The Influence of Knowledge, Trust, and Perceived Risk on Firefighters’ Preparedness and Willingness to Respond to Nuclear Emergencies: The Case of South Korea

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1 Introduction

Although governmental and industrial authorities have attempted to reassure the public that nuclear power plants (NPPs) are safe, nuclear accidents continue to occur due to human error (for example, the 1979 Three Mile Island accident in the United States, and the 1989 Chernobyl disaster in the Ukraine), or due to natural hazards (for example, the 2011 Fukushima nuclear disaster in Japan) (IAEA 2014). Because nuclear accidents have the potential to result in cascading disasters, rapid responses are particularly important to reduce the impacts of these accidents. The faster emergency personnel respond to hazardous situations, the less likely losses are to occur. In the case of the Fukushima nuclear disaster, delayed responses exacerbated the situation and aggravated the damage (Funabashi and Kitazawa 2012). When a nuclear emergency occurs, firefighters are the first to arrive at the scene of the accident and assume responsibility for suppressing fires and rescuing workers from leaked radiation. During a nuclear emergency, these firefighters, in collaboration with the nuclear power plant authorities, play crucial roles in mitigating the loss of lives and property (Kelly 1995; Ford and Schmidt 2000; Tierney et al. 2001). Hence, we expect that firefighters’ timely response to a nuclear emergency can prevent or minimize the catastrophic impacts of a nuclear accident. Preparedness and willingness to respond are key to firefighters’ emergency responses to nuclear events.
Despite the importance of firefighters’ roles in the case of nuclear emergencies, little is known about the factors that influence their nuclear emergency responses, in particular, their preparedness and willingness to respond. Recent studies have mainly focused on health workers’ preparedness and willingness to respond to disasters (Ogedegbe et al. 2011; Al-Hunaishi et al. 2019; Zewudie et al. 2021). However, some studies have revealed that preparedness and willingness to respond to emergencies are different from the ability to respond to such emergencies (Dimaggio et al. 2005; Qureshi et al. 2005). Research on medical emergency responses to an influenza pandemic also suggest that preparedness and willingness to respond to emergencies among emergency personnel could be influenced by perceived risk, but not actual risk (Balicer et al. 2006; Barnett et al. 2009). These findings suggest that psychological factors such as risk perception, along with skills and experience, could determine firefighters’ preparedness and willingness to respond to nuclear emergencies.

In this study, we examined the factors that influence firefighters’ emergency responses with respect to their preparedness and willingness to respond to nuclear events. We explored whether and how firefighters’ knowledge regarding nuclear accidents and trust in the authorities operating nuclear power plants where the firefighters were located related to their risk perceptions of nuclear accidents and predicted their preparedness and willingness to respond to nuclear emergencies. We recruited Korean firefighters posted near NPPs who are responsible for suppressing fires and rescuing workers from leaked radiation. We assessed their levels of knowledge, trust, risk perception, and preparedness and willingness to respond through self-reported survey questionnaires.

The remaining parts of the introductory section provide an overview of risk perception regarding nuclear events, a brief review of the literature to identify potential psychological factors that affect firefighters’ preparedness and willingness to respond to nuclear emergencies, and an outline of our research hypotheses. Section 2 explains the methods and data of the study, and Sect. 3 presents the results. Finally, we discuss the results along with the implications and limitations of the study, and provide suggestions for future research.

1.1 Knowledge, Trust, and Risk Perception Regarding Nuclear Events

Risk perception is defined as the cognitive ability to discern the risk inherent in emergencies (Hunter 2002), and is considered as a factor that contributes to emergency responses. Risk perception is vital to firefighters’ performance and safety in emergencies (Slovic 1987; Nahrgang et al. 2011). Accurate perceptions of the risk in emergencies enable firefighters to take quick and safe actions in dangerous situations, while the misperception of risk can create catastrophic consequences for both victims and firefighters. Underestimating the risk can result in reckless responses to emergencies, whereas overestimating the risk can result in sluggish responses.

Firefighters have more accurate risk perceptions of fire events than laypeople (Hahm et al. 2016). As experts in fire-related emergencies, they are likely to assess the degree of risk regarding fire events on the basis of objective and quantitative measures rather than subjective judgments, on which laypeople mainly rely (Slovic et al. 1980; Barke and Jenkins-Smith 1993; Flynn et al. 1994; Holgate and Clancy 2009; Tancogne-Dejean and Laclémence 2016). In the case of nuclear emergencies, however, firefighters may not perceive risks differently from laypeople. Firefighters situated near NPPs (even veterans with a great deal of experience in firefighting) are not likely to have experienced nuclear accidents. Thus, they are unlikely to have extensive professional skills and knowledge about nuclear emergencies, even though they are given training and education for nuclear events. Therefore, the risk perception of nuclear emergencies among firefighters may be determined by intuitive and subjective judgments rather than technical truths or statistics (Slovic 1987; Sjöberg 2000; Melo et al. 2020).

Recent research has shown that firefighters situated near NPPs perceive nuclear events just as highly risky as laypeople do, and are likely to consider nuclear events as involuntary, uncontrollable, and potentially catastrophic threats (Choi et al. 2018). Such high risk perceptions of nuclear accidents among firefighters can be attributed to a lack of knowledge to respond to nuclear accidents. This limited knowledge might lead them to consider nuclear accidents as a dreaded risk. They may perceive nuclear events as more risky than nuclear experts, as proposed by the psychometric paradigm (Fischhoff et al. 1978; Slovic et al. 1984; Slovic 1987; Siegrist and Árvai 2020). Sjöberg and Drottz-Sjöberg (1991) revealed that nuclear power plant employees who know less about radiation perceive greater risk, supporting the notion that knowledge is a critical factor that influences risk perception of nuclear events (Katsuya 2001; Kashiwazaki et al. 2022). In this regard, we reasoned that the more firefighters know about nuclear accidents, the less risky they will perceive nuclear events.

Along with knowledge, the level of trust in nuclear power plant authorities may contribute to risk perceptions of nuclear events among firefighters situated near NPPs. With respect to complex technologies, such as nuclear energy, it is difficult for laypeople to possess sufficient knowledge about their intricacies. As a result, risk perception concerning such technologies may be influenced by social trust (Earle and Cvetkovich 1995; Siegrist 2021). As laypeople develop more trust in experts or authorities in these technologies, they are
more likely to perceive fewer risks (Siegrist 1999, 2000). With regard to nuclear technologies, social trust has been closely related to risk perception (Pijawka and Mushkatel 1991; Dunlap et al. 1993; Ryu et al. 2018; Seidl et al. 2022). Biel and Dahlstrand (1995) found that trust in experts and authorities was strongly and negatively related to perceived risk; specifically, the correlation coefficient between trust and risk perception regarding a high-level nuclear waste repository amounted to −0.63. Given that firefighters situated near NPPs have no expertise in nuclear technology, their trust in the authorities responsible for nuclear power plant operation would be closely related to their risk perception, just as it would be for laypeople. Furthermore, in the context of nuclear events, firefighters may need to collaborate with the nuclear power plant authorities and receive technical aid from them when responding to such emergencies. Thus, trust in nuclear power plant authorities may serve as an important determinant of firefighters’ risk perception.

Trust in experts and authorities can lower the perceived risks experienced by people who do not possess sufficient knowledge of or experience in nuclear accidents (Siegrist and Cvetkovich 2000). The function of trust is to reduce the complexity that people are confronted with (Luhmann 1989; Earle and Cvetkovich 1995). People who trust experts and authorities may rely mainly on experts’ guidance in assessing the risks. As a result, they can perceive the risk of nuclear accidents as accurately as experts do, without having professional knowledge of nuclear events. In this regard, we reasoned that trust may qualify the relationship between knowledge and firefighters’ risk perception of nuclear events. Trust in nuclear power plant authorities may weaken the influence of knowledge on risk perception among firefighters.

1.2 Risk Perception and Preparedness and Willingness to Respond to Nuclear Emergencies

Nuclear power plant accidents, similar to other crises, involve unique and unforeseen elements (Pearson and Clair 1998; Goetsch 2005). Thus, emergency response protocols and procedures cannot completely address the unpredictability and novelty of nuclear accidents (LePine 2005; Yu et al. 2008). Furthermore, even veteran emergency personnel often have not experienced nuclear events themselves, and they have not been able to learn how to respond from experience. Hence, firefighters situated near NPPs can hardly be expected to be thoroughly prepared in terms of what to do during a nuclear emergency, and they can hardly be expected to respond willingly or without reservations (Barnett et al. 2006; Balicer et al. 2011; Ogedegbe et al. 2012; Sheikh et al. 2012).

Given that firefighters are compelled to confront uncertain hazards during nuclear events, their preparedness and willingness to respond may be influenced by how they perceive the risk of nuclear events. Several streams of research provide support for this. The literature on the extended parallel process model (Witte 1992, 1994), which is useful for understanding adaptive behavior in the face of unknown risks, suggests that threat perception may cause feelings of fear, which in turn could lead individuals to control their fear rather than the present danger. More recent research focusing on medical service workers has shown that the perception of threat can result in their unwillingness to respond to emergencies (Barnett et al. 2006; Barnett et al. 2009). Terrorism studies have shown that perceived dread and unknown risks (which characterize the risks of nuclear events) could generate fear, which could lead people to avoid action when confronted with the risk (Somer et al. 2005; Sheppard 2011; Malik et al. 2018). The job demands-resource model (Baker and Demerouti 2007) proposed that job demands, such as risk perception, may be detrimental to a variety of organizational outcomes. Previous studies focusing on nuclear power plant workers revealed that a greater perception of risk could lead not only to poorer safety behaviors (Rao et al. 2017), but also to lower organizational commitment (Kivimäki and Kalimo 1993).

These streams of research together suggest that firefighters situated near NPPs who perceive greater risk regarding nuclear events, compared to those who perceive lower risk, would feel less prepared and be less willing to respond to nuclear events.

1.3 Hypotheses

Our research aimed to shed light on the preconditions of the preparedness and willingness to respond to nuclear emergencies among firefighters situated near NPPs by exploring the relationship between cognitive and psychological factors (that is, knowledge about nuclear accidents, trust in the authorities operating nuclear power plants, and the perceived risk regarding nuclear events), and preparedness and willingness to respond. By integrating the literature from disparate lines of research and theorizing, we proposed five research hypotheses:

Hypothesis 1: The lack of knowledge about nuclear accidents is negatively related to firefighters’ risk perceptions of nuclear events.

Hypothesis 2: Trust in nuclear power plant authorities is positively related to firefighters’ risk perception of nuclear events.

Hypothesis 3: Trust in nuclear power plant authorities will moderate the relationship between knowledge and firefighters’ risk perception of nuclear events. This relationship will be weaker for firefighters who trust the authorities than for firefighters who do not trust the authorities.
Hypothesis 4: Increased risk perception of nuclear events is negatively related to firefighters’ preparedness and willingness to respond to nuclear emergencies.

Considering Hypotheses 1–4 together, we also posit that risk perception mediates the relationship between knowledge and preparedness and willingness to respond; the mediation effect may be moderated by trust of the nuclear power plant authorities.

Hypothesis 5a: Perceived risk of nuclear events mediates the relationship between knowledge and firefighters’ preparedness and willingness to respond to nuclear emergencies.

Hypothesis 5b: Trust moderates the mediated relationship between knowledge and preparedness and willingness to respond; perceived risk mediates the indirect effect of knowledge on preparedness and willingness to respond when firefighters’ trust is low, but not when it is high.

2 Method

To test our hypotheses, we recruited in-service Korean firefighters working in NPPs and asked them to complete surveys to assess their knowledge of nuclear power, trust in NPP authorities, perceived risk of nuclear events, and preparedness and willingness to respond to nuclear emergencies.

2.1 Participants and Procedure

The data were collected from Korean firefighters currently working near nuclear power plants through self-reported survey questionnaires. With the respective consent of the stations, we recruited the participants from five fire stations located near three nuclear power plant sites in three provinces—Hanbit nuclear power site in Jeollanam-do, Wolsong nuclear power site in Gyeongsangbuk-do, and Kori nuclear power site in Busan Metropolitan City. The firefighters at these fire stations serve as first responders to nuclear emergencies when nuclear events happen in the nuclear power plants under their jurisdiction. One author and a research assistant visited each fire station and administered the paper-pencil survey. All firefighters on duty were requested to voluntarily participate in our study. While on duty, the participants were given the questionnaire and asked to answer it individually. All data collection was undertaken from June to July 2018.

Out of 201 firefighters, 179 provided completed surveys. The response rate was 89.05%. Missing data from 22 incomplete surveys in which the participants did not complete the items for our variables of interest were removed from further analysis. The majority of the respondents were male (96%), and 75% were married. The average age was 41 years old ($SD = 9.68$)—16% were between the ages of 20 and 30; 30% between the ages of 30 and 40; 30% between the ages of 40 and 50; and 24% were 50 years of age or older. The average tenure of service was 13.14 years ($SD = 9.45$).

2.2 Measures

The participants completed four questionnaires regarding knowledge about nuclear power, social trust in nuclear power plant authorities, perceived risk of nuclear events, and preparedness and willingness to respond to nuclear emergencies.

2.2.1 Knowledge

On the basis of the scale items from previous research regarding self-reported knowledge about nuclear power (Huang et al. 2013) and face-to-face interviews with firefighters working near NPPs (Choi et al. 2018), four statements were developed to assess firefighters’ knowledge of how to respond to nuclear accidents:

- I have the professional skill and experience to suppress fires in nuclear power plants;
- I fully understand the risk of radiation;
- I know how to respond to the leakage of radiation; and
- I have enough basic knowledge about nuclear power to respond to nuclear emergencies.

The coefficient alpha was 0.82. Participants were asked to respond to all measures from 1 (strongly disagree) to 7 (strongly agree).

2.2.2 Trust

We modified previous scale items regarding social trust in authorities operating and managing nuclear power plants (Huang et al. 2013) to fit our context, whereby firefighters need to collaborate with the authorities for emergency responses in the context of nuclear events. The four statements to assess firefighters’ trust in nuclear authorities were:

- I believe that nuclear power plant authorities provide firefighters with correct information regarding nuclear emergencies;
- I have trust in nuclear power plant authorities while collaborating with them to respond to nuclear emergencies;
- I believe firefighters can effectively collaborate with nuclear power plant authorities to respond to nuclear emergencies; and
- I have confidence in the directions offered by nuclear power plant authorities in the context of nuclear events.”

The coefficient alpha was 0.87.
2.2.3 Risk Perception

Three scales items from previous literature (Huang et al. 2013; Huang et al. 2018; Tantitaechochart et al. 2020) were used in the questionnaire to assess risk perception regarding nuclear events, with minor modifications to adapt them to the working context of firefighters:

- I’m worried that an accident, accompanied by environmental pollution, property loss, or health damage may occur in Korean nuclear power plants in the future;
- If a nuclear power accident happened in my working area, the danger would be catastrophic and dreadful; and
- I feel afraid to work near nuclear power plants.

The coefficient alpha was 0.82.

2.2.4 Preparedness and Willingness

On the basis of previous literature in the fields of emergency preparedness (Syrett et al. 2007; Dallas et al. 2017) and willingness to respond to emergencies (Veenema et al. 2008; Balicer et al. 2011), we developed three statements to assess firefighters’ preparedness and willingness to respond to nuclear emergencies:

- I can do my emergency work flexibly and efficiently, according to necessity in the context of a nuclear event;
- I can willingly take on additional roles during a nuclear emergency; and
- I will take the initiative in responding to nuclear emergencies.

The coefficient alpha was 0.78

2.3 Statistical Analysis

We used the IBM SPSS version 24 (IBM Corp 2016), along with Hayes’ process macro in SPSS (Hayes 2013) to conduct a series of data analyses, including common variance bias detection, descriptive statistics, multiple hierarchical regression models, moderation analyses, simple analyses, and mediated moderation analyses. In addition, confirmatory factor analysis (CFA) was performed with the R package lavaan (Rosseel 2012).

3 Results

We first examined the validation of our scales by conducting a series of confirmatory factor analyses. Next, we performed moderation, mediation, and moderated mediation analyses to test our hypotheses.

3.1 Confirmatory Factor Analysis Results

To confirm and validate the factor structure of the scales, we conducted confirmatory factor analysis (CFA). First, we examined a four-factor CFA model that included knowledge, trust, risk perception, and preparedness and willingness. The four-factor model provided acceptable model fitness:

- $\chi^2/df = 2.375$; Comparative Fit Index (CFI) = 0.923; Tucker-Lewis Index (TLI) = 0.902; Root Mean Square Error of Approximation (RMSEA) = 0.088; Standardized Root Mean Residual (SRMR) = 0.068 (Browne and Cudeck 1992; Hu and Bentler 1999; Schumacker and Lomax 2004; Sharma et al. 2005). The standardized factor loadings of each item ranged from 0.45 to 0.90 and were all significant at $p < 0.001$ levels, indicating structural validity.

Next, we compared the four-factor model with three alternative models:

(1) a three-factor model with knowledge and trust combined into a single factor ($\chi^2/df = 5.516; CFI = 0.737; TLI = 0.677; RMSEA = 0.159; SRMR = 0.104$);
(2) a two-factor model with knowledge, trust, and risk perception combined into a single factor ($\chi^2/df = 7.596; CFI = 0.606; TLI = 0.528; RMSEA = 0.192; SRMR = 0.128$); and
(3) a one-factor model in which all items were combined to create a common factor ($\chi^2/df = 8.615; CFI = 0.539; TLI = 0.456; RMSEA = 0.206; SRMR = 0.133$).

For the model comparisons, the chi-square difference tests were significant (all $p < 0.001$), supporting the notion that the four-factor model fit our data better than any other alternative model.

We also calculated the Construct Reliability (CR) and Average Value Extracted (AVE) indicators to assess the models’ convergent and discriminant validity in CFA (Fornell and Larcker 1981). The results show that the CR and AVE for all constructs were greater than 0.78 and 0.58, respectively. This provides evidence of the convergent validity of our measures. Furthermore, we computed the square roots of AVE for all latent variables and compared these values to correlations with other latent variables. All square roots of AVE were higher than the corresponding correlations, which supports the notion that our latent variables are distinct.
3.2 Common Variance Bias Detection

Given that all of the data were collected by self-report measures at the same time, the issue of common variance related to the method may overestimate the relation between the variables (Podsakoff et al. 2003; Podsakoff et al. 2012). To address potential concerns of such common variance bias, we conducted several post-hoc tests. We first carried out Harman’s one-factor test and found that one factor did not explain most of the variance (33.78%), confirming the notion that the correlational findings in the study would not simply reflect common method variance (Podsakoff et al. 2003). In addition, we performed a collinearity test to generate the variance inflation factor (VIF), which informs the presence of common method variance in the data (Kock and Lynn 2012; Kock 2015). The results revealed that all VIF values (1.16−1.48) were lower than 3.3, which is the cutoff value for the presence of common method variance, as suggested by Moqbel and Kock (2018). Taken together, this means that common variance bias is not a critical issue in the data of the current study.

3.3 Descriptive Statistics

Correlational analyses revealed that knowledge and trust were negatively associated with risk perception, while they had a positive relationship with preparedness and willingness. Risk perception and preparedness and willingness were negatively related to each other. Table 1 shows the descriptive statistics and Pearson correlational coefficients.

3.4 Moderation Analyses

We conducted hierarchical multiple regression to examine the main effects of knowledge and trust and their interaction effect on risk perception. Demographic variables such as job tenure and gender (1 = male, 2 = female) were entered in the first step. Knowledge and trust were entered in the second step, and the interaction term (that is, knowledge × trust) was entered in the third step. All variables included in the interaction terms were converted to mean deviation scores (Aiken and West 1991).

Table 2 shows that neither job tenure (β = 0.07, \( p = 0.327 \)) nor gender (β = 0.05, \( p = 0.535 \)) were significantly predictive of risk perception in the first step (\( R^2 = 0.01, \ p = 0.519 \)). Knowledge (β = −0.19, \( p = 0.024 \)) and trust (β = −0.17, \( p = 0.041 \)) in the second step (\( \Delta R^2 = 0.09, \ p < 0.001 \)) were significantly associated with risk perception (supporting Hypotheses 1 and 2).

Firefighters with deep knowledge about nuclear events and radiation exposure reported lower levels of risk perception in nuclear emergencies. Similarly, those who expressed greater trust in authorities managing nuclear power plants reported perceptions of lower risk of nuclear power plants. Most importantly, the interaction terms between knowledge and trust were significant, suggesting that the effect of knowledge on risk perception is moderated by trust.

### Table 1: Means, standard deviations, and Pearson correlations of the study variables related to firefighters located near nuclear facilities in South Korea

| Variables                        | M    | SD   | 1    | 2    | 3    | 4    | 5    | 6    |
|----------------------------------|------|------|------|------|------|------|------|------|
| 1. Gender                        | 1.04 | 0.21 | -    | -    | -    | -    | -    | -    |
| 2. Tenure of service (months)    | 160.93 | 114.07 | −0.03 | -    | -    | -    | -    | -    |
| 3. Knowledge                     | 3.87 | 1.23 | −0.10 | 0.17* | (0.82) | -    | -    | -    |
| 4. Trust                         | 3.90 | 1.27 | −0.09 | −0.05 | 0.44*** | (0.87) | -    | -    |
| 5. Risk perception               | 5.91 | 1.04 | 0.04  | 0.07  | −0.25** | −0.26** | (0.82) | -    |
| 6. Preparedness and willingness  | 3.59 | 1.29 | −0.19* | 0.01  | 0.46*** | 0.48*** | −0.25** | (0.78) |

\( N = 179 \). Gender (1 = male; 2 = female) is a dummy variable. Alpha reliabilities are shown on the diagonal in parentheses. Scores of knowledge, trust, risk perception, and preparedness and willingness are calculated by simple averaging. \( *p < 0.05; **p < 0.01; ***p < 0.001 \).
and trust accounted for additional variance in the third step ($\Delta R^2 = 0.02, p = 0.032$). The relationship between knowledge and risk perception was significantly qualified by trust ($\beta = 0.16, p = 0.032$) (supporting Hypothesis 3).

To explore the moderation effect, further simple slope analyses were performed (Fig. 1). As predicted, the significantly negative relationship between knowledge and risk perception was observed for participants who did not trust authorities (at 1 SD below the mean) ($\beta = -0.29, p = 0.002$). There was no significant relationship between knowledge and risk perception for participants who strongly trusted nuclear power plant authorities (at 1 SD above the mean) ($\beta = -0.04, p = 0.740$). This finding indicates that professional knowledge of nuclear technology could predict firefighters’ risk perception when they lack trust in authorities managing nuclear power plants. Conversely, the level of knowledge was irrelevant for risk perception when firefighters considered authorities in nuclear power plants as more trustworthy.

We found that knowledge and trust were significantly and negatively associated with risk perception. More importantly, the association between knowledge and risk perception was moderated by the level of trust. For firefighters with weak trust, professional knowledge of nuclear technology was related to decreased risk perception. Conversely, the level of knowledge was irrelevant for risk perceptions regarding nuclear events among firefighters who have strong trust in nuclear power plant authorities. Notably, the low $R^2$ values of the models ($\Delta R^2$ in step 2 = 0.09 and $\Delta R^2$ in step 3 = 0.02) and small effects of the independent variables (knowledge’s $f^2 = 0.03$, trust’s $f^2 = 0.02$) and their interaction term ($f^2 = 0.02$) indicate that the main interaction effects of knowledge and trust on the perceived risk of nuclear accidents were relatively weak even though they are beyond the threshold for statistical significance.

### 3.5 Simple Mediation Analyses

Next, we examined whether risk perception was related to preparedness and willingness to respond, and whether it mediated the association between knowledge and preparedness and willingness. First, we conducted a hierarchical regression analysis to examine the main effect of risk perception on preparedness and willingness. Gender and tenure of service were entered in the first step, and risk perception was entered in the second step. Gender in the first step ($R^2 = 0.04, p = 0.039$) was significantly correlated with preparedness and willingness, indicating that male firefighters were more prepared and willing to take charge of nuclear events than female firefighters ($\beta = -0.19, p = 0.011$). Job tenure was irrelevant to preparedness and willingness ($\beta = 0.004, p = 0.958$). In the second step ($\Delta R^2 = 0.60, p < 0.001$), the level of risk perception ($\beta = -0.25, p < 0.001$) was a significant predictor—the higher the level of perceived risk experienced by firefighters, the less prepared and willing they were to take the initiative to fight fires in nuclear power plants (supporting Hypothesis 4).

In addition, we conducted bootstrap analyses (Hayes 2013, model 4) to examine the mediation effect of risk perception on the relationship between knowledge and preparedness and willingness, with the sample size set to 5,000.

![Fig. 1 Interaction effect of knowledge and trust on firefighter risk perception of nuclear events in South Korea](image-url)
A 95% confidence interval (CI) that does not include 0 is evidence of mediation (Hayes 2009). Simple mediation analyses revealed that knowledge had an indirect effect on preparedness and willingness through decreased risk perception ($B = 0.04, SE = 0.02; 95\% CI = [0.002, 0.083]$) (supporting Hypothesis 5a).

### 3.6 Moderated Mediation Analyses

In the moderation and mediation analyses reported above, we found that knowledge interacted with trust in predicting risk perception, and that the effect of knowledge on preparedness and willingness was mediated by the level of risk perception. On the basis of these results, we examined whether the indirect effect of knowledge on preparedness and willingness through risk perception was moderated by the level of trust, thereby adopting a moderated mediation model (Fig. 2) (Hayes 2013, model 7). The results presented in Table 3 reveal a conditional indirect effect of knowledge on preparedness and willingness through risk perception. The indirect effect of knowledge was significant at the lower level of trust ($B = 0.04, SE = 0.02, 95\% CI = [0.004, 0.087]$), while the indirect effect was not significant at the higher level of trust ($B = 0.004, SE = 0.02, 95\% CI = [-0.033, 0.044]$). This finding suggests that decreased risk perception mediated the link between knowledge and preparedness and willingness.

![Proposed moderated mediation model depicting risk perception mediating the relation between knowledge and preparedness and willingness to respond to nuclear emergencies among firefighters situated near nuclear power plants in South Korea, with trust as the moderator](image)

**Table 3** Regression results for the conditional indirect effects of risk perception on preparedness and willingness to respond of firefighters located near nuclear power plants in South Korea

|                | B   | SE  | t    | p   | Boot LLCI | Boot ULCI |
|----------------|-----|-----|------|-----|-----------|-----------|
| Mediator variable model: risk perception | | | | | | |
| Constant       | 5.69| 0.40| 14.24| < 0.001 | 4.905     | 6.483     |
| Knowledge      | −0.14| 0.07| −1.96| 0.052 | −0.273    | 0.001     |
| Trust          | −0.17| 0.07| −2.49| 0.013 | −0.299    | −0.035    |
| Knowledge × Trust | 0.08| 0.04| 2.16 | 0.032 | 0.007     | 0.159     |
| Gender         | 0.05| 0.36| 0.13 | 0.897 | −0.664    | 0.757     |
| Tenure of service | 0.001| 0.001| 1.04 | 0.298 | −0.001    | 0.002     |
| Dependent variable model: preparedness and willingness to respond | | | | | | |
| Constant       | 5.65| 0.66| 8.57 | < 0.001 | 4.348     | 6.949     |
| Knowledge      | 0.44| 0.07| 6.01 | < 0.001 | 0.295     | 0.582     |
| Risk perception| −0.17| 0.08| −2.03| 0.044 | −0.339    | −0.005    |
| Gender         | −0.90| 0.41| −2.19| 0.030 | −1.710    | −0.089    |
| Tenure of service | −0.001| 0.001| −0.83| 0.406 | −0.002    | 0.001     |
| Conditional indirect effect of trust = M +/- 1 SD | | | | | | |
| Trust boot indirect effect | Boot SE | | | | | |
| −1 SD (−1.20)  | 0.04| 0.02| 0.004 | 0.087 |
| M (0.00)       | 0.02| 0.02| −0.002 | 0.059 |
| +1 SD (+1.20)  | 0.004| 0.02| −0.033 | 0.044 |
| Index of moderated mediation | | | | | | |
| Risk perception | −0.01| 0.01| −0.035 | −0.002 |

Bootstrap sample size = 5,000. LL = lower limit; CI = confidence interval; UL = upper limit.
preparedness and willingness for firefighters who had lower levels of trust in nuclear power plant authorities, but not for firefighters who had higher levels of trust. A negative and significant index of moderated mediation ($B = -0.01$, $SE = 0.01$, 95% CI $= [-0.035, -0.002]$), which indicates the slope line for the association between the indirect effect and the moderator (that is, trust) corroborated the result (Hayes 2015) (supporting Hypothesis 5b).

4 Discussion

The main purpose of the study was to explore whether and how cognitive and psychological factors (such as knowledge about nuclear accidents, trust in the authorities operating nuclear power plants, and the perceived risk regarding nuclear events) could affect the preparedness and willingness to respond to nuclear emergencies among firefighters situated near NPPs. On the basis of theoretical consideration and previous empirical studies, we hypothesized that knowledge and trust would have main and interaction effects on risk perception, which would affect the firefighters’ levels of preparedness and willingness to respond. The results show that (1) knowledge and trust are related to risk perception; (2) trust moderates the association between knowledge and risk perception; and (3) risk perception predicts firefighters’ levels of preparedness and willingness. Moreover, a pattern of moderated mediation was found—perceived risk mediated the indirect effect of knowledge on preparedness and willingness to respond when the firefighters had low trust in the authorities operating nuclear power plants, but not when they had high trust. These results revealed the relationship between knowledge, trust, perceived risk, and preparedness and willingness to respond to nuclear events.

The results of the study offer several theoretical contributions. First, they demonstrate that knowledge about nuclear accidents and trust in authorities operating nuclear power plants were significant contributors to firefighters’ risk perception regarding nuclear events. While previous literature on nuclear risk perception has exclusively focused on how either laypeople, experts, or residents living near nuclear facilities perceive risk regarding nuclear technology or radiation, little is known about risk perceptions among firefighters situated near NPPs, who work as professional emergency personnel to respond to nuclear events. Our study investigated the factors that influence firefighters’ risk perception of nuclear events and revealed that it is negatively associated with knowledge and trust, which is in line with the psychometric paradigm literature on risk perception regarding nuclear technologies. Therefore, our study can be a useful supplement to risk perception studies that focus on other professional emergency personnel.

Second, the research revealed that risk perception is significantly predictive of firefighters’ preparedness and willingness to respond to nuclear emergencies. With the presence of high risk perception, firefighters felt less prepared to respond to nuclear emergencies and were less willing to take on roles in the context of nuclear events. The perceived risk of nuclear events was found to be negatively associated with firefighters’ preparedness and willingness to respond to nuclear emergencies. Our findings offer new evidence to support the argument that subjective evaluations of risk about a certain event, rather than objective risk, influence individuals’ preparedness and willingness to respond (Barker et al. 2006; Barnett et al. 2009). Along with the fact that higher perceived risk could be related to the levels of fear that individuals feel when they confront emergency events (Loewenstein et al. 2001; Slovic et al. 2004; Slovic and Peters 2006), our results suggest that not only cognitive appraisals, but also emotional reactions to these events can affect an individual’s preparedness and willingness to respond.

Finally, the study confirmed that trust moderates the direct effect of knowledge on firefighters’ risk perception of nuclear events, and moderates the indirect effect on their preparedness and willingness to respond to nuclear emergencies. The relationship between knowledge and perceived risk was significant for firefighters with low trust, but it was insignificant for firefighters with high trust. This result provides additional support for the argument that social trust in the authorities operating and managing technologies can serve as the boundary condition of the relationship between knowledge and perceived risk regarding these technologies (Siegrist and Cvetkovich 2000). Moderated mediation analyses revealed that trust qualified the relationship between knowledge and firefighters’ preparedness and willingness to respond to nuclear emergencies. Knowledge about nuclear accidents had an indirect effect, mediated by risk perception, on firefighters’ preparedness and willingness to respond to nuclear emergencies, but only for firefighters with low trust in the authorities operating nuclear power plants. This was not the case for firefighters with high trust. These findings indicate that for firefighters who must collaborate with nuclear power plant authorities, social trust in these authorities can have an impact on their preparedness and willingness to respond, beyond their risk perception. While previous literature has examined the effect of trust in coworkers on performance in hazardous situations (Colquitt et al. 2011), no empirical studies have investigated the effect of trust in the case of collaborating partners in emergency responses. The current research explored the effect of firefighters’ trust in collaborating partners—the authorities operating nuclear power plants—in the context of nuclear events. The findings suggest that social trust in other emergency collaborators may influence emergency workers to
have high preparedness and willingness to respond to emergencies. Our findings broaden the current understanding of how social trust can influence emergency workers’ responses during an emergency.

In addition to these theoretical implications, the study has important practical implications for nuclear safety organizations. Our findings illustrate that knowledge about nuclear accidents is directly correlated with firefighters’ perceived risk, and indirectly correlated with their preparedness and willingness to respond to nuclear emergencies. Thus, organizations should develop education programs aimed at building firefighters’ knowledge about nuclear accidents and incorporate it into existing training programs mainly designed to foster skills and abilities to respond to nuclear events (for example, the Nuclear Regulatory Commission’s Radiological Emergency Preparedness program and the Federal Emergency Management Agency’s Radiological Emergency Preparedness program). It is important for firefighters to be provided with a broad range of scientific and technical information about nuclear power and radiation. With such information, firefighters can develop their professional knowledge in terms of responding to fires in nuclear power plants. This knowledge development can be effective in reducing firefighters’ risk perceptions of nuclear events and promote their preparedness and willingness to respond to nuclear emergencies. However, it is noteworthy that the magnitude of the effect of knowledge on firefighters’ preparedness and willingness to respond to nuclear emergencies ($f^2 = 0.26$) is arguably moderate (Sawilowsky 2009; Acock 2014). This suggests that the development of knowledge about nuclear accidents could lead to enhanced preparedness and willingness among firefighters in NPPs to a certain extent. However, the improvement of skills and abilities for radiation protection, as well as personal protective equipment, is also necessary to achieve a high level of preparedness and willingness to respond.

Our study also showed that trust in nuclear power plant authorities could qualify the association between knowledge and risk perception, and the association between knowledge, and preparedness and willingness to respond to nuclear emergencies. This suggests that high trust in the authorities can buffer the detrimental effects of low knowledge in the context of firefighters’ risk perception and their preparedness and willingness to respond. Therefore, organizations must offer more opportunities for firefighters situated near NPPs to communicate and interact with authorities operating nuclear power plants to strengthen their trust in these authorities. Given that firefighters in NPPs repeatedly reported difficulties in accumulating deep knowledge about nuclear accidents due to their lack of a basic understanding of radiation (Choi et al. 2018), building strong trust in the authorities operating nuclear power plants could effectively help firefighters develop their preparedness and willingness to respond to nuclear emergencies, although it takes considerable effort and time to build strong trust with authorities.

5 Conclusion

The current research contributes to the safety literature by expanding the understanding of psychological factors that influence firefighters’ preparedness and willingness to respond to nuclear emergencies. However, there are several limitations that should be considered for future research. First, firefighters’ preparedness and willingness to respond to nuclear emergencies was measured by self-reports. Previous literature on preparedness and willingness to respond to emergencies collected data from participants’ self-reported questionnaires as well. However, it is possible that participants who are professional emergency personnel, such as the firefighters in this study, may provide inflated levels of preparedness and willingness to respond due to social desirability (Phillips and Clancy 1970, 1972; Klassen et al. 1976). The culture of firefighting, in which self-sacrifice is an integral part of a firefighter’s job, might lead to higher self-reporting of preparedness and willingness to respond to nuclear emergencies. Future research should assess firefighters’ preparedness and willingness to respond from multiple sources, such as using informant reports and implicit measures.

Second, we measured only the perceived knowledge that firefighters situated near NPPs stated and did not take into account their actual knowledge. Previous studies have shown that perceived knowledge is more closely related to risk perception and risk acceptance (Grasmück and Scholz 2005; Jaccard et al. 2005; Choi and Kim 2011). Park and Kim (2015) systematically examined the relative importance of actual and perceived knowledge on risk perception among residents around Korean nuclear power plants and found that only perceived knowledge (not actual knowledge) predicted the level of perceived risk. In line with these findings, the current study focused on examining the relationship between perceived knowledge (rather than actual knowledge), perceived risk, and preparedness and willingness to respond to nuclear emergencies. However, given that perceived and actual knowledge moderately correspond with each other (Radecki and Jaccard 1995; Alba and Hutchinson 2000), and are differentially related to hazard perception (Vandemoore 2008), future studies need to investigate whether and (if so) how actual knowledge could influence preparedness and willingness to respond to nuclear emergencies, independently of perceived knowledge.

Third, since the current research is correlational in nature, we are unable to make strong causal inferences. All variables were simultaneously collected by self-report measures. Such a collection procedure not only raises concern

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about common method variance, but also reduces the data's predictive value. However, we utilized several methods to investigate common method variance and found that our results were not due to common method bias. It is also noteworthy that the significant moderation effect and the moderated mediation effects we found in the current study are unlikely to be explained by common method bias (Siemsen et al. 2010). Nevertheless, it is important for future research to systematically determine the causal relationship between knowledge, trust, perceived risk, and preparedness and willingness to respond to nuclear emergencies with research designs other than a cross-sectional survey. A longitudinal intervention design, whereby firefighters situated near NPPs regularly engage in new training programs to improve their knowledge and trust (or reduce perceived risk), can provide experimental evidence for causality.

Finally, this study did not include first responders other than firefighters in the context of nuclear events. Firefighters assume crucial roles in initial responses to nuclear emergencies, but they cannot successfully respond without collaborating with other first responders such as nuclear power plant workers, medical service workers, and police officers. Our results might not reflect the preparedness and willingness to respond to nuclear emergencies and its determinants among other first responders. Future research should extend this line of inquiry to other first responders and explore additional psychological factors that can influence effective collaboration among first responders in the context of nuclear events.

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