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Revisiting the Person-relative-to-Event (PrE) model of coping with threat: a study in the Azores (Portugal)

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Abstract

Background Approximately 20 years have passed since the Person-relative-to-Event (PrE) Model of Coping with Threat was conceptualized. Despite its familiar name, this model has been under-researched. This study investigates the main assumptions of the PrE, identifies predictors of actual household earthquake adjustments in the absence of fear appeals using a non-experimental design, and proposes an alternative model: the Sequential Person-relative-to-Event Model of Coping with Threat (SPrE).

Methods A survey methodology was employed with self-completed questionnaires from 822 residents of the Azores, an earthquake-vulnerable location. The associations between variables were examined. Structural Equation Modeling was applied to test the PrE and SPrE models.

Results Actual household earthquake adjustment was associated with *person*, *event*, and person-relative-to-event appraisals, responsibility attributions, age, and educational level. There was a non-significant association with gender. Person-relative-to-event appraisal was a non-significant predictor of actual household earthquake adjustments and responsibility attributions did not moderate this relationship. We found that *event* appraisal predicted *person* appraisal and that its relationship with actual household earthquake adjustments was moderated by the responsibility attributions. Thus, a new hypothesis is proposed regarding the relationship between risk perception (equivalent to *event* appraisal) and actual household earthquake adjustments.

Conclusions These results contribute to the literature, practice and cumulative scientific knowledge.

Keywords Earthquake, Household earthquake adjustments, Person-relative-to-Event, Sequential Person-relative-to-Event, Earthquake preparedness, Earthquake mitigation, Psychological determinants

Introduction

Scientific knowledge is constructed through the confirmation, revision, dispute, and rebuttal of models, theories, and assumptions that capture unequal attention among researchers. Those that capture the most attention persist within a given scientific field. Others may remain "forgotten" or unchanged until they capture the attention of researchers, resurfacing years after their initial conceptualization. This study tests the main assumptions of a theory/model that explains the actual adoption of earthquake protection behaviors by households: the Person-relative-to-Event (PrE) Model/Theory of Coping with Threat (PrE) (Mulilis & Duval 2003). The decision to study PrE was based on the fact that: (a) this model is understudied; (b) the few studies using PrE applied experimental methodology, which allows the verification

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of causal assumptions (Kline 2016); (c) PrE could be a valid model because no consensus exists on the factors that explain the adoption of actual protective behaviors against earthquakes by households (Spittal et al. 2008; MacPherson-Krutsky et al. 2023). However, there is lack of cumulative evidence on its utility.

Understanding coping and decision-making regarding protection from natural hazards: conceptual definitions and models

Over the years, researchers have used, adapted, and proposed both models and theories to understand the complex processes of human coping and protection decision-making (Ejeta et al. 2015). Regarding natural hazards, the coping process and decision-making relate to actions to reduce risk and enhance the probability of survival if a natural hazard of great magnitude occurs. Considering households, the adoption of this set of actions by individuals and groups of cohabiting individuals characterizes the household's state of readiness of to face such an event, often termed preparedness (e.g., Lamjiry & Gifford 2022) or hazard adjustments (e.g., Lindell & Perry 2000). A closer inspection reveals theoretical differences between these two concepts, despite their interchangeable use. Preparedness exclusively regards active protection actions, whereas the concept of hazard adjustments includes preparedness (termed emergency preparedness), mitigation (passive protection), and recovery preparedness actions, such as buying insurance (e.g., Lindell & Perry 2000; Wu et al. 2017). Frequently, these differences are overlooked, and the term preparedness is often adopted. This study focuses on actual household hazard adjustments for earthquakes. Nevertheless, the findings of previous studies on household earthquake preparedness cannot be disregarded. The common nature of active and passive actions to face and deal with earthquakes led us to recognize that, until proven otherwise, findings on household earthquake preparedness can apply to the study of household earthquake adjustments. Therefore, these findings were considered here.

There are several models and theories on coping and decision-making in the natural hazards' context. These include, but might not be restricted to, the Health Belief Model (Lachlan et al. 2021; Rostami-Moez et al. 2020; Noor et al. 2022), the Precaution Adoption Process Model (Glik et al. 2014), the Extended Parallel Process Model (Salita et al. 2021; Weber et al. 2018), the Protection Motivation Theory (Greer et al. 2020; Grothmann & Reusswig 2006), the Protective Action Decision Model (PADM; Wei et al. 2019; Wu et al. 2017), the Social-Cognitive Preparation Model (Paton 2003; Paton et al. 2003), and the Person-relative-to-Event Model of Coping with Threat (PrE; Mulilis & Duval 2003). These models and theories include similar variables, but their operationalization (Corwin et al. 2017), organization, and proposed mediational processes can differ (Rogers 1983). However, a full understanding of the factors that drive protection regarding natural hazards is yet to be achieved (Spittal et al. 2008; MacPherson-Krutsky et al. 2023).

Research articles proposing (e.g., Lindell & Perry 2000; Paton 2003) and applying (e.g., Greer et al. 2020; Wu et al. 2017) models and theories to understand human behavior regarding natural hazards often mention the Person-relative-to-Event Model/Theory of Coping with Threat. For example, Paton et al. (2001) stated that the PrE has "demonstrated a capability to predict the adoption of risk reduction behaviors" (Paton et al. 2001, p. 48). However, this model has been underexplored both empirically (Basolo et al. 2009; Lindell & Perry 2000; Duval & Mulilis 1999) and theoretically, which could explain the absence of evidence in the literature regarding the limitations of PrE.

Person-relative-to-Event (PrE) model of coping with threat

PrE is a value-expectancy model that includes the variables proposed in the Protection Motivation Theory (PMT; Rogers 1975, 1983) (admitting the inclusion of other variables) (Mulilis & Duval 1995, 2003). Their organization and combinatory rule were based on the Cognitive Appraisal Theory and Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984).

PMT was conceptualized under the negative threat or fear appeals (communication that arouses fear and recommends how to avoid imposing danger) paradigm (Maddux & Rogers 1983; Rogers 1983). However, it is possible to apply this model to the study of attitude change in situations involving threats without fear appeals because the effects of fear on protection motivation are indirect. These effects occur through the four cognitive appraisal processes that are the core of the PMT and the elicitors of protection motivation (Rogers 1983). PrE was conceptualized and studied under the same paradigm. Notwithstanding, we assume that like PMT, PrE can be applied and tested without fear appeals.

Mulilis and Lippa (1990) tested the predictability of actual earthquake preparedness behavior using the revised PMT. The authors found an interaction effect of the PMT cognitive processes on the earthquake preparedness mean scores in the experimental group during five weeks (Mulilis & Lippa 1990). Specifically, these cognitive processes include probability of occurrence of a threatening event, its severity, coping response efficacy, and self-efficacy expectancy regarding the coping response (Maddux & Rogers 1983). However, the main effect of each of the PMT cognitive processes on the earthquake preparedness mean scores in the experimental group was missing (Mulilis & Lippa 1990). Moreover, the authors found no evidence of an additive combinatory rule, but rather partial support for a subadditive combinatory rule between the effects of the variables: probability of threat occurrence, coping response efficacy, and self-efficacy regarding the coping response (Mulilis & Lippa 1990).

Acknowledging these results, Mulilis and Duval (1995) conceptualized PrE to explain how different levels and combinations of variables influenced actual problem-focused coping behavior, understood as adopting preparedness (Mulilis & Duval 1995).

Variables in the PrE model: model organization and conceptual definitions

The PrE model considers three groups of variables: (a) related to the *person*, respecting personal resources to deal with the threat; (b) related to the *event*, regarding the characteristics or degree of the threat; (c) other variables, such as attributions of responsibility for the coping response (responsibility attributions, from now on). Previous studies using PrE also assessed demographic variables, such as age (Mulilis 1999; Mulilis & Lippa 1990; Duval & Mulilis 1999; Mulilis et al.2000), gender (Duval & Mulilis 1999; Mulilis & Duval 1995, 1997; Mulilis 1999; Mulilis et al. 2000), and educational level (Duval & Mulilis 1999; Mulilis et al. 2000).

Mulilis and Duval (1995) stated that for model testing purposes, it is sufficient to consider self-efficacy regarding the coping response and outcome expectancy in *person* appraisal, and perceived probability of occurrence and perceived threat severity in *event* appraisal. Thus, these were the variables considered here, along with age, gender, and educational level.

In this study, self-efficacy was understood as the perceived capacity or ability to perform behaviors (Bandura 1997) to reduce or avoid personal physical damage (Mulilis & Duval 1995, 1997). Outcome expectancy was understood as the perceived efficacy of behaviors (Bandura 1997) to reduce or avoid personal physical damage (Mulilis & Duval 1995, 1997). Tang and Feng (2018) and Lamjiry and Gifford (2022) found a significant correlation between self-efficacy and actual household earthquake preparedness, mitigation, or adjustments. Furthermore, Rostami-Moez et al. (2020), Tang and Feng (2018), and Kinanthi et al. (2023) found a significant predictive effect of self-efficacy on actual household earthquake preparedness, mitigation, or adjustments.

Several authors have considered perceived likelihood or probability of occurrence and perceived severity of consequences as components of earthquake risk perception (e.g., Han et al. 2017; Lindell & Perry 2000; Wu et al. 2017). Thus, this concept is equivalent to *event* appraisal in PrE. Overall, previous studies obtained mixed results on: (a) the correlations between risk perception and actual household earthquake preparedness, mitigation, or adjustments; (b) the influence of risk perception on actual household earthquake preparedness, mitigation, or adjustments (Solberg et al. 2010) (see Table 1).

In addition to inconsistent results, the measurement of the perceived likelihood or probability of occurrence and perceived severity of consequences has also been inconsistent. The perceived probability of occurrence has been assessed in relation to different periods, or without mentioning a specific period (see Lindell & Whitney 2000; Han et al. 2017; Spittal et al. 2008). Perceived threat severity, that is, the assessment of the potential damage from a threatening event, has also been assessed regarding different aspects, namely property (e.g., Lindell & Prater 2000; Wu et al. 2017) and personal, or family, safety (e.g., Han et al. 2017).

In the PrE model, responsibility attributions concern attributing to the self or others responsibility for the coping response (Mulilis & Duval 2003). Lindell and Perry (2004) stated that personal responsibility for hazard adjustments might vary with the type of hazard (familiar vs. unfamiliar) and perceived resources, influencing the implementation of adjustments. Findings regarding the correlation between attributions of responsibility to self or others and earthquake preparedness/adjustments

Table 1 Results of previous studies analyzing the relationship between risk perception and actual earthquake preparedness, mitigation or adjustments

Variable	Statistical significance	Relationship with actual earthquake preparedness, mitigation or adjustments	
		Correlation	Effect/Prediction
Risk perception	Significant	Lindell & Prater (2000)	Lindell & Prater (2000) Wu et al. (2018)
	Non-significant	Lamjiry & Gifford (2022) Lindell & Whitney (2000) Wu et al. (2017)	Basolo et al. (2009) Tang & Feng (2018)

are inconsistent. For example, Lindell and Whitney (2000) found a significant correlation between attributing responsibility to self and the adoption of earthquake adjustments, but a non-significant correlation between attributing responsibility to family, government, and stakeholders and the actual adoption of earthquake adjustments. In contrast, Wu et al. (2017) found a non-significant correlation between attributions of responsibility to self and the actual adoption of earthquake adjustments.

Lindell and Perry (2000) reviewed studies on seismic adjustments (and/or earthquake preparedness), finding mixed results on the correlation between demographic variables and minor significant correlations. Here the demographic variables assessed were gender, age, and educational level. Table 2 summarizes the findings from previous studies that analyzed the relationship between these variables and actual household earthquake preparedness, mitigation, or adjustments.

Given that Rüstemli and Karanci (1999) made no distinction between actual and planned behaviors, both considered earthquake preparedness, their results were not included in Table 2 for the sake of clarity. The authors found a lack of correlation and non-significant effects of gender, age, educational level, on adopted or planned earthquake preparedness (Rüstemli & Karanci 1999). Moreover, for participants with direct earthquake experience, Kim et al. (2024) found a non-significant predictive effect of gender, age, and education on actual earthquake preparedness. Regarding participants with indirect earthquake experience, the authors found a significant predictive effect of age (older participants) and a non-significant predictive effect of gender and education level on actual earthquake preparedness (Kim et al. 2024).

Results of PrE applications indicated no gender differences in actual household earthquake preparedness (e.g., Duval & Mulilis 1999, 1995). However, Mulilis (1999) found that males developed more earthquake preparedness activities related to utilities, whereas females developed more planning and mitigation preparedness activities. Those differences were attributed to gender identity and socialization (Mulilis 1999). There were no gender differences regarding survival preparedness activities (Mulilis 1999).

Table 2 Results of previous studies analyzing the relationship between the demographic variables in this study and actual household earthquake preparedness, mitigation or adjustments

Variables	Statistical significance	Relationship with actual earthquake preparedness, mitigation or adjustments	
		Correlation	**Effect/Prediction**
Gender/Sex	Significant	Lindell & Perry (2000)† Ranjbar et al. (2018) (males‡) Lindell & Whitney (2000) (females‡)	Ranjbar et al. (2018) (males‡) Wu et al. (2018) (males‡)
	Non-significant	Kirschenbaum et al. (2017) Oral et al. (2015) Spittal et al. (2008) Wu et al. (2017) MacPherson-Krutsky et al. (2023)	Basolo et al. (2009) Han et al. (2017) Lindell & Prater (2000) Kirschenbaum et al. (2017) Oral et al. (2015)
Age	Significant	Lindell & Perry (2000)† Lindell & Whitney (2000) (older participants‡) Spittal et al. (2008) (older participants‡) MacPherson-Krutsky et al. (2023) (older participants‡)	Wu et al. (2018) (younger participants‡) Lindell & Prater (2000) (older participants‡) MacPherson-Krutsky et al. (2023) (older participants‡)
	Non-significant	Oral et al. (2015) Kirschenbaum et al. (2017) Ranjbar et al. (2018) Wu et al. (2017)	Basolo et al. (2009) Han et al. (2017) Kirschenbaum et al. (2017) Oral et al. (2015) Ranjbar et al. (2018)
Educational level	Significant	Lindell & Perry (2000)† Kirschenbaum et al. (2017) (higher educational levels‡) Rostami-Moez et al. (2020) (higher educational levels‡)	Kirschenbaum et al. (2017) (higher educational levels‡) Rostami-Moez et al. (2020) (higher educational levels‡) Wu et al. (2018) (higher educational levels‡)
	Non-significant	Oral et al. (2015) Ranjbar et al. (2018) Spittal et al. (2008) Wu et al. (2017) MacPherson-Krutsky et al. (2023)	Basolo et al. (2009) Han et al. (2017) Lindell & Prater (2000) Oral et al. (2015)

† Results of a review of research

‡ Group that exhibited higher earthquake preparedness/adjustments levels

PrE model assumptions

According to PrE, the adoption of problem-focused coping (behavior) results from the interaction of *person* (resources appraisal) and *event* (threat appraisal) (Mulilis 1999; Mulilis & Duval 1995, 1997). The authors assumed that this interaction, called person-relative-to-event, is a better predictor of problem-focused coping than the absolute values of *person* and *event* variables independently. The level of personal responsibility for the coping response moderates the relationship between person-relative-to-event and the coping response (Mulilis 1999; Mulilis & Duval 1995, 1997, 1998). When faced with the possibility of a threatening event, a primary and a secondary appraisal occur (Mulilis & Duval 1995, 1997, 2003). An initial appraisal of an event as threatening activates two secondary appraisal processes that are independent, parallel, and simultaneous (Mulilis & Duval 2003): (a) person-relative-to-event appraisal (Mulilis & Duval 1995, 1997); (b) appraisal of personal responsibility for the coping response (Mulilis & Duval 2003). Thus, the model differs from the Cognitive Appraisal Theory and the Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984) by adding an appraisal process regarding responsibility attributions. Furthermore, PrE differs from the PMT by proposing a different combinatory rule and including an appraisal of personal responsibility for the coping response, which is central to the PrE model (Mulilis & Duval 2003).

The combination of fluctuating levels of the *person* and *event* variables produces three conditions of person-relative-to-event: *person-greater-than-event* (P > E), *person-equal-to-event* (P = E), and *person-less-than-event* (P < E). The model specifically predicts problem-focused coping in the conditions P > E and P < E. Mulilis et al. (2000) empirically verified the moderating role of responsibility in the relationship between person-relative-to-event appraisal and problem-focused coping. For all the appraisals of P > E, P = E and P < E, in situations with low responsibility, the interaction between *person* and *event* did not influence problem-focused coping efforts. In other words, if problem-focused coping is considered someone else's problem, the level of resources relative to threat magnitude bears no relevance on an individual's behavior (Mulilis & Duval 1995, 1997, 2003). However, there were differences in the problem-focused coping efforts exhibited when responsibility for the coping response was high, that is, when it was self-attributed.

In the condition P > E, the resources (*person*) are appraised as sufficient in quality and quantity relative to the threat magnitude (*event*). In this condition, problem-focused coping efforts would be significantly greater than in the conditions P = E and P < E (Mulilis & Duval 1995, 1997). Moreover, individuals attribute more responsibility to self for the coping efforts (Mulilis & Duval 2003). Specifically, when there is a feeling of personal responsibility for the coping response, the individual activates personal resources if they are perceived as sufficient in quality and quantity relative to the threat's magnitude (P > E) (Mulilis & Duval 1997). In this case, the individual formulates problem-focused plans and develops greater efforts to implement problem-focused coping compared to conditions of P > E and low responsibility, P = E and P < E and high responsibility (Mulilis & Duval 1995, 1997, 2003).

In the condition P < E, the resources (*person*) are appraised as insufficient in quality and quantity relative to the threat magnitude (*event*). In this condition, problem-focused coping efforts would be lower than in the condition P > E (Mulilis & Duval 1995, 1997, 2003) even when responsibility for the coping response is self-attributed. Moreover, individuals may engage in avoidance or non-problem-focused plans (Mulilis & Duval 1997, 2003). Additionally, individuals attribute more responsibility to others for the coping efforts, when they perceive resources to be insufficient to reduce or avoid the negative consequences of a threat (Mulilis & Duval 2003). Moreover, the model predicts that when resources are appraised as insufficient, the greater the perceived threat magnitude, the lower the problem-focused coping efforts (Duval & Mulilis 1999; Mulilis & Duval 1995, 1997).

Overall, the model explains the impact of PrE appraisal when personal responsibility for the coping response is recognized, assuming that the higher the perceived resources relative to the threat, the higher the preparedness/adjustments. In situations of low responsibility, PrE appraisal has no effect on preparedness/adjustments. The PrE model was tested using an experimental design where participants read texts that contained manipulated levels of *person*, *event* (Duval & Mulilis 1999; Mulilis & Duval 1995, 1997, 1998) and responsibility attributions variables (Mulilis & Duval 1995, 1997).

This study

Over the last 20 years, the literature has recognized the PrE as a valid model to explain the actual adoption of preparedness or adjustments behavior for extreme natural events. However, to the best of our knowledge, this model, as conceptualized by their authors, has not been tested or applied since the studies of Mulilis, Duval, and colleagues in the 90s and initial 2000s. The only exception is the study by Martel and Mueller (2011) that found significant main effects of PrE appraisal and anticipated service interruptions in preparedness intentions for earthquakes and floods. In contrast to the study by Martel and Mueller (2011) and previous works by Mulilis, Duval and colleagues (e.g., Duval & Mulilis 1999; Mulilis

& Duval 1995, 1997, 2003), the present study investigates the main assumptions of the PrE model without fear appeals and considering actual household earthquake adjustments. Moreover, in this study, all the variables were measured and not manipulated, as previously done.

Specifically, we conducted two studies. The first (Model 1) assessed the predictive effect of PrE appraisal on actual household earthquake adjustments adoption and the moderating effect of attributions of personal responsibility for the coping response (actual household earthquake adjustments). The model includes the demographic variables age, gender, and educational level. Based on the results of the first study (Model 1), a second study was conducted to test an alternative model (Model 2), which includes the same variables of the PrE model. However, we follow a different structure inspired by the Cognitive Appraisal Theory and the Transactional Model of Stress and Coping regarding primary and secondary appraisals (Lazarus 1966; Lazarus & Folkman 1984).

The results of this study add to the literature and practice. It contributes to research on models of coping with threat and protection decision-making regarding natural hazards by: (a) testing the assumptions of a model that has been underexplored; (b) proposing an alternative model; and (c) presenting a review of the PrE assumptions and findings from earlier studies, which is absent from the literature. It also adds to the literature on actual household earthquake readiness by reviewing and presenting results on both the associated and predicting variables. Regarding practice, these results can inform policies (Li et al. 2023) and risk communication programs. According to Lindell and Perry (2004), such programs should focus on mutable variables associated with higher levels of hazard adjustments adoption (e.g., personal responsibility, self-efficacy, and outcome expectancy), seeking to enhance their levels and ultimately influencing the implementation of household adjustments. Moreover, the results of this study can inform the identification of population segments that require reinforced risk communication programs (Lindell & Perry 2004).

Method

The present study is part of a larger investigation addressing actual household earthquake adjustments and associated variables. Thus, only a part of the collected data was analyzed here. This study followed a non-experimental research design.

The Ethics Committee of the University of the Azores (27/2023) approved this study.

Data were collected in the Azores, a Portuguese archipelago with nine islands vulnerable to seismic and volcanic risks, which was experiencing an increase in regular seismic activity during 2023. Consequently, the residents felt more earthquakes than usual.

Participants

A non-probabilistic self-selected sample of 921 residents in the Azores, who were at least 18 years old, was used. Table 3 includes the distribution of participants by island.

Most participants were female (n = 624, 68.1%), had a higher education (n = 654, 71.5%), and were between 18 and 73 years old (M = 45.33, SD = 9.92). The majority were employed (n = 902, 98.5%), owned a home (n = 650, 71.4%), and had children as dependents (n = 474, 52.4%).

Minimum sample size was calculated à priori, using the formula of Yamane (1967 *in* Israel 2012). Minimum quotas of participation were calculated and established considering the number of residents per island older than 18 years, according to the census 2021 data (PORDATA 2022). The census age groups were 15–24, 25–64, and 65 years old or more (N = 202701) (PORDATA 2022). Thus, it was decided to include the age group from 15–24 in the sample calculation formula. However, only participants aged 18 years or older were admitted in this study. The minimum sample size was 401 residents of all nine Azores Islands, calculated with a 95% confidence level (e = 0.05). Quota participation on eight islands was surpassed, whereas on one island (Flores), minimum quota participation was reached.

A direct comparison between sample and population characteristics is limited by the age groups used in the census 2021. Notably, the sample of this study had more females and individuals with higher education than the population (PORDATA 2023a, b).

Procedure

An online questionnaire available on the platform Lime Survey (Lime Survey Community Edition, Version 6.3.9) was used to gather data on participation. Before questionnaire completion, participants agreed to participate voluntarily and anonymously, as well as

Table 3 Distribution of Participants by Island

Island	Number of participants
Santa Maria	16
São Miguel	380
Terceira	311
Graciosa	10
São Jorge	73
Flores	6
Corvo	5
Total	921

guaranteed their understanding of the research goals. Confidentiality was ensured.

The study link was disseminated between October 14 and November 23, 2023, via social media and e-mail to public, private, community and professional organizations, groups, associations, and institutions. In total, the research team conducted 278 e-mail contacts, asking for help with the diffusion of the study link.

Considering the incomplete questionnaires, the response rate was 73%.

Measures

The research team developed a questionnaire based on the literature. The instrument included 72 items assessing variables in the PrE model, other variables associated with household earthquake adjustments, sociodemographic characteristics, and actual household earthquake adjustments. This study does not include an analysis of variables other than those included in the PrE model. Table 4 includes the items used to assess self-efficacy, outcome expectancy, perceived probability of occurrence, perceived threat severity, responsibility attributions, the

Table 4 Assessment of Self-efficacy, Outcome Expectancy, Perceived Probability of Occurrence, Perceived Threat Severity and Responsibility Attributions

Variable	Description	Based on	
Self-efficacy	Item(s)	I feel capable of taking actions to… (a) prevent injury or death caused by a destructive earthquake (b) reduce damage to my home caused by a destructive earthquake (c) deal with the lack of basic services (e.g., electricity, water, communications, or other basic services) due to a destructive earthquake (d) deal with the disruption or stoppage of activities in my community caused by a destructive earthquake (e.g. closed services)	Bandura (2005) Lamjiry and Gifford (2022) Lindell & Perry (2000) Macpherson-Krutsky et al. (2023)
	Answer type	Scale with 10-unit intervals ranging from (0%) *Not capable* to (100%) *Fully capable*	
Outcome expectancy	Item(s)	In your opinion, in the event of an earthquake, how effective is preparedness/mitigation for: (a) reducing the number of deaths and injuries caused by a destructive earthquake (b) overcoming the lack of basic services (e.g., electricity, water, communications, or other basic services) due to a destructive earthquake (c) reducing material damage (destruction and collapse) to homes due to a destructive earthquake (d) overcoming the consequences of the disruption or stoppage of activities in your community due to a destructive earthquake (e.g. closed services)	Lindell & Perry (2000) McClure et al. (1999) Mulilis & Lippa (1990)
	Answer type	5-point Likert scale ranging from (1) *Not effective at all* to (5) *Fully effective*	
Perceived probability of occurrence	Item(s)	In the next 10 years, could a destructive earthquake in the Azores that threatens your safety occur?	Han et al. (2017) Lamjiry & Gifford (2022) MacPherson-Krutsky et al. (2023) McClure et al. (1999) Perry (1990)
	Answer type	5-point Likert scale ranging from (1) *Highly improbable* to (5) *Extremely probable*	
Perceived threat severity	Item(s)	In the next 10 years, you and your family could be affected by a destructive earthquake on land that causes… (a) death and injuries (b) disruption or stoppage of electric, water, communications or other basic services (c) material damage (infrastructure destruction and collapse) (d) economic or income losses (e) disruption of daily community activities	Lindell & Perry (2000) Macpherson-Krutsky et al. (2023) McClure et al. (1999) Scovell et al. (2021) Wei & Lindell (2017)
	Answer type	5-point Likert scale ranging from (1) *Highly improbable* to (5) *Extremely probable*	
Responsibility attributions	Item(s)	What is your opinion on the sentence: *"Citizens have an obligation to prepare for a destructive earthquake"*?	Mulilis & Duval (1995)
	Answer type	5-point Likert scale ranging from (1) *Completely disagree* to (5) *Completely agree*	

type of answer, and sources used in the design of items and answers.

To assess earthquake preparedness, studies using the PrE model have applied the Mulilis-Lippa Earthquake Preparedness Scale (MLEPS) (e.g., Mulilis et al. 1990). The present study addresses actual household earthquake adjustments, thus requiring the assessment of structural mitigation, which is absent from the MLEPS (Spittal et al. 2006). Moreover, the MLEPS includes items that do not assess household earthquake preparedness (Spittal et al. 2006). Thus, data were collected using the Earthquake Adjustments Checklist (EAC; Pereira et al. 2024). This checklist includes forty items referring to actual household earthquake adjustments devised from the literature on actual and intended earthquake preparedness and adjustments, as well as earthquake recommendations from Portuguese Civil Protection (ANEP, s.d., 2022). The response options were *No* (coded with 1), *Not sure* (coded with 2), and *Yes* (coded with 3). Higher scores indicated higher levels of actual household earthquake adjustments.

The demographic characteristics analyzed in this study were age (open answer), gender (*male*, *female*, and *other*), and educational level. The educational level item had seven response options ranging from *Incomplete 1st cycle of education* to *University education*.

Gender was considered a social construct referring to roles, behaviors, and identities (Heidari et al. 2016).

Data analysis

Using 29.0 (SPSS Inc., Chicago, IL, USA) the following were conducted: descriptive statistics, Pearson product-moment correlations to examine associations between continuous variables, Pearson's chi-square test to analyze associations between categorical variables, and Kruskal–Wallis H test to analyze associations between categorical and continuous variables.

Structural Equation Modeling (SEM) was applied to test the direct effect of person-relative-to-event appraisal and demographic variables (gender, age, and educational level) (exogenous or independent variables) on actual adoption of household earthquake adjustments (endogenous or dependent variable) and the moderating effect of attributions of self-responsibility for the coping response (Model 1; see Fig. 1).

Based on Model 1, an alternative model was tested (Model 2), which we called Sequential Person-relative-to-Event Model of Coping with Threat (SPrE). This model included *person* score, *event* score, demographic variables (gender, age, and educational level) (exogenous or independent variables), and attributions of self-responsibility for the coping response (mediator variable) as predictors of actual household earthquake adjustments (endogenous or dependent variable) (Model 2; see Fig. 2). All the variables included in SEM were manifest.

R version 4.31. (The Core Team 2023), package "lavaan" (Rosseel et al. 2023) was used because it allows performing SEM applying estimation methods appropriate to violations of assumptions (Kline 2016). SEM includes confirmatory techniques (Ullman 2013), analyzing patterns of variance and covariance between variables and indicating the maximum variance explained by the model, considering error and rejecting models which fit poorly with the data (Kline 2016; Ullman 2013). Nevertheless, it is possible to retain equivalent models with a good fit to the data, even if different causal hypotheses are tested (Kline 2016).

SEM can be applied to non-experimental designs, admitting different types of variables as predictors, as well as the analysis of models with violations to multivariate normality, which are common in social sciences (Finney & DiStefano 2006; Kline 2016). The presence of multivariate non-normality and categorical variables requires the use of appropriate estimation methods or corrections to avoid biased results (Finney & DiStefano

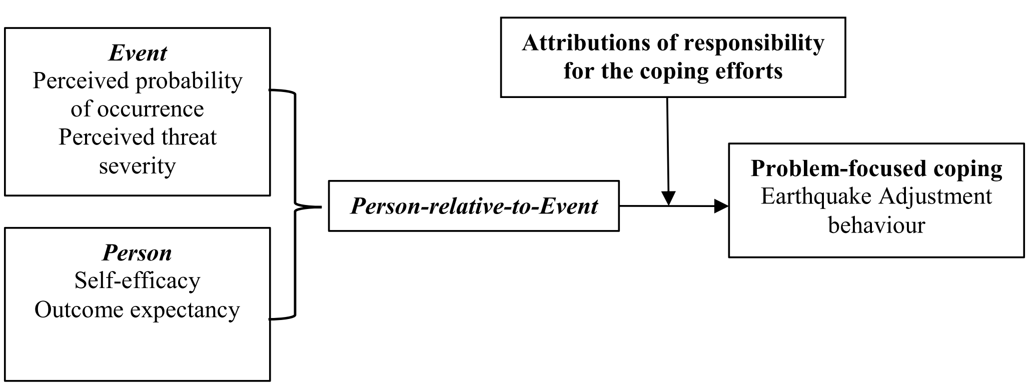

Fig. 1 Person-relative-to-Event Model of Coping with Threat: Illustration

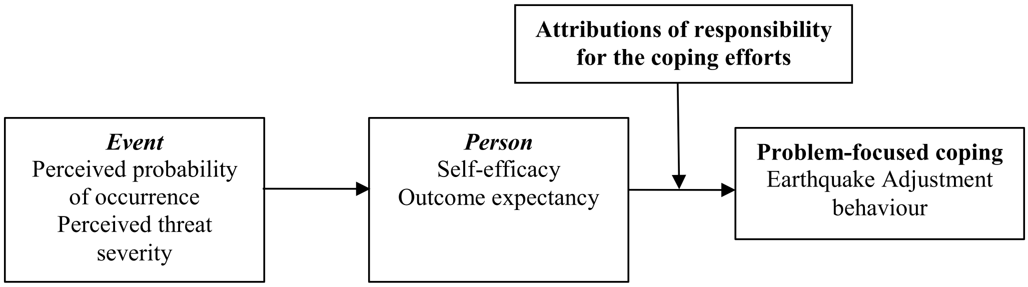

Fig. 2 Sequential Person-relative-to-Event Model of Coping with Threat: Illustration

2006; Kline 2016). Such possible methods include the Satorra-Bentler scaled or adjusted chi-square and robust standard errors applied to maximum likelihood estimation (MLM) (Finney & DiStefano 2006; Kline 2016; Ullman 2013).

The model fit to the data was indicated by χ2/degrees of freedom ratio (CMIN/DF) values inferior to 5 (Carmines & McIver, 1981); comparative fit index (CFI) values greater than 0.95 (Byrne 2010); Tucker–Lewis Index (TLI) values close to 0.95 (Byrne 2010; Hu and Bentler 1999); root mean square error of approximation (RMSEA) values inferior to 0.05 (Byrne 2010); and standardized root mean square residual (SRMR) values equal or inferior to 0.05 (Byrne 2010).

Given that the design was non-experimental, results should be replicated in different samples and settings to infer causation (Kline 2016). Notwithstanding, this study provides evidence of the influence of the analyzed variables on actual household earthquake adjustments and the plausibility of the analyzed models to explain these behaviors.

Transformation of the variables

Variables were transformed using the Statistical Package for the Social Sciences (SPSS, version 29, IL, USA) before SEM.

To simplify the interpretation of results, and considering the severe uneven distribution of answers, the variable 'perceived probability of occurrence' was recoded into three levels: 1. *Improbable*, 2. *Probable*, and 3. *Highly probable.* The detailed distribution of this variable was: five participants (0.6%) mentioned *Highly improbable*, 78 (9%) mentioned *Unlikely*, 435 (50.4%) mentioned *Likely*, 244 (28.3%) mentioned *Very likely*, and 101 (11.7%) mentioned *Extremely likely*. Similarly, 'responsibility attributions' was recoded into two levels: 1. *Do not recognize personal responsibility* and 2. *Recognize personal responsibility*. Specifically, the responses were: one participant (0.1%) mentioned *Completely disagree*, 11 (1.3%) mentioned *Disagree*, 30 (3.5%) mentioned *Do not agree or disagree*, 427 (49.5%) mentioned *Agree*, and 394 (45.7%) mentioned *Completely agree*. Moreover, the variable 'educational level' was recoded in two levels: 1. *Without university degree* and 2. *With university degree.* Within this variable, the data reflected: one participant (0.1%) mentioned having *Incomplete 1st Cycle of education*, no participants mentioned having *Complete 1st Cycle of education*, three participants mentioned having the *2nd Cycle of education*, 23 (2.7%) mentioned having the *3rd Cycle of education*, 166 (19.2%) mentioned having *Secondary education*, 52 (6%) mentioned having a *Professional degree*, and 618 (71.6%) mentioned having a *University degree.*

Dummy coding was used for exogenous or independent categorical variables, namely, 'perceived probability of occurrence', 'responsibility attributions', 'gender', and 'educational level' (Tabacknick & Fidell 2013; Kline 2016).

'Perceived threat severity' (four items), 'self-efficacy' (four items), 'outcome expectancy' (four items), and 'actual household earthquake adjustments' (40 items) were transformed into composite scores. Internal consistency reliability of scores (*Cronbach's alpha*) was evaluated. Values around 0.90, 0.80 and 0.70 are considered "excellent", "very good," and "adequate", respectively (Kline 2016, p. 70). Higher scores indicated higher levels of perceived threat severity ($\alpha = 0.94$), self-efficacy ($\alpha = 0.85$), outcome expectancy ($\alpha = 0.87$), and actual household earthquake adjustments ($\alpha = 0.86$).

The variable 'person-relative-to-event' (PrE) conveyed the relationship between the *person* score and *event* score, expressed by the subtraction of scores. First, a summed composite *person* score was computed ($\alpha = 0.78$) with the variables 'self-efficacy' (four items) and 'outcome expectancy' (four items). Second, a summed composite *event* score was computed ($\alpha = 0.91$) with the variables 'probability of occurrence' (one item) and 'perceived threat severity' (four items). The scores had different number of items and metrics. Thus, to allow comparison, the scores were scaled using the proportion of maximum scoring (POMS) (Little 2013; Moeller 2015). This transformation allows metric convergence, maintaining the multivariate distribution, covariance, and the strength of the association between the variables (Little 2013; Moeller 2015). The *person* score ranged from 8 to 64. The first value (8) was subtracted from each observation, resulting in a scale ranging from 0 to 63. *Event* score ranged from 5 to 25. The first value (5) was subtracted from each observation, resulting in a scale ranging from 0 to 24. Subsequently, each score was divided by 24, resulting in a scale ranging from 0 to 1. Finally, each *event* score was multiplied by 63, resulting in a scale ranging from 0 to 63. After obtaining the same metrics (scores ranging from 0 to 63), the *event* score was subtracted from the *person* score, resulting in the variable 'person-relative-to-event' (PrE). PrE positive values reflect the condition of *person-greater-than-event*, whereas negative values reflect the condition of *person-less-than-event.* The higher the values, the greater the difference between *person* and *event* scores.

Assumptions verification

The dataset was screened for missing data, univariate and multivariate outliers, along with univariate Skewness and Kurtosis coefficients (Field 2009; Ullman 2013). Cases with missing data and univariate outliers were deleted (Field 2009; Ullman 2013). However, the exclusion of multivariate outliers meant a loss of variability in the variable 'responsibility attributions'. Thus, multivariate outliers were kept in the dataset (Tabachnick & Fidell 2013).

Univariate Skewness ranged from −4.47 to 0.62 (M = -0.70), and Kurtosis ranged from −1.36 to 18.00 (M = 1.71), indicating univariate non-normality ($SK > |2|$; $Ku > |7|$) (Fabrigar et al. 1999; Finney & DiStefano 2006). The independence of errors was confirmed by the Durbin-Watson statistic (1.774), which obtained a value close to two (Field 2009). The normality of errors was verified by the inspection of standardized residuals histogram and the Kolmogorov–Smirnov test ($D(822) = 0.024$, $p = 0.200$) (Field 2009; see Fig. 3). Linearity and homoscedasticity were verified in the plot of standardized residuals and standardized predicted residuals, which indicated random dispersion of points (Field 2009) (see Fig. 3).

Despite the fact that there were no severe violations to normality (Vogt 1999), the Maximum Likelihood estimation method was applied with the correction Satorra-Bentler scaled or adjusted chi-square and robust standard errors (MLM) (Finney & DiStefano 2006; Kline 2016; Ullman 2013).

Results

Sample composition and descriptive statistics

After removing missing data and univariate outliers, the sample consisted of 822 participants. From these, 258 (31.4%) were males and 564 (68.6%) were females. Furthermore, 233 (28.3%) did not had a university degree and 589 (71.7%) had a university degree. The participants were between 21 and 70 years old (M = 45.2, SD = 9.79). For the coping response, 36 participants (4.4%) did not recognize personal responsibility, and 786 (95.6%) did recognize personal responsibility. On average, the actual household adjustments score was 83.63 (SD = 12.10) and person-relative-to-event appraisal (PrE scaled score) was −3.64 (*person-less-than-event*) (SD = 11.30). Participants' *person* scores ranged from six to 55 (M = 29.33, SD = 9.78), and *event* scores ranged from 13.13 to 52.5 (M = 32.97, SD = 8.53).

Associations between the analyzed variables in model 1 and model 2

The Appendix includes the complete analysis of the associations of the variables included in Model 1 (Person-relative-to-Event) and Model 2 (alternative model). Table 5 summarizes the associations of the analyzed variables and actual household earthquake adjustments score**.**

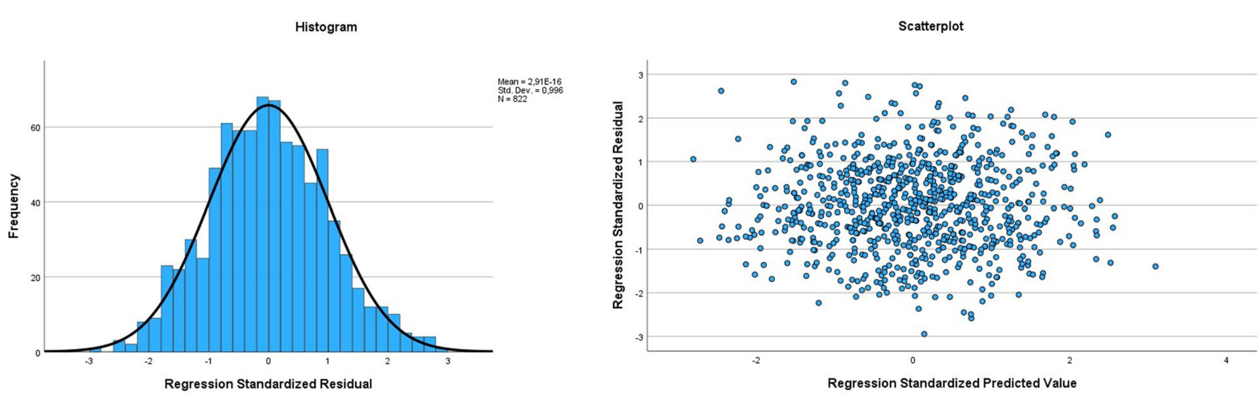

Fig. 3 Normality of Errors, Linearity, and Homoscedasticity (Dependent Variable: Actual Earthquake Adjustments Score)

Table 5 Results on the Association of Analyzed Variables with Actual Household Earthquake Adjustments Score

Variables	Statistical significance	Tests and results
Person score (scaled)	Significant	Pearson product-moment correlations $r = 0.36$, $p < 0.01$
Event score (scaled)	Significant	Pearson product-moment correlations $r = 0.01$, $p < 0.01$
PrE score (scaled)	Significant	Pearson product-moment correlations $r = 0.24$, $p < 0.01$
Responsibility attributions	Significant	Kruskal–Wallis H test ($H(1) = 13.11$, $p < 0.00$),
Age	Significant	Pearson product-moment correlations $r = 0.16$, $p < 0.01$
Gender	Non-significant	Kruskal–Wallis H test ($H(1) = 0.924$, $p = 0.34$)
Educational level	Significant	Kruskal–Wallis H test ($H(1) = 6.766$, $p = 0.009$) Mean rank Earthquake adjustment score of 425.04 for *With university degree* and 377.26 for *Without university degree*

Structural equation modeling of Person-relative-to-Event model (Model 1) and alternative model (Model 2)

Model 1: Person-relative-to-Event

The model applied was recursive (unidirectional causal effects), saturated, had 22 parameters and was considered identified (model degrees of freedom equal or superior to zero; Kline 2016; $df = 6$). Thus, the estimation of a unique numerical estimate was possible for the all the parameters in the model (Kline 2016).

An adequate fit of the hypothesized model was indicated by χ^2 (adjusted) = 7.692 (adjusted $p = 0.999$), CMIN/DF = 1.282, CFI (robust) = 0.999, TLI (robust) = 0.998, RMSEA (robust) = 0.019, 90% CI [0.000, 0.052], SRMR = 0.026 (see Table 6).

Attributions of self-responsibility for the coping response (responsibility attributions) ($\beta = 0.12$, $p = 0.00$), age ($\beta = 0.17$, $p = 0.00$), and educational level ($\beta = 0.07$, $p = 0.03$), presented a direct effect on actual household earthquake adjustments. Specifically, older individuals with a college education who recognize personal responsibility for the coping response tend to present higher household earthquake adjustments levels.

However, there was a non-significant effect of PrE appraisal (PrE score) ($\beta = 0.10$, $p = 0.47$), and gender ($\beta = 0.02$, $p = 0.46$) on actual household earthquake adjustments.

Moreover, the interaction between PrE appraisal and attributions of self-responsibility for the coping response

Table 6 Model 1- Person-relative-to-Event SEM: Unstandardized and Standardized Coefficients, Wald statistic, *p* value, and 95% Confidence Intervals

Variable	Unstandardized coefficients		Wald statistic (*z-value*)	*P* value P(>|z|)	*B* 95%CI [LL, UL]	Standardized coefficients		Wald statistic (*z-value*)	*P* value P(>|z|)	*β* 95%CI [LL, UL]
	B	SE *B*[§]				*β*	SE *β*[‡]			
PrE score (scaled)[†]	0.10	0.14	0.73	0.47	[−0.17, 0.38]	0.10	0.13	0.73	0.47	[−0.16, 0.35]
Responsibility attributions[†]	7.00	1.98	3.53	0.00	[3.11, 10.88]	0.12*	0.04	3.43	0.00	[0.05, 0.19]
Moderation effect[‡†]	0.18	0.14	1.21	0.23	[−0.11, 0.46]	0.16	0.13	1.22	0.22	[−0.10, 0.42]
Age[†]	0.21	0.04	5.39	0.00	[0.13, 0.29]	0.17*	0.03	5.39	0.00	[0.11, 0.23]
Gender[†]	0.64	0.86	0.74	0.46	[−1.05, 2.32]	0.02	0.03	0.74	0.46	[−0.04, 0.09]
Educational level[†]	1.89	0.85	2.22	0.03	[0.22, 3.56]	0.07*	0.03	2.22	0.03	[0.01, 0.13]

[†] Endogenous or dependent variable: Actual household adjustment score

[‡] PrE score (scaled) multiplied by Responsibility attributions

[§] (Robust)

CI = confidence interval; LL = lower limit; UL = upper limit

*Significant at $p < 0.05$.

was non-significant ($\beta = 0.16$, $p = 0.22$). This result indicates that attributing the responsibility to self for household earthquake adjustments is not a moderator on the relationship between PrE appraisal and actual household earthquake adjustments.

Model 2: alternative model

The previous findings led to the elaboration of an alternative model, assuming that *event* and *person* appraisals are two dependent sequential cognitive processes (*event* appraisal determining *person* appraisal). *Person* appraisal predicts actual household earthquake adjustments in a relationship moderated by attributions of self-responsibility for the coping response.

The hypothesized model was tested through a recursive (unidirectional causal effects) and saturated model with 23 parameters. The model was considered identified because the degrees of freedom were equal or superior to zero (Kline 2016; $df = 13$), allowing the estimation of a unique numerical estimate for all the parameters in the model (Kline 2016).

An adequate fit of the hypothesized model was indicated by χ^2 (adjusted) = 33.765 (adjusted $p = 0.001$), CMIN/DF = 2.60, CFI (robust) = 0.992, TLI (robust) = 0.984, RMSEA (robust) = 0.044, 90% CI [0.026, 0.062], SRMR = 0.039 (see Table 7).

There was a significant interaction between *person* appraisal (*person* score) and attributions of responsibility to self for the coping response (responsibility attributions) ($\beta = 0.41$, $p = 0.01$) on predicting actual household earthquake adjustments. In addition, *event* appraisal (*event* score) significantly predicted *person* appraisal (*person* score) ($\beta = 0.26$, $p = 0.00$).

There was a significant direct effect of age ($\beta = 0.18$, $p = 0.00$) and educational level ($\beta = 0.06$, $p = 0.04$) on actual household earthquake adjustments. Specifically, older individuals with a college education tend to present higher actual household earthquake adjustment levels.

The magnitude of the Wald statistic indicates that age had the highest impact on actual household earthquake adjustments adoption, followed by the interaction of *Person* appraisal (*person* score) and attributions of self-responsibility for the coping response (responsibility attributions). The educational level had the lowest impact.

Discussion

In this study, we investigated the main assumptions of the Person-relative-to-Event Model/Theory of Coping with Threat regarding actual household earthquake adjustments in the absence of fear appeals. Furthermore, we tested an alternative model we called the Sequential Person-relative-to-Event Model of Coping with Threat (SPrE).

The reasons that drive protective action for natural hazards are still not fully understood (MacPherson-Krutsky et al. 2023; Spittal et al. 2008) despite the diversity of models and theories on coping and decision-making in the natural hazards context (e.g., Glik et al. 2014; Greer et al. 2020; Grothmann & Reusswig 2006; Lachlan et al. 2021; Lindell & Perry 2000; Mulilis & Duval 2003; Noor et al. 2022; Paton 2003; Rostami-Moez et al. 2020; Salita et al. 2021; Weber et al. 2018; Wei et al. 2019; Wu et al.

Table 7 Model 2—Alternative Model SEM: Unstandardized and Standardized Coefficients, Wald statistic, p value, and 95% Confidence Intervals

Variable	Unstandardized coefficients		Wald statistic (*z-value*)	*P* value P(>|z|)	*B* 95%CI [LL, UL]	Standardized coefficients		Wald statistic (*z-value*)	*P* value P(>|z|)	*β* 95%CI [LL, UL]
	B	SE *B*¶				*β*	SE *β*¶			
Person score (scaled)†	0.03	0.17	0.15	0.88	[−0.31, 0.36]	0.02	0.14	0.15	0.88	[−0.25, 0.29]
Responsibility attributions†	−6.05	5.28	−1.15	0.25	[−16.40, 4.31]	−0.10	0.09	−1.14	0.25	[−0.28, 0.07]
Moderation effect†‡	0.44	0.18	2.51	0.01	[0.10, 0.79]	0.41*	0.16	2.51	0.01	[0.09, 0.73]
Age†	0.22	0.04	5.56	0.00	[0.14, 0.29]	0.18*	0.03	5.55	0.00	[0.11, 0.24]
Gender†	−0.07	0.83	−0.09	0.93	[−1.70, 1.55]	−0.00	0.03	−0.09	0.93	[−0.07, 0.06]
Educational level†	1.72	0.83	2.07	0.04	[0.09, 3.34]	0.06*	0.03	2.07	0.04	[0.00, 0.13]
Event score (scaled)§	0.23	0.03	7.83	0.00	[0.17, 0.29]	0.26*	0.03	8.03	0.00	[0.20, 0.33]

† Endogenous or dependent variable: Actual household adjustment score

‡ Person score (scaled) multiplied by Responsibility attributions

§ Endogenous or dependent variable: Person score (scaled)

¶ (Robust)

CI = confidence interval; LL = lower limit; UL = upper limit

*Significant at $p < 0.05$

2017). The variables included in these models and theories are similar, although they can have different operationalization (Corwin et al. 2017) and organization (Rogers 1983). Distinct mediational processes can also be considered (Rogers 1983). The attention researchers have devoted to models, theories, and assumptions in a given field is unequal. For example, the Person-relative-to-Event (PrE) Model/Theory has been understudied (Basolo et al. 2009; Lindell & Perry 2000; Duval & Mulilis 1999) for decades, with the exception of the study by Martel and Mueller (2011). Since the work of Mulilis and colleagues (Duval & Mulilis 1999; Mulilis 1999; Mulilis & Lippa 1990; Mulilis & Duval 1995, 1997, 1998, 2003; Mulilis et al. 2000), PrE has not been tested regarding household earthquake readiness, understood here as a result of the actual adoption of household earthquake adjustments (e.g., Lindell & Perry 2000; Wu et al. 2017). However, researchers often recognize its validity (e.g., Greer et al. 2020; Lindell & Perry 2000; Paton 2003; Paton et al. 2001, 2003; Wu et al. 2017).

The PrE is a value-expectancy model based on the original and revised Protection Motivation Theory (PMT; Maddux & Rogers 1983; Rogers 1975, 1983), Cognitive Appraisal Theory, and Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984). This model aims to explain processes that influence actual coping behavior, in this case, actual household earthquake adjustments. The variables included were those from the PMT. Their organization and combination were based on the Cognitive Appraisal Theory and Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984). The PrE considers three groups of variables: (a) related to the *person*, respecting personal resources to deal with the threat; (b) related to the *event*, that is, the threat characteristics or degree; (c) other variables, such as attributions of responsibility for the coping response. The model assumes that when facing the possibility of a threatening event, primary and secondary appraisals occur (Mulilis & Duval 1995, 1997, 2003). An initial appraisal of an event as threatening activates two secondary appraisal processes that are independent, parallel, and simultaneous (Mulilis & Duval 2003). One regards person-relative-to-event appraisal (Mulilis & Duval 1995, 1997) and the other regards the appraisal of personal responsibility for the coping response (Mulilis & Duval 2003), which moderates the relationship between person-relative-to-event and the coping response (Mulilis 1999; Mulilis & Duval 1995, 1997, 1998). Differing levels of the *person* and *event* variables in combination produce three conditions of person-relative-to-event: *person-greater-than-event* (P > E), *person-equal-to-event* (P = E), and *person-less-than-event* (P < E). The PrE model specifically predicts problem-focused coping in conditions P > E and P < E when personal responsibility for the coping response is recognized. When personal responsibility for the coping response is not recognized, the interaction between person-relative-to-event has no influence on problem-focused coping efforts (Mulilis, et al. 2000). Appraisals of resources (*person*) as sufficient in quality and quantity relative to the threat magnitude (*event*) would lead to greater problem-focused efforts. Conversely, appraisals of resources (*person*) as insufficient in quality and quantity relative to the threat magnitude (*event*) would lead to lower problem-focused efforts, avoidance, or non-problem-focused plans (Mulilis & Duval 1995, 1997, 2003).

Previous works using PrE also assessed the demographic variables included in the present study, namely age (Duval & Mulilis 1999; Mulilis 1999; Mulilis & Lippa 1990; Mulilis et al. 2000), gender (Duval & Mulilis 1999; Mulilis 1999; Mulilis & Duval 1995, 1997; Mulilis et al. 2000), and educational level (Duval & Mulilis 1999; Mulilis et al. 2000), which can be considered main demographic characteristics, justifying their inclusion in this study. The PrE was conceptualized and studied under the paradigm of negative threat or fear appeals, but similarly to PMT it can be applied and tested without fear appeals because of the focus on cognitive appraisal processes (Maddux & Rogers 1983; Rogers 1983).

Regarding the association between analyzed variables, the actual earthquake adjustments score was significantly associated with the *person* score, the *event* score, the PrE score, responsibility attributions, age, and educational level. The results regarding the *event* score, although significant, are small, indicating an extremely weak correlation with earthquake adjustments. Nevertheless, this result is congruent with the one by Lindell and Prater (2000) on risk perception, contradicting the results by Lindell and Whitney (2000) and Wu et al. (2017), who found a non-significant association. The results on *person* score align with those from Tang and Feng (2018) and Lamjiry and Gifford (2022), who found a significant correlation between self-efficacy and actual household earthquake preparedness, mitigation, or adjustments. The results regarding responsibility attributions indicate an association with actual household earthquake adjustments, as hypothesized by Lindell and Perry (2004). These results also agree with those found by Lindell and Whitney (2000) regarding personal responsibility, but contradict those by Wu et al. (2017) that found a non-significant association. It was found a significant positive association between age and earthquake adjustments, which is congruent with the results by Lindell and Perry (2000), Lindell and Whitney (2000), MacPherson-Krutsky et al. (2023), and Spittal et al. (2008). At the same time, these results are incongruent with those of Kirschenbaum et al. (2017), Oral et al. (2015), Ranjbar et al. (2018), Rüstemli and Karanci (1999), and Wu et al. (2017). The association between gender and earthquake adjustments was non-significant, as found by Duval and Mulilis (1999), Kirschenbaum et al. (2017), MacPherson-Krutsky et al. (2023), Mulilis and Duval (1995), Oral et al. (2015), Rüstemli and Karanci (1999), Spittal et al. (2008), and Wu et al. (2017). This result contradicts the findings of Lindell and Perry (2000), Lindell and Whitney (2000), Mulilis (1999), and Ranjbar et al. (2018). The association between educational level and earthquake adjustments was positive and significant, which conforms to the findings of Lindell and Perry (2000), Kirschenbaum et al. (2017), and Rostami-Moez et al. (2020), but contradicts the findings of MacPherson-Krutsky et al. (2023), Oral et al. (2015), Ranjbar et al. (2018), Rüstemli and Karanci (1999), Spittal et al. (2008), and Wu et al. (2017).

Structural Equation Modeling (SEM) was applied to test two models. Model 1 assessed the basic assumptions of the PrE model, specifically, the predictive effect of person-relative-to-event appraisal in the actual adoption of household earthquake adjustments. Furthermore, this model evaluated the moderating effect of responsibility attributions, including age, gender, and educational level as predictors of actual household earthquake adjustments. The model fit to the data adequately. Results indicated that PrE appraisal had a non-significant effect on actual household earthquake adjustments score, contradicting the main assumption of the PrE model. In addition, there was a non-significant interaction between PrE appraisal and responsibility attributions. This finding contradicted the assumption that recognizing personal responsibility for the coping response moderated the relationship between PrE appraisal and problem-focused coping, in this case, actual household earthquake adjustments. However, there was a significant direct effect of recognizing personal responsibility, age, and educational level on the actual adoption of earthquake adjustments. Regarding age, these results are in agreement with the results of Lindell and Prater (2000), and MacPherson-Krutsky et al. (2023). However, they contradict the results from Basolo et al. (2009), Han et al. (2017), Kirschenbaum et al. (2017), Oral et al. (2015), Ranjbar et al. (2018), Wu et al. (2018), and Kim et al. (2024) on participants with direct earthquake experience. Regarding educational level, these results conform to those of Kirschenbaum et al. (2017), Rostami-Moez et al. (2020), Wu et al. (2018). They differ from the results of Basolo et al. (2009), Han et al. (2017), Lindell and Prater (2000), and Oral et al. (2015). Overall, the main PrE assumptions were not validated. Nevertheless, the variables included (except for PrE appraisal) play a role in the decision to adopt household earthquake adjustments, which justified their inclusion in Model 2 (alternative model).

The PrE studies (Duval & Mulilis 1999; Mulilis & Duval 1995, 1997, 1998, 2003; Mulilis & Lippa 1990; Mulilis et al. 2000) never mention a subtraction or any other mathematical operation to express the relationship between *person* and *event* variables, which configures person-relative-to-event. However, assuming person-relative-to-event appraisal as a single cognitive process, we believe that our operationalization of this variable (subtracting *event* score from *person* score, with positive values indicating $P > E$, and negative values indicating $P < E$) fully captures the conceptualization advanced by the authors of the model. This conceptualization states that *person-higher-than-event* ($P > E$) refers to appraisals of resources (*person*) as sufficient in quality and quantity relative to the magnitude of threat (*event*), and *person-less-than-event* ($P < E$) refers to appraisals of resources (*person*) as insufficient in quality and quantity relative to the magnitude of threat (*event*).

Based on the results of Model 1 (Person-relative-to-Event), we tested Model 2 (alternative model), which includes the same variables as Model 1 except for PrE score. The alternative model, which we named the Sequential Person-relative-to-Event Model of Coping with Threat (SPrE), fit adequately with the data. Results indicated that *event* appraisal (*event* score) significantly predicted *person* appraisal (*person* score), and *person* appraisal significantly interacted with responsibility attributions on predicting actual household earthquake adjustments. In addition, age and educational level predicted actual household earthquake adjustments.

These results indicated that when faced with the possibility of a threatening event, the individual engages in a primary and two secondary appraisals. An initial appraisal regards the level of threat of the event (*event*), including the assessment of its likelihood and the severity of its consequences (Mulilis & Duval 1995, 1997). This primary appraisal activates two secondary appraisal processes (Mulilis & Duval 2003), that are independent, parallel, and simultaneous (Mulilis & Duval 2003). The first regards the appraisal of personal resources to face and deal with the threat. This appraisal involves assessing the personal ability to perform the coping behavior and its efficacy to reduce or avoid personal physical damage (*person*), which is determined by the *event* appraisal. Thus, *event* and *person* appraisal occur *sequentially*, as proposed in the Cognitive Appraisal Theory and the Transactional Model of Stress and Coping regarding primary and secondary appraisals (Lazarus 1966; Lazarus & Folkman 1984), with *event* appraisal predicting *person* appraisal. Therefore, this model assumes that these are two dependent sequential cognitive processes. Alongside the *person* appraisal, the assessment of responsibilities occurs, in which the individuals consider whether the responsibility of protection lies with them or others (Mulilis & Duval 2003). This responsibility appraisal moderates the relationship between *person* appraisal and the actual adoption of earthquake adjustments. Problem-focused behavior will occur when personal responsibility for the coping behavior is recognized and assumed. Conversely, when this responsibility is attributed to others, the behavior would not occur regardless of the perceived sufficiency of resources to reduce or avoid the danger. Nevertheless, alternative models testing different causal hypotheses are possible (Kline 2016).

The Sequential Person-relative-to-Event Model of Coping with Threat (SPrE) resembles PrE because it assumes a relationship between *person*, *event*, and appraisals of responsibility for the coping response (independent moderator process) capable of explaining the actual adoption of earthquake adjustments (Mulilis & Duval 1995, 1997, 2003). Differing from the PrE, the combinatory rule between *person* and *event*, expressed by person-relative-to-event, is not assumed. The Sequential Person-relative-to-Event Model of Coping with Threat (SPrE) differs from the Cognitive Appraisal Theory and the Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984) by adding responsibility attributions. Our model also diverges from the PMT by suppressing the combinatory rule between *person* and *event* appraisals.

The results of this study have implications for the literature and practice, contributing to: the production of scientific cumulative knowledge, understanding of the cognitive processes and predictors of actual household earthquake readiness or adjustments, development of risk policies and communication programs, and identification of population segments that require reinforced risk communication efforts (Li et al. 2023; Lindell & Perry 2004).

Limitations

We recognize that there are some limitations to this study.

The sample used in this study was self-selected, limiting the generalization of the results to the larger population. However, we consider this sample appropriate for this study because the focus was on testing a model focused on cognitive processes that are universal.

Data on household earthquake adjustments was self-reported. Thus, participants may have recalled the presence of earthquake adjustments, which could introduce bias in the assessment of adjustments. Nevertheless, the results represent an approximation to reality.

This study followed a non-experimental research design. Thus, causation cannot be inferred (Kline 2016). However, the results suggest that the analyzed variables influence actual household earthquake adjustments and the SPrE model plausibly explains earthquake adjustment adoption.

Future research

There are still gaps in the existing knowledge regarding the assumptions, theories, and models used to explain the actual adoption of natural hazard adjustments. We believe that this field of research would gain more solidity if there were a stronger focus on confirming, improving, or refuting existing assumptions, theories, and models, rather than creating or applying new ones. Consistency in the measurement of variables may also contribute to this end.

Future replication studies using different representative samples from other locations or cultures must be conducted to test the validity of the hypothesized causal relations (Kline 2016) and the applicability of the SPrE model to other contexts and populations. Studies with experimental research design are also required. If one assumes that the *event* appraisal included in the PrE is equivalent to risk perception, then the SPrE model assumes that the *person* appraisal (self-efficacy and outcome expectancy) mediates the relationship between risk perception and actual household earthquake adjustments, which is moderated by responsibility attributions. This hypothesis should be tested further.

The assessment of actual household adjustments for earthquakes and other natural risks using methods other than self-reporting is worth further study.

Moreover, studies testing alternative causal hypotheses to those presented here can be conducted.

Given that the PrE model allows the inclusion of other variables in *event* and *person* appraisals, this can also be tested. Furthermore, other demographic variables can be included.

The strategy to disseminate the study link among public, private, community, and professional organizations, groups, associations, and institutions, along with the timing of data collection (during a period of seismic activity above regular levels), produced a response rate of 73%. Future studies can apply the same strategy or collect data during a similar period.

Conclusions

A complete understanding of the reasons that drive protective action for natural hazards, specifically earthquakes, is still to be achieved. The Person-relative-to-Event Model/Theory of Coping with Threat is a known model that gathers elements from the original and revised Protection Motivation Theory (PMT; Maddux & Rogers 1983; Rogers 1975, Rogers 1983), Cognitive Appraisal Theory, and Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984). However, it is understudied. This study sought to test the main assumptions of the PrE model by applying a non-experimental research design, identifying predictors of the actual adoption of household earthquake adjustments, and proposing an alternative model with a different causal hypothesis. The results indicated an association between actual household earthquake adjustments and *person* appraisal, *event* appraisal, person-relative-to-event appraisal, attributions of responsibility regarding the coping response, age, and educational level. There was a non-significant association between actual household earthquake adjustments and gender. Moreover, results indicated that person-relative-to-event appraisal is a non-significant predictor of actual household earthquake adjustments and that the recognition of personal responsibility does not moderate this relationship. Instead, we found evidence that *event* appraisal predicts *person* appraisal, whose relationship with actual household earthquake adjustments is moderated by the recognition of personal responsibility. The Cognitive Appraisal Theory and Transactional Model of Stress and Coping (Lazarus 1966; Lazarus & Folkman 1984) inspired this variable organization. In this model, the relationship between risk perception (equivalent to *event* appraisal) and actual household earthquake adjustments is mediated by *person* appraisal (self-efficacy and outcome expectancy) and moderated by responsibility attributions to self. We called this model the Sequential Person-relative-to-Event Model of Coping with Threat (SPrE).

Appendix

Associations between the Analyzed Variables in Model 1 and Model 2: complete analysis

To assess the associations between the analyzed variables in Model 1 and Model 2, three tests were conducted using SPSS 29.0 (SPSS Inc., Chicago, IL, USA). These tests included: Pearson product-moment correlations to examine associations between continuous variables; Pearson's chi-square test to examine associations between categorical variables; Kruskal–Wallis H test to examine associations between categorical and continuous variables.

Table 8 presents the Pearson product-moment correlations for the continuous variables analyzed in Model 1 and Model 2.

There was a significant and positive correlation between earthquake adjustment score, *person* score, *event* score, person-relative-to-event score, attributions of responsibility for the coping response, and age. All variables were significantly correlated with each other, except for the non-significant correlation between age, *person* score, and *event* score. There was a significant and negative association between person-relative-to-event score, *event* score, and age.

Table 8 Pearson Product-moment Correlations Conducted with the Continuous Variables Analyzed in Model 1 and Model 2 (N = 822)

Variable	1	2	3	4	5
1. Earthquake adjustment score	–				
2. *Person* score (scaled)	0.36**	–			
3. *Event* score (scaled)	0.01**	0.24**	–		
4. PrE score (scaled)	0.24**	0.68**	−0.54**	–	
5. Age	0.16**	−0.06	0.04	−0.87*	–

**$p < 0.01$

*$p < 0.05$

A Kruskal–Wallis H test was conducted to assess analyze associations between the categorical variables responsibility attributions (1. *Do not recognize personal responsibility*; 2. *Recognize personal responsibility*), educational level (1. *Without university degree*; 2. *With university degree*) and gender (*male*, *female*, *other*), and the continuous variables analyzed.

Regarding responsibility attributions, a Kruskal–Wallis H test indicated that there was no significant variations in PrE scores ($H(1) = 0.156$, $p = 0.693$) and age ($H(1) = 2.34$, $p = 0.126$) across the two levels of responsibility attributions. However, there was a statistically significant difference in earthquake adjustment score ($H(1) = 13.11$, $p < 0.00$), *person* score ($H(1) = 10.05$, $p = 0.002$) and *event* score ($H(1) = 9.05$, $p = 0.003$) across the two levels of responsibility attributions (see Table 9).

Regarding educational level, a Kruskal–Wallis H test indicated that there was no significant variations in *person* score ($H(1) = 1.37$, $p = 0.24$), *event* score ($H(1) = 0.258$, $p = 0.61$), PrE score ($H(1) = 1.19$, $p = 0.28$), and age ($H(1) = 0.583$, $p = 0.45$) across the two levels of educational level. However, there was a statistically significant difference in earthquake adjustment score ($H(1) = 6.766$, $p = 0.009$) across the two educational levels, with a mean rank earthquake adjustment score of 425.04 for *With university degree* and 377.26 for *Without university degree*.

Regarding gender, a Kruskal–Wallis H test indicated that there was no significant variations in earthquake adjustment score ($H(1) = 0.924$, $p = 0.34$), *event* score ($H(1) = 0.684$, $p = 0.41$), and age ($H(1) = 0.327$, $p = 0.57$) across the two levels of gender (*male*, *female*). However,

Table 9 Kruskall-Wallis H Test with Responsibility Attributions and the Continuous Variables Analyzed in Model 1 and Model 2 (N = 822)

Continuous variable	Attributions of responsibility for the coping response	
	Do not recognize personal responsibility (*n* = 36)	Recognize personal responsibility (*n* = 786)
	Mean Rank	Mean Rank
Earthquake adjustment score	271.44	417.91
Person score (scaled)	288.90	417.12
Event score (scaled)	297.14	416.74

there was a statistically significant difference in *person* score ($H(1) = 17.11$, $p < 0.00$) and PrE score ($H(1) = 5.87$, $p = 0.02$) across the two levels of gender, with a mean rank *person* score of 462.12 for *male* and 388.34 for *female;* and a mean rank PrE score of 441.17 for *male* and 397.93 for *female.*

Pearson's chi-square test was conducted to analyze associations between responsibility attributions, gender and educational level. There was no significant association between responsibility attributions, gender (χ^2 (1, $N = 822) = 0.07$, $p = 0.80$), and educational level (χ^2 (1, $N = 822) = 0.21$, $p = 0.65$). Moreover, there was no significant association between educational level and gender (χ^2 (1, $N = 822) = 0.27$, $p = 0.60$).

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Author contributions
SMP was responsible for Conceptualization, Data curation, Methodology, Formal analysis; Validation, Investigation, Visualization, and Writing—original draft; IER contributed to Conceptualization and performed Supervision and Writing—review & editing; LSMM contributed to Methodology and performed Supervision, and Writing—review & editing. All authors have contributed substantially to this study, read and approved the final manuscript.

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Availability of data and materials
The data used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Competing interests
The authors declare no competing interests.

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