effect” or a “floor effect” that causes variance restriction (Lindell & Perry, 2000). The available data from PDX indicates that neither of these effects is a problem.

6.5 | Study limitations

Study limitations include the sample, generalizability of findings, and imperfect model fits. Though we had hoped for a response rate closer Lindell and Prater's (2000) 35%, ours was less than 20%, which is consistent with a broader reduction in mail survey response rates over the last 50 years (Kohut et al., 2012; Kreuter, 2013). Despite the modest response rate, ~400 responses provided a large enough sample to provide adequate statistical power for detecting correlations of a practically meaningful size. Additionally, our sample overrepresented certain demographic categories (age, wealth, and education) when compared to the population of the study area. However, since much of the research on disasters finds demographic characteristics to have weak and inconsistent relationships with preparedness (Baker, 1991; Huang et al., 2016; Lindell, 2013a; Lindell & Perry, 2000), we do not anticipate that the results from our sample would change significantly if it were more demographically representative.

A second limitation includes whether we specified the models correctly. Although we included variables that have been shown to influence household hazard adjustment adoption, the model fits were relatively low and accounted for 1–24% of the variance in the dependent variables. This is due, in part, to relevant variables that were omitted in order to avoid losing respondents because of excessive questionnaire length. One discouraging observation here is that the Six City study had almost twice the response rate despite its questionnaire being eight pages rather than the present study's four pages.

A third limitation is the imperfect reliability, ranging from $0.58 \leq \alpha \leq 0.92$, in the measurement of the model's variables. However, since increasing the reliability of the variables' measures can only increase correlations, imperfect reliability does not threaten any of the conclusions about hypotheses that are supported. Yet, improving the reliability of the variables' measures might turn nonsignificant correlations into significant correlations, so further research to improve the reliability of measures is needed.

A final limitation is the cross-sectional nature of this study and its impact on the variable ordering for the regression modelling. A cross sectional survey does not allow us to decipher precisely when past information seeking happened in relation to past hazard adjustment adoption or when risk perceptions were formed. However, our survey design does allow us to ask people to reflect on their past (presurvey), assess their feelings or perceptions at the time of the survey (syn-survey), and assess their future intentions (syn-survey). Presurvey variables are those that measure existing constructs (e.g., past actions and personal characteristics) and are indicated in Figures 1 and 2. Syn-survey variables are those measured at the time of survey (e.g., perceptions, affect/feelings, and intentions). We ordered the variables to account for when these factors were measured and according to ordering that has been used in previous models (e.g., intentions come after perceptions—Kahlor, 2010). Yet, it is impossible to know whether all information seeking occurred before all protective actions or if, more realistically, people engaged in multiple cycles of seeking information and taking protective actions prior to taking our survey. We heeded the recommendations of Weinstein and Nicolich (1993) and Bubeck et al. (2012) by measuring both past hazard adjustment adoption and hazard adjustment adoption intentions, as well as past information seeking and information seeking intentions. However, many researchers such as (Siegrist, 2013, 2014) still recommend longitudinal studies to determine whether and how those intentions translate into actual adoption of hazard adjustments, despite their challenges (Hudson et al., 2019). Though arguments could be made for another ordering of the variables, we ordered them in as reasonable a way as possible. Longitudinal studies are needed to better understand what ordering is most appropriate.

7 | CONCLUSIONS

The findings presented here support existing theories that information seeking, along with variables such as risk perception and affective response, are essential to the earthquake hazard adjustment adoption process. Additionally, this study assesses past actions and future intentions for both information seeking and preparedness. By doing this, we aim to advance our understanding of the relationship between behaviors and intentions, which is critical since it is simpler to measure past actions and future intentions in a cross-sectional study than actions in successive waves of a longitudinal study. This study examines constructs associated with the PADM and other theories of protective action and information seeking. By testing these relationships in new regional contexts and with different hazards, we can determine which relationships hold (e.g., information seeking and preparedness) and which need additional study (e.g., earthquake experience and preparedness).

To date, research on information seeking and protective action have been somewhat siloed in terms of investigating the factors that influence them. In this study, we include information seeking and protective actions in our regression model as both independent and dependent variables. To advance our understanding, more study is needed to refine and test information seeking models (Dunwoody & Griffin, 2014; Kahlor, 2010) and to investigate how they correspond with the PADM and other models of protective action. To build on this work, we recommend longitudinal studies that replicate existing measures and assess changes in hazard adjustment adoption across locations and time. It is through these methods that we can develop better risk information strategies and outcomes.

In any study of household preparedness it is also valuable to provide recommendations for practice. We have three such recommendations, the first of which follows from the finding that we and others (Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1992) have documented information seeking behavior to be a strong predictor of preparedness. Consequently, we echo others' sentiments that scientific and emergency management agencies should reduce barriers to information seeking by increasing risk and protective action information accessibility and understandability. Importantly, this should involve consolidating and simplifying information and putting it in places where people already frequent—grocery stores, community centers, social media platforms, fitness centers, and faith-based institutions (For a list of additional recommendations for risk communication best practices, see Campbell et al., 2020; Mileti et al., 2004). Second, in contrast to some studies, we did not find earthquake experience to predict hazard adjustment adoption. This may be because much of our sample had low earthquake experience, despite being in a region with moderately high seismic risk. For areas like this, which is much of the northern portion of the CSZ, risk communicators should consider ways to help people personalize earthquake impacts. This could be done by using interactive formats that provide location-specific information (e.g., games, storytelling, scenarios, etc.), which have been shown to be more effective method of engaging the public (Joffe et al., 2016; Perez-Fuentes et al., 2016). Third, in order to investigate whether intentions translate into actions, a connection that remains blurry (Paton et al., 2005), researchers and practitioners should find opportunities to assess people's preparedness intentions and actions over time. This may include following up with people after risk and preparedness events or campaigns (e.g., workshops, community events, social media posts, etc.). Together, these recommendations can help practitioners develop more effective risk communication campaigns and researchers conduct more robust studies that can link information with action. For additional recommendations for practice based on this work, see MacPherson-Krutsky et al. (2022).

While this study has limitations, it offers insights into the role key factors play in influencing household seismic preparedness and provides suggestions for practice. Though these findings are a step forward in understanding the connections between past and future protective actions, more work is needed to test causal chains that lead to household hazard adjustment adoption. Additionally, future work should examine the stability of these relationships across hazards and regions because communities that have varied experience, social norms, and demographics may react to risk information differently. Given the complex nature of human perceptions, intentions, and behaviors in the context of environmental hazards and the inevitable nature of earthquakes, research that helps to reduce future disaster impacts by even a small amount is valuable and necessary.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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