Intentions of university students and staff members to re-enter chemical storage buildings immediately after a major earthquake: A case study in Japan

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Highlights

- Investigating post-evacuation behaviors immediately after a major earthquake
- Exploring intentions and selective attention toward reentry into evacuated buildings
- Discovering that a combination of given situations significantly increases intentions to reenter
- Concluding that knowledge of chemical hazards governs selective attention during reentry

Abstract

This questionnaire-based study primarily intended to explore unsafe post-evacuation behaviors of university students and staff members in Japan immediately after the occurrence of a major earthquake. The intentions of evacuees to re-enter vacated buildings under simultaneous independent conditions (e.g., cold and rainy weather) were investigated along with features that attracted their selective attention to establish effective emergency plans for universities/colleges where hazardous materials are handled and stored. A questionnaire survey was administered to 265 people at a national university in Japan. The question items queried risk perception, intentions to return to vacated buildings, knowledge of hazardous materials, and demographics. The survey results indicated that several combined situations significantly increased the respondents' intentions to reenter evacuated buildings: cold and rainy weather, personal belongings left in a building that was severely damaged, and persons with disabilities left behind in a severely damaged building. A co-occurrence network analysis performed along with correspondence analyses revealed that people who were aware of chemical hazards paid greater attention to gas release and fire events. Conversely, those who were not as knowledgeable merely directed their selective attention to items easily conceived in the event of seismic occurrences (e.g., footing, broken window, helmet, etc.). Correlation analysis demonstrated that (i) the knowledge of hazardous materials was not significantly correlated with intentions to reenter, and (ii) a negative relationship existed between risk perception variables and intentions.

Keywords: post-evacuation behavior; major earthquake; unsafe action; return decision-making; text mining; emergency management

1. Introduction

Japan occupies only around 0.25% of the Earth's surface but experiences almost 10% of all earthquakes. A major earthquake often causes a loss of containment at facilities that store, transport, and handle chemicals, exacerbating the risk of fire, explosion, and toxic-release accidents. Such earthquake-prompted accidents are termed natural hazard-triggered technological disasters (Natech) [1]. For instance, the 9.1-magnitude 2011 Tohoku earthquake caused large LPG boiling liquid expanding vapor explosions (LPG BLEVEs) at an oil refinery [2].

Chemical-handling laboratories at universities and colleges store diverse hazardous materials including toxic, biohazardous, asphyxiating, flammable, and explosive gases, liquids, and solids. Such materials should be appropriately stocked in laboratories and workshops. However, zero-risk is an impossible claim: residual risks remain even after all risk reduction measures are taken. For instance, accidental spills or mixing of certain pairs of chemicals (e.g., flammable organic solvents and nitric acid, which is an oxidizing agent) may result in heat and toxic releases that could eventually cause serious disasters. Unfortunately, earthquake-induced accidents have been reported at university laboratories in Japan. To cite an example, many chemical storage cabinets at laboratories tipped over during the 7.5-magnitude Miyagi-Ken-Oki earthquake and caused chemical releases. In addition, five earthquake-triggered fires were reported in chemical laboratories at two universities and a university professor suffered a burn injury [3]. Yamada reported that fire engines finally arrived four hours later owing to the period of confusion that ensued immediately after the Great Hanshin earthquake. Ultimately, six laboratory rooms of a university were burned down [4]. A national university also reported accidental hydrogen release from gas cylinders and a fire in chemical laboratory after the 2011 Tohoku earthquake [5]. Hence, all university members must understand that chemicals-storing university buildings pose risks associated with fires, explosions, and suffocation.

It is thus crucial for laboratories to conduct risk assessment/reduction/management activities associated with such chemicals [6, 7]. In addition, regular evacuation drills present vital familiarizing exercises for university members (i.e., students, faculties, and staff). Chen and Adefila have indicated that student safety is greatly benefited by the inclusion of disaster-related risk reduction education in university curricula [8]. It is also important for universities to undertake operational and discussion-based emergency management exercises to inform all their members of potential hazards and risks (i.e., fires, explosions, poisoning, and suffocation). Besides, universities should post clear instructions about protocols that must be followed in the event of a major earthquake in prominent places in buildings and other locations where hazardous materials are used or stored.

According to the Fire and Disaster Management Agency, people should stay away from windows and remain cautious about the handling of chemicals in laboratories in the event of a strong earthquake [47]. In Japan, university members participate in the ShakeOut earthquake drill ("Drop, Cover, and Hold On" [48]), and most universities conduct an annual hands-on emergency drill with all members. University emergency manuals generally stipulate that all members must shut down experiments or procedures when a major earthquake occurs, and everyone should exit buildings through the pre-determined routes after the shaking stops. People must then await emergency instructions from university authorities. However, the number of campus police and fire department officials is limited and such personnel cannot simultaneously attend to numerous university buildings to guide evacuees in periods of confusion that immediately follow major earthquakes. Thus, people can use their own judgment and reenter buildings that appear intact. In fact, the authors of this paper witnessed many university members returning to buildings that appeared intact immediately after the 2011 Tohoku earthquake without such instructions being issued by campus police and fire department officials. Regardless of an emergency drills/training conducted at universities, violations such as unauthorized returns to vacated buildings are bound to occur. Prati et al. reported that a few people returned to evacuated buildings after a major earthquake to retrieve personal properties such as bags [25].

In Japan, the authorities charged with university buildings are supposed to utilize "Emergency Risk Discriminators" (*Ohkyudo-Hantei-Shi* in Japanese [49]) to visually evaluate building safety after a large earthquake. However, such a determination of the structural integrity of buildings is one-sided because the edifice is evaluated only from the architectural perspective, and not from the chemical viewpoint.

1.1 Review of related literature

In this context, it is critical to attain fundamental insight into the evacuation behaviors of individuals to institute effective emergency plans and management guidelines that can contribute to the reduction of potential disaster-induced fatalities. Some previous investigations have addressed the evacuation and post-disaster behaviors of people. Li et al. simulated the earthquake evacuation conduct of high school students from classrooms and reported the impact of classroom arrangement and opened/closed doors on total evacuation times [9]. In the aftermath of an eruption disaster in Indonesia, Muir et al. studied the influence exerted by types of recovery aids (i.e., financial, health, food, or cash remittances) on the return of evacuees to their original communities [10]. Do's study pertained to how far people evacuated in disasters and explored the destinations to which evacuees relocated after the Fukushima nuclear disaster [11]. Feng et al. employed immersive virtual reality and Serious Games techniques to scrutinize the post-earthquake evacuation preparedness of 93 study participants in a structurally damaged building and report behavioral responses to earthquakes [12]. Groen and Polivka surveyed the victims of the Category 5 hurricane Katrina, which formed on August 23, 2005, to ascertain the percentage of evacuees who returned to their pre-Katrina addresses between October 2005 and October 2006 [13]. Fussell also reported the return rates of New Orleans residents to the city over a period of around two years after the hurricane [14].

Unfortunately, unlike such studies of evacuation and post-disaster behaviors, there exist insufficient reports of post-evacuation behaviors (PEBs) immediately after a major earthquake. For instance, Koshiba et al.'s study of evacuee decisions to return to vacated buildings under several circumstances immediately following a major earthquake revealed that PEBs were widely divergent depending on evacuee situations [15, 16]. Unfortunately, their previous studies assumed that each condition was independent of the others for the sake of simplicity. However, in reality, at least two conditions may co-occur in combination (e.g., rainy and cold weather).

As has been mentioned above, violations (i.e., returning) may ensue regardless of the rigorous implementation of emergency drills/training. Universities cannot accept circumstances in which individuals who survive a major earthquake die because they return to unsafe structures. It is thus crucial to understand PEBs, particularly of students who account for the majority of a university's members.

Fear is known to be a dominant factor in risk perception [20]. Reniers et al. have posited the *Knowledge* → *Perception* → *Attitude* → *Behavior*→ *Consequence* (KPABC) model, which highlights the strong influence exerted by perception on human behavior [21]. In this model, the arrow (X→Y) represents the direction of the influence exercised from X to Y. Nandedkar and Midha have also postulated that behavioral intentions depend on perception [22]. Maddux and Rogers's Protection Motivation Theory [23] suggests that perceived likelihood directly affects behavioral intentions. Gollwitzer projected the individual implementation intention framework in terms of if-then plans: "if situation X occurs, then I will perform goal-directed response Y" [24]. Prati et al. investigated individual responses to the 1997 Umbria–Marche earthquake through interviews and reported several categories of behaviors immediately after the tremors: returning to houses, recovery of personal belongings, undertaking specific activities, and observing the scene [25]. The examples cited for the "recovery of personal belongings" and "undertaking specific activities" respectively included "I went back to the office and took my bag" and "I went back to the factory to see what happened and to find out if my co-workers needed help." Horney et al. argued that the behaviors of friends, family, and neighbors influenced individual evacuation behavior [26]. Optimism denotes the tendency of individuals to expect a more desirable or less undesirable event outcome than their peers. Thus, the term "optimism bias" can be defined as the difference in perceived risks observed between individuals and groups [22].

Selective attention is a cognitive process that allows people to focus on specific phenomena for some time so they can eliminate superfluous elements from their consideration to accomplish particular tasks. Richards et al. posited that individuals harbor attentional biases toward threats [17]. Unfortunately, attention is a limited resource [18]; information identified as non-threatening is thus ignored when one perceives a threat, and such oversight is potentially harmful. When people return to chemicals storage laboratories after an earthquake, they must not merely observe the damage to ceilings/walls; they should also note the hazards associated with chemicals and gases stored in such structures. Inadequate attention to such hazards could expose people to accidental fires, explosions, poisoning, and suffocation. Therefore, it is crucial for universities to attain appropriate insight into selective attention associated with the PEBs of their members. However, such awareness remains unavailable in the extant literature.

1.2 Objectives

The present study aims primarily to elucidate the PEBs of university members in combined situations immediately after a major earthquake. In addition, the selective attention associated with the returning actions of individuals to evacuated buildings is investigated via a text mining approach. To describe the structure of the rest of this paper, Section 2 explains the design and methodology of the administration of the questionnaire-based survey; Section 3 details the survey results pertaining to the PEBs under combined situations and overviews the study's findings of the selective attention of individuals when they return to vacated buildings; Section 4 addresses the study's discussion, limitations, and remarks on its results; and Section 5 summarizes the conclusions achieved from the study.

2. Methodology

2.1 Survey participants

The study participants (undergraduates, graduates, non-professional office/professional personnel, and academic faculty) occupied buildings designated for the science and engineering departments of a national university located in the Greater Tokyo Area. They were selected according to student/staff ID numbers using a random number generator and were invited to fill the questionnaire via a web survey system. To receive a high response rate, the participants were offered a 1000-JPY gift card for efforts expended to complete and submit the questionnaire (response rate: 100%). It must be noted that chemical agents and gas cylinders are stored and utilized within the premises of the surveyed buildings. A total of 265 individuals consented and participated in the computer-aided online survey. It is acknowledged that Internet-based questionnaires present the major disadvantage of limiting participants to web-users [19]. However, most university members are daily users of computers and Internet technology.

Table 1 presents the demographic characteristics of the respondents. Approximately 28% of the respondents described their membership category as undergraduates and around 44% reported themselves as masters or doctoral students. In sum, students (both undergraduate and graduate) accounted for around 72% of the study's participants.

More than half of the 265 respondents reported majors in biology, medicine, and pharmacy. The second and third highest majors were respectively recorded as "agriculture" and "chemistry and materials science." In Table 1, the term "none" signifies a person who does not use chemicals, and thus indicates non-professional office workers earning liberal arts degrees. Approximately three-quarters (76.2%, n = 202) of the participants occupied building levels lower than the 5th floor, and around two-thirds (62.3%, n = 165) of the respondents were male.

2.2 Survey design and procedures

2.2.1. Survey items: Perceptions and selective attention

The survey instrument presented in Table 1 was developed for this study on the basis of the findings reported by several previously conducted scholarly projects [15, 16, 20–26]. The following statement introduced the survey instrument: "You have just temporarily vacated your university building along with other occupants immediately after the occurrence of a major earthquake of a seismic intensity of 6-lower." The "6-lower" (*Shindo 6-jaku* in Japanese; described as difficult to remain upright [50]) is an earthquake potency defined by the Japan Meteorological Agency seismic intensity scale. The Japanese government designates major earthquakes in the vicinity of the survey campus as those registering a minimum intensity of *Shindo 6-jaku* [27].

Initially, participants were queried about their level of fear (Q1): "To what extent do you feel fear when you return to your building?" Subsequently, the survey items asked the following two questions (Qs 2 and 3): "To what extent do you think you/others are injured when you return your building?" The present study calculated the differences in the rated values between Q2 and Q3 according to Nandedkar and Midha's findings that the level of optimism bias is pivotal to the formation of an individual's intentions [22]. The next question (Q4) sought an open response to determine selective attention: "What elements will you watch out for when you return to your building?"

2.2.2. Survey items: PEBs under independent conditions

Informed by the findings reported by the extant investigation, the participants of the present study were asked to rate the extent to which they felt they would return to their building (i.e., return intention) in nine independent scenarios: if they had left the building without their personal belongings (Q5); if persons with disabilities were left behind in the vacated building (Q6); if they desired to inspect their office/laboratory (Q7); under cold conditions (Q8); if it was raining (Q9); if other evacuees began returning to the building (Q10); if the building was not visually damaged (Q11); if the building was severely damaged (Q12); and if a gas release had occurred in the building (Q13).

To discourage ambiguous responses, all the items required participants to rate their reactions on a 6-point Likert-type scale ranging from 1 (not at all likely) to 6 (very likely) without the inclusion of a neutral mid-point. The Likert-type scale also offered the major advantages of ease of understanding and responding simplicity [28]. The questionnaire did not present respondents with detailed conditions for each question such as the intensity of the rainfall (heavy/light rain, Q9) because augmenting details about conditions would remarkably increase the number of questions, which would unnecessarily burden the respondents and could eventually raise the rate of abandonment.

2.2.3. Survey items: PEBs under combined conditions

Creating combinations of all the conceived situations would considerably increase the number of queried items. Thus, limited combinations were investigated in this study for the sake of simplicity (Qs14–17): under cold and rainy weather conditions (Q14); if personal belongings were left in the building but the building was severely damaged (Q15); if persons with disabilities were left behind in the building but the building was severely damaged (Q16); and if the individual wanted to inspect the office/laboratory but the building was severely damaged (Q17). These specific combinations were selected in this study because of the probability of their occurrence. For example, the Q14 situation (cold and rainy) is a likely scenario in Japan. If situations A and B, which increase the intention to reenter, and situations C and D, which decrease such an intention, are respectively assigned, the combination of increase in situations $A + B$ probably strengthens the intention. Conversely, it was expected that the combination of situations $C + D$ decreases the intention. However, the intention to return cannot be accurately predicted if A and C co-occur in a combined situation (i.e., Qs 15–17).

2.2.4. Survey items: Knowledge of chemicals' hazards and others

As has been noted above, chemicals are handled and stored in the surveyed buildings. The next two questions asked the participants whether they would want to return to the building if chemicals (Q18) and biohazardous materials (Q19) were stored in the building.

The knowledge of hazards is understood to influence behavioral intention [21]. This survey also queried the extent of the participants' knowledge pertaining to the toxicity of chemicals to human beings (Q20); physical hazards (e.g., fires and explosions [29, 30]) (Q21), and biohazardous materials (Q22).

2.2.5. Survey items: Demographic questions

Finally, the participants were asked to provide four demographic details: their university membership category (Q23); their academic major (Q24); the name of their building and the floor on which they worked/studied (Q25); and their gender (Q26).

2.2.6. Survey period

The survey was conducted between October and November 2019. Participant ratings could be influenced by current occurrences; we therefore confirmed that no major earthquakes transpired in Japan during the period in which the project was conducted. The questionnaire took approximately 12 minutes to complete. The survey protocol was approved by an ethics committee as described in the Acknowledgments section.

2.3 Survey data analysis

Participants were required to answer all the items and the dataset was thus complete, with no missing items. The mean values rated by respondents were calculated to evaluate the likelihood of reentering buildings in each given condition.

The Welch's *t*-test was employed to compare the Q1 rated scores between males and females, since several scholars strongly recommend that (i) no pre-tests should be performed prior to the t test and (ii) Welch's *t*-test should be employed by default when sample sizes are unequal [51, 52]. A parametric repeated-measures analysis of variance (rANOVA) was performed to test differences in rated values under the combined situations. This study also performed Sidak's multiple comparison test, which is typically used for *post hoc* pairwise comparisons and is more conservative than Tukey's method [31]. The survey data were analyzed using the SPSS software (Ver. 25) with a significance level set to 0.05.

KH Coder (Ver. 3) [32], a text mining software, was utilized for the identification of the selective attention elements associated with the reentering actions of respondents to evacuated buildings (Q4). The KH Coder program can analyze text data in Catalan, Chinese, Dutch, English, French, German, Italian, Japanese, Korean, Portuguese, and Russian. The survey for this study was conducted in Japanese; hence, Japanese text data were used for the co-occurrence network and correspondence analyses. Before the analyses were performed, different words with the same meaning were unified to avoid the double-counting of terms such as *Shiyaku*/*Yakuhin* and *Hinan*/*Nigeru*. Typical methods for detecting communities of words in the co-occurrence analysis include Kruskal's and Summon's algorithms. In the current study, the former algorithm was deployed because of its preeminence and its simplicity in addressing the minimum-spanning forest problems [33].

The modularity algorithm [34] was utilized in this study to perform a co-occurrence network analysis. Words are called nodes in a co-occurrence network diagram and the lines between words are labeled edges. Larger circles denote the higher frequency of words in texts. The Jaccard similarity coefficient, J, is generally employed to determine co-occurrence relations [35]. Given two sets of elements X and Y, the coefficient of the X and Y sets may be noted as $J(X, Y)$ and defined as the ratio of the size of the intersection of X and Y (the number of the common element) to the size of their union (the total number of different elements found in the X and Y elements). The Jaccard similarity coefficient varies from 0 to 1 and is represented by Eq. (1):

$$J(X, Y) = n(X \cap Y)/n(X \cup Y) \quad (1)$$

A solid edge is drawn in the network chart if a word is strongly associated with other terms. Convincingly related words are also depicted in the same color. Non-characteristic words and phrases are positioned near point O (i.e., the coordinate origin) of a two-dimensional scatterplot in the correspondence analysis. In contrast, characteristic words and phrases used in a similar manner in texts are distant from point O and placed in proximity to each other. In this context, a characteristic term is identified both on the basis of its frequency and distribution [36]. The analysis results are generally interpreted based on the direction and distance of words from point O.

3. Results

3.1 Rated scores

The mean values (*Ms*) and standard deviations (*SDs*) for the survey variables are listed in Table 2. As shown in Table 1, the items were rated on a Likert-type scale that ranged from 1 to 6. Larger values indicated greater intentions to reenter evacuated buildings and higher levels of risk perception, likelihood, or knowledge. It should be noted that the floor effects were observed for Qs 14–16 and 18–20 [37]. These were defined as $(M + SD)< 1$ and >30% of the participants answered “1.”

3.1.1. Perceptions and knowledge

The fear associated with reentering buildings (Q1) was rated at $M_{Q1} = 4.42$, indicating a great sense of dread in the respondents. The M values for males and females were calculated as $M_{male} = 4.27$ ($SD = 1.04$) and $M_{female} = 4.66$ ($SD = 1.10$), respectively. A Welch’s t-test revealed that the value assigned by females was higher than the value designated by males ($p < 0.01$). This result is consistent with previous findings that females perceive risk at higher levels than males [38].

A one-way analysis of variance (ANOVA) was performed to identify the effects exercised by the floor level of a building. Levene’s test demonstrated the homoscedasticity of the data ($p >0.05$). The one-way ANOVA revealed no significant differences among the floors of a building in the values rated for fear ($F = 1.18$, $df = 10$, $p = 0.30$). It is pertinent to note that the df value of 10 is attributable to the integration of the >10-story data because of the small sample size for floors higher than the 10th level.

The M values for the likelihood of injury to self (Q2) and to others (Q3) were both approximately 3.6, indicating no difference. Thus, the effects of an optimism bias that could potentially influence individual intention and decision-making are negligible in this study. The M values for the knowledge of chemical toxicity, physical hazards, and biohazards, were computed at 3.19, 3.13, and 3.33, respectively.

3.1.2. PEBs under independent conditions

Table 2 demonstrates that people were deemed to be inclined to reenter buildings under a given condition if the *M* value exceeded 3.5 (i.e., arithmetic mean value 1–6). The *M* values yielded reasonable results for personal belongings left behind in the evacuated building (Q5: $M_{Q5} = 3.88$), persons with disabilities remaining in the vacated building (Q6: $M_{Q6} = 3.83$), other evacuees starting to reenter the evacuated structure (Q10: $M_{Q10} = 4.14$), and the building being undamaged (Q11: $M_{Q11} = 3.94$). As expected, respondents were inclined to return to buildings when the structures were not visibly damaged (Q11).

Conversely, the *M* values were low when buildings were severely damaged (Q12: $M_{Q12} = 1.93$) and gas was potentially released in them (Q13: $M_{Q13} = 1.48$), suggesting that most respondents would not choose to return in such severe circumstances.

3.1.3. PEBs under combined conditions

Section 3.1.2 showcased the results pertaining to the PEBs under independent conditions. However, emergency situations can potentially present at least two concurrent circumstances. As described earlier, the number of combinations of all the situations presented in Table 1 would be very large and unwieldy; hence limited combinations were probed for the present study in the interests of simplicity (Q14–Q17).

Interestingly, the participant ratings registered for return to a vacated building under cold and rainy conditions (Q14: $M_{Q14} = 4.02$) revealed *M* values that clearly implied that this combined circumstance would be an accelerating factor for the return. Table 2 exhibits the independent *M* values for cold conditions (Q8) as $M_{Q8} = 3.26$ and for rainy weather (Q9) as $M_{Q9} = 3.52$. These values indicate that independently, these conditions are neither inhibiting nor accelerating factors. A one-way ANOVA was conducted to test for differences in the *M* values among the three conditions (i.e., Q 8, Q9, and Q14), and the results revealed significant situational effects on the *M* value ($F = 149.48$, $df = 2$, $p < 0.001$). A *post hoc* Sidak's test also underlined significant differences in the *M* values of the three situations (all $p < 0.001$).

Lu et al. [39] demonstrated experimentally that earthquake-induced building debris remarkably increases the time required for evacuation. Thus, a strong psychological burden is associated with reentry into a severely damaged evacuated building. The outcomes for the condition stipulating that respondents abandoned their building without personal belongings and the building was severely damaged (Q15: $M_{Q15} = 2.23$) registered an *M* value below 3.5. Interestingly, the ANOVA and *post hoc* Sidak's test indicated significant differences in the *M* values of the three situations (all $p < 0.001$, Q5, Q12, and Q15). Put differently, the *M* value for Q15 was significantly higher than the value computed solely for Q12. A similar result was also confirmed for the Q16 (M_{Q16} = 2.66) combination, whose individual situations (Q6 and Q12) were computed to be M_{Q6} = 3.83 and M_{Q12} = 1.93, respectively. Interestingly, the *post hoc* test revealed no significant interactions between the rated values for Q12 and Q17 for the Q17 condition of returning to a severely damaged evacuated building to inspect one's office or laboratory (Q7 + Q12) even though the ANOVA indicated a significant difference ($p < 0.001$).

3.2 Relationship between PEBs and chemical hazard/risk perceptions

Text mining and correlation analyses were conducted to elucidate the relationship between the PEBs of individuals and their knowledge of chemical hazards or other risk perceptions. These results are discussed below.

3.2.1 Co-occurrence network analysis

A word frequency analysis was conducted, and the top 42 words with occurrence frequency of ≥ 10 were extracted (Fig. 1) before the co-occurrence network analysis (see Fig. 2). The five words with the highest occurrence frequency were guarantee (81), building (57), reenter (56), glass (53), and helmet (51). The numbers following the terms in parentheses indicate the frequency of their occurrence. The resulting co-occurrence network associated the elements of selective attention (Q4) and identified the nine communities (Fig. 2). The solid and dashed edges respectively represent the correlations with the J coefficients of >0.10 and ≤0.10; the larger J values signify stronger correlations between two words. The blue-green community comprised the terms *body*, *head*, *guard*, *route*, and *evacuation*. The light-yellow community demonstrated several high-frequency nodes such as *glass, attention, watch out, footing,* and *overhead* and showed complicated connections among the nodes. Further, the light-yellow community connected to the light-blue (*helmet*, *shoe*, and *wear*), purple (*cabinet*, *tip over*, *item*, and *fall off*), and orange (*wall* and *ceiling*) communities. In short, the light-yellow, light-blue, purple, and orange communities were found to be related to events and items that individuals could spontaneously imagine from the stimulus of a seismic event (i.e., availability heuristic [40]). The pink community included terms related to the physical hazards posed by chemicals: *chemical agent*, *gas*, and *fire*.

3.2.2. Correspondence analysis

The co-occurrence network analysis presented in Section 3.2.1 revealed that words recalled by seismic events and physical hazards posed by chemicals did not co-occur in each text. Next, a correspondence analysis was conducted to elucidate the relationship between selective attention (Q4) and knowledge of physical hazards presented by chemicals (Q21). The correspondence analysis diagram (Fig. 3) exhibits the rated values for Q21 plotted along with the selective attention words. The high scores for Q21 (> 4) were plotted in the 1st and 2nd quadrants whereas the low scores (< 3) were located in the 3rd and 4th quadrants. This figure illustrates that the words associated with Q21 (*chemical agent*, *gas*, and *fire*) were placed in the 1st quadrant. In contrast, most words immediately associated with seismic events (e.g., *footing*, *head*, *window*, *helmet*, and *cabinet*) were positioned in the 3rd and 4th quadrants. Hence, the elements of selective attention were strongly related to the rated values for Q21 (the knowledge of potential physical hazards posed by chemicals) when people reported their return to evacuated buildings.

3.2.3. Correlation analysis

The correspondence analysis presented in Section 3.2.2 demonstrated that respondents with high knowledge scores on the physical hazards presented by chemicals tended to selectively pay attention to the chemical hazards (i.e., gas/chemical releases and fires) as they returned to vacated buildings. This section reports on the correlation analysis conducted to investigate the relationship between the variables of PEB, risk perception, and knowledge.

Word count limitations prevent a detailed discussion of the results of the relationship between Q11 (building not damaged) and variables probed through Qs 1, 2, 20, and 21. Table 3 displays the Pearson zero-order correlations among the variables in instances when the evacuated building was not damaged (Q11). As previously described, the optimism variable (i.e., Q2−Q3) was eliminated as no significant optimism bias effects were noted for this study.

Unsurprisingly, the correlation analysis divulged that the variable of an undamaged building (Q11) was significantly and negatively correlated with the fear (Q1) and likelihood of injury (Q2) variables ($r = -0.24$, $p < 0.001$ and $r = -0.35$, $p < 0.001$, respectively). In short, the result was reasonable: those who perceived lower risk and lesser subjective probability of injury were inclined to reenter undamaged vacated buildings immediately after a major earthquake. A positive relationship was found between the Q1 and Q2 variables ($r = 0.50$, $p < 0.001$). A significant and positive correlation was also discovered between the knowledge variables (Q20 and Q22, $r = 0.90$, $p < 0.001$). It has been mentioned above that knowledge affects risk perception and can potentially influence behavioral intentions [21]. However, contrary to expectations, the knowledge variables evinced no significant correlations with any of the other variables (all *p*s > 0.05).

The findings of the present study suggest that the inclusion of awareness about the potential hazards of chemicals within the educational curriculum for emergency protocols would not in itself be adequate to foster good judgment that would prevent evacuees from reentering vacated buildings in the aftermath of a disaster.

4. Discussion, limitations, and remarks

As listed in Table 2, the *M* values for Q5, Q6, Q10, and Q11 were $M_{Q5} = 3.88$, $M_{Q6} = 3.83$, $M_{Q10} = 4.14$, and $M_{Q11} = 3.94$, respectively. These results are reasonable. In the context of Q5, Prati et al. have indicated that the retrieval of personal items can prompt people to return to evacuated buildings [25]. Raacke and Bonds-Raacke have reported that in recent years, college students have taken to the use of social networking services to communicate with friends [41]. Similarly, Hara has demonstrated that most people use their smartphones immediately after a large earthquake to search for related information [42]. In terms of Q10, evacuation behaviors in emergencies are generally influenced by the actions of other people. Tomova and Pessoa investigated the risky choices made by 52 college students (average age: 20.3, $SD = 2.1$) and experimentally demonstrated that unsafe actions taken by neighbors exert an impact on hazardous decisions taken by the participants [43].

The present study must admit a few limitations. First, it did not investigate the effects of a direct or recent experience of a major earthquake. The participants of this study were asked to assess the likelihood of returning to vacated buildings under hypothetical conditions. Direct disaster experience is considered an important predictor of evacuation behaviors. For example, Pan's questionnaire survey assessed evacuation decision-making in a typhoon disaster and demonstrated a positive relationship between "past typhoon experience" and the evacuation decision [44]. Ho et al. [45] also disclosed that direct earthquake experience strongly affects an individual's risk perception and probably influences reentering intentions. This survey was not administered to victims of a recent major earthquake; however, approximately 40% of Japanese people experience at least one major earthquake in their lifetimes [46]. Nevertheless, it must be noted that it is difficult to accurately investigate factors that influence PEBs through hypothetical situations.

Second, a necessary bias exists in the respondent's academic majors. Thus, the present study could not investigate the effects of specific academic majors on individual PEBs. Most of the participants of this study specialized in biology, medical sciences, and pharmaceutical subjects (approximately 59%). The second and third groups were agriculture (around 13%) and chemistry and materials sciences (around 11%), respectively. Most respondents except for the non-professional office workers were thus regular users of chemicals. Third, this study did not investigate the ages of participants or query any disabilities. It is known that behavior and risk perception are strongly associated with age [53]. However, the ANOVAs revealed no significant differences among the university membership categories (i.e., non-professional office staff, undergraduate, master's student, doctoral student, postdoctoral fellow, professional/technical staff, and academic faculty member) in terms of the Qs 1, 2, and 11 variables. This result implies that the influence of age on the rated values may be negligible. Future research is needed on the influences of age on the PEBs, as age data were unavailable in this study. Fifth, several psychological models were used to investigate intentions to reenter evacuated buildings; however, other related psychological models exist. For instance, according to Roger's protection motivation theory, the key elements of people's actions in emergency include *self-efficacy*, *response costs*, *severity*, and *extrinsic*/*intrinsic rewards* [54]. Hence, future research is crucial for comprehensive investigation of PEBs immediately after a major earthquake.

Finally, in the interests of simplicity, this study did not scrutinize the influences exerted by situation intensity. Hence, the effects of aspects such as the magnitude of the earthquake or the density of the rainfall were not probed. In particular, this study did not query the effects of the initial condition provided at the beginning of the survey instrument: "You have just temporarily vacated your university building along with other occupants immediately after the occurrence of a major earthquake of a seismic intensity of 6-lower." Individual intentions to reenter buildings are likely to be greater in the aftermath of a moderate earthquake because the damage to buildings would be minor. However, seismic effects could cause gas cylinders and chemical storage cabinets to overturn even in the event of a moderate earthquake, potentially leading to fires, explosions, poisoning, or suffocation. Hence, further research is required on the effects of the initial condition to determine whether the results can be generalized.

Sections 3.1.2 and 3.1.3 indicated that respondents were inclined to reenter buildings immediately after a major earthquake under several conditions regardless of their familiarity with the potential hazards posed by chemicals and their awareness that the building was open to risks associated with fires, explosions, suffocation, and toxication. Table 3 also demonstrates that individual intentions to reenter a building decreased remarkably when information about hazards was specifically presented (M_{Q18} = 1.86, M_{Q19} = 1.93).

Interestingly, in the context of selective attention as discussed in Section 3, those who were knowledgeable about physical hazards paid attention to fire, chemicals, and gas releases; conversely, those who were less knowledgeable of physical hazards attended only items easily envisioned as affected by seismic events (e.g., ceiling, helmet, window). People may be exposed to accidental explosions, suffocation, and poisoning if they return to chemical-handling buildings without paying attention due to chemicals and gas cylinders. Hence, the resultant insights into the selective attention would be effective at reducing risks associated with the PEBs.

Chen and Adefila claimed that the inclusion of disaster-related risk reduction in the education curriculum of a university greatly benefits student safety [8]. Baytiyeh and Naja, who investigated the earthquake preparedness of university students in Lebanon, indicated that educational programs greatly facilitate the reduction of earthquake disaster risks when such instructive courses accompany the implementation of an earthquake safety culture on campuses [55]. Hence, it is crucial for institutions to undertake operational and discussion-based emergency management exercises to inform all university members of potential hazards and risks (i.e., fires, explosions, poisoning, and suffocation). Besides, prominent instructions about protocols to be followed in the event of a major earthquake should be posted in buildings wherever hazardous materials are used or stored. In any case, further research on recommended student PEBs would be required for the establishment of effective emergency management plans and disaster education programs in universities/colleges.

Thus far, only a few studies have addressed PEBs. Notwithstanding the limitations discussed above, the present investigation contributes significantly to the extant literature by enhancing the scholarly understanding of unsafe PEBs displayed immediately after a major earthquake. It can also help universities/colleges or industrial facilities that handle and store chemicals design useful emergency management plans.

5. Conclusions

This study aimed primarily to elucidate PEBs presented in combined situations and to illuminate the elements of selective attention associated with unsafe reentering actions to evacuated buildings immediately after a major earthquake had occurred. The major results of this investigation can be outlined as follows:

- The one-way ANOVA and *post hoc* test revealed that the combined situations (Q14–16; Q14: under cold and rainy weather conditions; Q15: if personal belongings were left in the building but the building was severely damaged; Q16: if persons with disabilities were left behind in the building but the building was severely damaged) significantly increased individual intentions to reenter a vacated building. Similar interactions were observed for the combined conditions probed through Q15 and Q16.
- The co-occurrence network analysis associated with selective attention elements during the return identified several communities: a chemical hazard community comprised the terms *chemical agent*, *gas*, and *fire*, and other communities related to seismic events.
- The correspondence analysis demonstrated that individuals who were knowledgeable of chemical hazards attended more to the possibility of gas release and fire events when returning to vacated buildings. Conversely, the selective attention of those who were less aware of the dangers posed by chemicals was merely directed to items easily conceived for seismic events, for example, *footing*, *window*, and *helmet*.
- The correlation analysis revealed negative relationships between the variable of fear (Q1) or the likelihood of injury (Q2) and the intention to return to an undamaged building (Q11). Contrary to expectations, the knowledge variables exerted no significant correlations with the intention to return.

The key findings of this study illuminate PEBs immediately after a major earthquake. The present investigation thus contributes substantially to the reduction of earthquake-induced fatalities by facilitating the institution of effective emergency management mechanisms or aiding the enhancement of such plans at facilities that use and store hazardous materials.

CRediT author statement

Yusuke Koshiba: conceptualization, methodology, formal analysis, investigation, writing, supervision, project administration, and funding acquisition. **Jo Nakayama**: methodology, formal analysis, investigation, resource, and writing. Both authors were responsible for the data collection and have approved the final version of the manuscript.

Conflict of interest

Neither author has conflicts of interest to declare.

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Table captions

Table 1

Questionnaire items and endpoints/categories utilized in this survey. As described in Section 2.2, the instrument began with the following statement: "You have just temporarily vacated your university building along with other occupants immediately after the occurrence of a major earthquake of a seismic intensity of 6-lower." The demographic characteristics of the respondents are also listed (n = 265).

Table 2

Mean and standard deviation values for the surveyed items.

Table 3

Zero-order correlation matrix (Questions 1, 2, 11, 20, and 21).

Figure captions

Figure 1

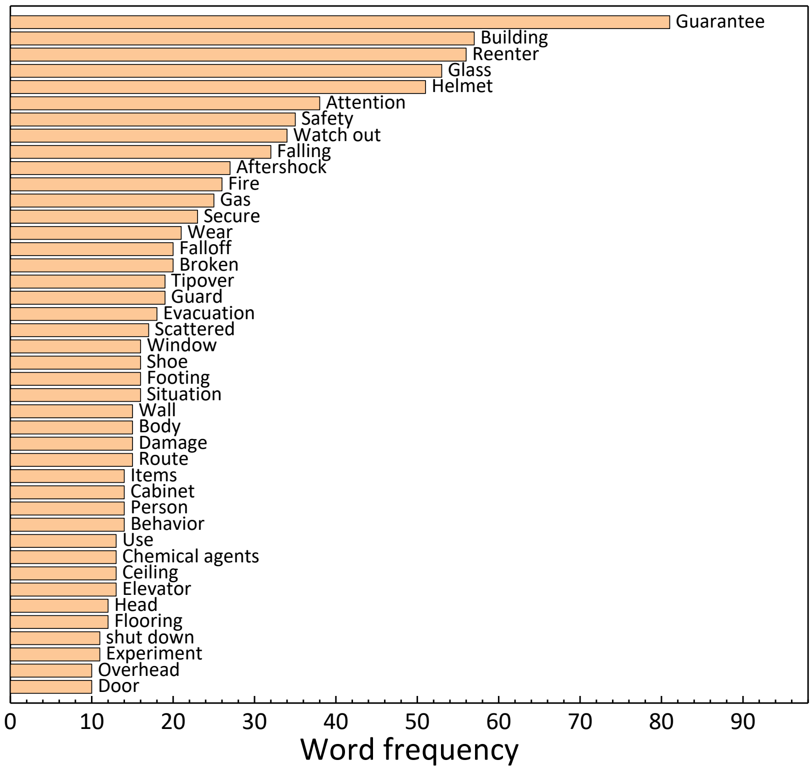
Extracted top 42 words top 42 words with occurrence frequency of ≥ 10. Here the frequency (i.e., the x-axis) is defined as the number of occurrences of a word in the Q4 document.

Figure 2

The co-occurrence network associated with elements of selective attention when individuals return to evacuated buildings. Larger circles respectively indicate stronger co-occurrence relations between the nodes and higher frequency words in texts. The solid and dashed edges (i.e., lines) represent the respective correlations with *J* coefficients of >0.10 and ≤ 0.10. As noted in the main text, Japanese text data were used for text mining. The presented co-occurrence network was translated into English by the authors.

Figure 3

Correspondence analysis of the elements of selective attention when individuals return to evacuated buildings. The rated values for Q21 (knowledge of physical hazards presented by chemicals, orange circles) are also plotted in this figure. As described in the main text, Japanese text data were used in the analysis, and the terms used in the figure were translated into English by the authors. Characteristic terms are distant from point *O* and are located in proximity to each other; in contrast, non-characteristic terms are positioned near point *O*.



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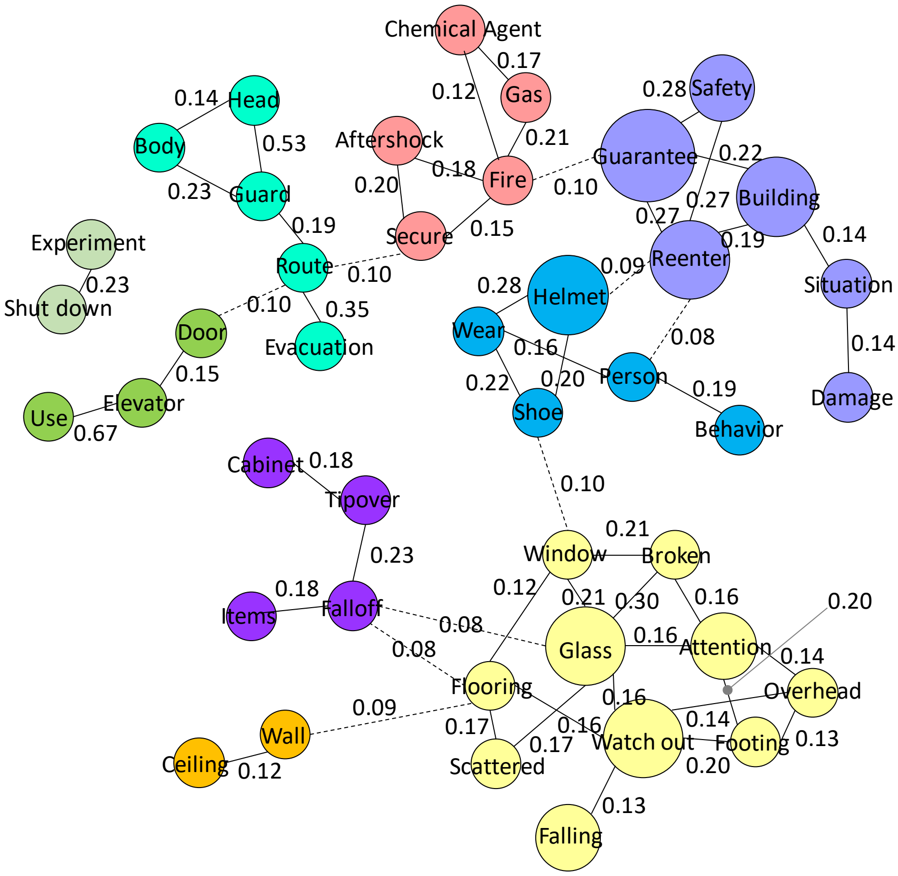

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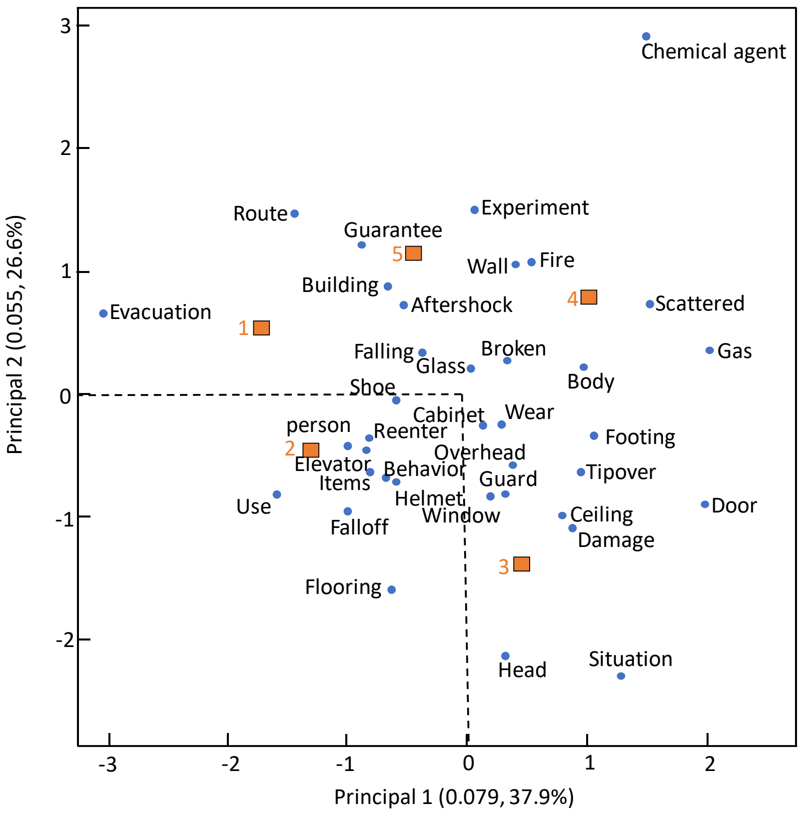

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Table 1: Question items and endpoints/categories established for the survey.

Item		Endpoints and category
Risk perception		
Fear associated with reentering the building		
Q1	To what extent do you feel fear when you return to your building?	1: Not at all; 6: Very
Likelihood		
Q2	To what extent do you think you may be injured when you return to your building?	1: Not at all; 6: Very
Q3	To what extent do you think others may be injured when your return to your building?	1: Not at all; 6: Very
Selective attention associated with reentering the building		
Q4	What elements will you watch out for when you return to your building?	Open response and multiple answer
Independent situation		
Under what conditions would you want to return to your building?		
Q5	If you evacuated the building without your personal belongings	1: Not at all likely; 6: Very likely
Q6	If persons with disabilities remain in the building	1: Not at all likely; 6: Very likely
Q7	If you want to check on your office/laboratory	1: Not at all likely; 6: Very likely
Q8	If it is cold	1: Not at all likely; 6: Very likely
Q9	If it is raining	1: Not at all likely; 6: Very likely
Q10	If other evacuees begin returning to your building	1: Not at all likely; 6: Very likely
Q11	If your building is **not** visibly damaged	1: Not at all likely; 6: Very likely
Q12	If your building is **severely** damaged	1: Not at all likely; 6: Very likely
Q13	If a gas leak may have occurred in your building	1: Not at all likely; 6: Very likely

Combined situation		
Q14	Under conditions described in Q8 and Q9	1: Not at all likely; 6: Very likely
Q15	Under conditions described in Q5 and Q12	1: Not at all likely; 6: Very likely
Q16	Under conditions described in Q6 and Q12	1: Not at all likely; 6: Very likely
Q17	Under conditions described in Q7 and Q12	1: Not at all likely; 6: Very likely
Others		
Q18	If chemicals are stored in your building	1: Not at all likely; 6: Very likely
Q19	If biohazardous materials are stored in your building	1: Not at all likely; 6: Very likely
Knowledge		
Q20	How much do you know about the human toxicity of chemicals?	1: Not at all; 6: Very
Q21	How much do you know about the physical hazards posed by chemicals (e.g., fires and explosions)? [25, 26]	1: Not at all; 6: Very
Q22	How much do you know about the effect of biohazardous materials on humans?	1: Not at all; 6: Very
Demographic questions		*n* (%)
Q23	University membership category	
	Undergraduate	73 (27.5%)
	Master's student	71 (26.8%)
	Doctoral student	46 (17.4%)
	Postdoctoral fellow	12 (4.5%)
	Non-professional office staff	28 (10.6%)
	Professional/technical staff	20 (7.5%)
	Academic faculty member	15 (5.7%)

Q24	Academic major	
	Mechanical engineering	3 (1.1%)
	Chemistry and materials science	28 (10.6%)
	Biology, medical sciences, and pharmacy	155 (58.6%)
	Electrical and information engineering	19 (7.2%)
	Physics	2 (0.7%)
	Architectonics and civil engineering	1 (0.4%)
	Agriculture	35 (13.2%)
	None of the above[a]	22 (8.3%)
Q25	Your building name and the level you occupy	
	−1	10 (3.8%)
	1	52 (19.6%)
	2	41 (15.5%)
	3	56 (21.1%)
	4	25 (9.4%)
	5	18 (6.8%)
	6	16 (6.0%)
	7	9 (3.4%)
	8	21 7.9%)
	9	6 (2.3%)
	>10	11[b] (4.2%)
Q26	Your gender	

Male	165 (62.3%)
Female	100 (37.7%)

a: Non-professional office worker who does not use chemicals. **b:** 10th floor: 2, 11th floor: 2, 12th floor: 2, 13th floor: 4, and 14th floor: 1. Note that the sum of the percentages does not always add up to 100.0% due to the round-off.

Table 2: Mean and standard deviation values for the surveyed items.

Items	*M*	*SD*
Risk perception		
Q1 (Fear)	4.42	1.08
Q2 (Likelihood of injury to self)	3.56	0.83
Q3 (Likelihood of injury to others)	3.60	0.82
Independent situation		
Q5 (Personal belongings left in the building)	3.88	1.28
Q6 (Persons with disabilities remain in the building)	3.83	1.10
Q7 (Checking on office/lab)	2.92	1.29
Q8 (Cold conditions)	3.26	1.37
Q9 (Rainy weather)	3.52	1.40
Q10 (Other evacuees are beginning to reenter the building)	4.14	1.09
Q11 (Building is **not** damaged)	3.94	1.19
Q12 (Building is severely damaged)	1.93	1.07
Q13 (Gas leaks)	1.48	0.84
Combined situation		
Q14 (Cold and rainy weather)	4.02	1.41
Q15 (Personal belongings are left behind but the building is severely damaged)	2.23	1.15
Q16 (Persons with disabilities remain in the building but the building is severely damaged)	2.66	1.17
Q17 (Checking on office/lab when the building is severely damaged)	1.82	0.92
Others		
Q18 (Chemicals are stored in the building)	1.86	0.99
Q19 (Biohazardous materials are stored in the building)	1.93	1.08
Knowledge		
Q20 (Knowledge of toxicity of chemicals)	3.19	1.24
Q21 (Knowledge of physical hazards posed by chemicals)	3.13	1.23
Q22 (Knowledge of biohazards)	3.33	1.39

Note: *M* and *SD* represent the mean and standard deviation values, respectively. *M* values range from 1 to 6. For Q1–3 and 20–22, larger *M* values respectively indicate higher fear, greater likelihood, and elevated knowledge. For Q5–Q19, larger *M* values signify individual inclinations to reenter the vacated building.

Table 3: Zero-order correlation matrix (Questions 1, 2, 11, 20, and 21).

	2	3	4	5
1. Intention to reenter undamaged buildings (Q11)	-0.24^{***}	-0.35^{***}	−0.08	−0.07
2. Fear (Q1)		0.50^{***}	0.12	0.11
3. Likelihood of injury (Q2)			0.04	0.04
4. Knowledge of toxicity of chemicals (Q20)				0.90^{***}
5. Knowledge of physical hazards posed by chemicals (Q21)				

Note: ***: p <0.001.