International Journal of Disaster Risk Reduction 125 (2025) 105597

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Human reactions to the 2023 Al Haouz earthquake in Marrakech, Morocco: Findings from a survey within the UNESCO Global Geoparks community

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A B S T R A C T

This study investigates human behaviour during the 2023 Al Haouz earthquake in Morocco, focusing on the experiences of a homogeneous population of experts, represented by the participants of the 10th International Conference on UNESCO Global Geoparks in Marrakech. This unique event—a major earthquake coinciding with a meeting of experts in geological, natural and cultural heritage—offered a rare opportunity to analyze reactions during an earthquake within a specialized community. Data were collected through an online questionnaire distributed to the Global Geoparks community, exploring emotional responses, actions taken during the earthquake and knowledge of earthquake process and seismic hazard and risk. The research examines the influence of factors such as gender, age, professional background and previous earthquake experience on individual reactions. Findings revealed that fear was a common emotion, particularly among women. A significant portion of participants did not follow recommended safety procedures like "drop, cover, and hold on" instead opting for actions such as running outside the buildings. Implications of these findings for improving earthquake preparedness and resilience within the Global Geoparks community have been discussed. It has been stressed that targeted training and educational programs are necessary within the UNESCO Global Geoparks Network, for both local communities and Geopark staff, to improve the conversion of knowledge into effective earthquake safety practices.

1. Introduction

Earthquakes, unpredictable natural events, represent one of the greatest threats to human communities, with often catastrophic effects. In the UNDRR report, earthquakes are the type of disaster that cause the most significant number of victims (721,318 deaths) in the 20 years considered (2000–2019; [1]). Due to three major earthquakes (Turkey-Syria, Morocco, Afghanistan), in the year 2023, earthquakes also caused by far the greatest number of fatalities (62,451) in comparison with other types of disasters [2]. To mitigate the risk associated with seismic hazard and improve best practices in the event of an emergency, it is essential to understand in depth how people react during an earthquake.

Several questionnaire-based studies have examined human behavioural responses to earthquakes (e.g. Refs. [3–8]). However, the strong earthquake that occurred in Morocco in September 2023 provided an almost unique opportunity to analyze the human behaviour of scientists and experts in geological, natural and cultural heritage during a major earthquake. In fact, on the day of the seismic event, the 10th International Conference on UNESCO Global Geoparks was underway in the city of Marrakech.

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https://doi.org/10.1016/j.ijdrr.2025.105597
Received 7 April 2025; Received in revised form 19 May 2025; Accepted 21 May 2025
Available online 22 May 2025

This study, based on data collected from a questionnaire, explores how the international community of the UNESCO Global Geoparks, attending the above-mentioned Conference, reacted when faced with a seismic event, identifying factors that influenced risk perception, decision-making and resilience. The main goal of this paper is to extend the literature regarding human behaviour during and immediately after unexpected natural events within a defined community consisting of a group of people with identical interests and values. The collected data allowed a deeper understanding of individual and collective dynamics in critical situations, providing valuable insights into the development of more effective behaviour during an earthquake and the elaboration of strategies for seismic risk prevention.

2. The Al Haouz seismic event

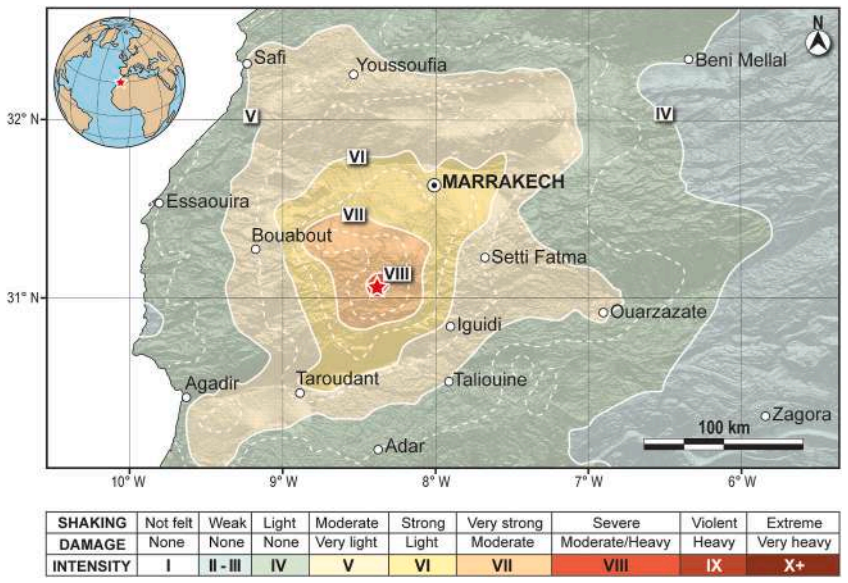
On September 8, 2023, at 22.11 UTC, the Al Haouz earthquake of magnitude Mw 6.8 occurred in the High Atlas mountains of Morocco (Fig. 1). The High Atlas region has been considered as a low-seismicity region with only a few big earthquakes recorded, including the devastating Mw 5.9 earthquake that destroyed the city of Agadir on February 29, 1960.

Nevertheless, the Al Haouz earthquake is now the strongest instrumentally recorded earthquake that ever occurred in Morocco and attests that the region is tectonically active (e.g. Ref. [9–11]). The hypocentre of the Al Haouz earthquake was located near the town of Adassil in the High Atlas mountains about 75 km southwest of Marrakech. The focal depth of the seismic event has been estimated between 19 km (USGS) and 25–27 km (European Mediterranean Seismological Centre (EMSC); [12,13]).

Based on geophysical observations, several papers provided the geodynamic model of the Al Haouz earthquake (e.g., Ref. [12–17]). However, the first updated tectonic framework of the Al Haouz earthquake epicentral area based on original field data collected during several years of geological-structural research preceding the seismic event, has been provided by Malusà et al. [18]. The Mw 6.8 earthquake was likely generated by rupture along a newly formed north-dipping high-angle fault, belonging to an orogen-scale WSW-ESE transpressional shear zone. Malusà et al. [18] highlighted that the geological evolution and seismotectonic structure of the Moroccan High Atlas was largely governed by the oblique convergence of tectonic plates, while the impact of asthenospheric uplift, if present, remains limited and may influence exclusively the geomorphological evolution of the Western High Atlas.

A macroseismic intensity map for the Al Haouz earthquake has been provided by the U.S. Geological Survey (https://earthquake.usgs.gov/earthquakes/eventpage/us7000kufc/dyfi/intensity) based on the effects reported by untrained Internet users by means of the "Did You Feel It?" (DYFI) system [19]. It points to a maximum intensity of 9.0 according to the Modified Mercalli Intensity (MMI) Scale in the epicentral area. The city of Marrakech falls between intensities 6.5 and 6.0, corresponding to strong/very strong shaking and damage to buildings ranging from slight to moderate/considerable.

The Al Haouz earthquake had a strong social impact. It caused 2946 fatalities, over 5500 injuries and the destruction of or damage to 60,000 houses in the epicentral area, including 580 schools. As a result, more than 500,000 people were initially displaced. Studies on post-traumatic stress disorder among survivors [20] and particularly in children and adolescents [21] from the epicentral area have been carried out. The earthquake was also felt in Spain, Portugal and Algeria, and impacted with great intensity Marrakech, a city of about 1 million inhabitants, where it caused numerous collapses of buildings—especially in the historic town—and 15 casualties.



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very heavy
INTENSITY	I	II - III	IV	V	VI	VII	VIII	IX	X+

Fig. 1. Macroseismic intensity map of the Mw 6.8 Al Haouz earthquake. Modified from USGS (https://earthquake.usgs.gov/earthquakes/eventpage/us7000kufc/dyfi/intensity). The dashed white lines represent the half-degree intensities.

3. Methodology

Following the Al Haouz earthquake, we created a questionnaire aimed at collecting the memories and emotional responses of the community of the UNESCO Global Geoparks Network, attending the 10th International Conference on UNESCO Global Geoparks, held in Marrakech on September 8, 2023, the day of the earthquake. The primary objective was to gain insight into how the earthquake was perceived, the immediate reactions and behaviors it triggered, and the level of awareness regarding seismic hazard and risk. A distinctive feature of the survey is its focus on a specific sample: the members of the Global Geoparks Network, typically well-versed in geological, natural, cultural heritage, and land management topics.

At the time of the main shock (11:11 p.m., local time), participants were not gathered at the conference venue but were instead dispersed throughout the city, either alone or in small groups. As a result, the survey captures individual experiences and behavioral responses to the earthquake. Importantly, none of the respondents or any conference participants reported physical harm or injuries resulting from the event.

The survey was developed starting from existing, available seismic survey provided by the following major international agencies: Felt Report – Tell Us! by USGS [19], BGS Earthquake Questionnaire by the British Geological Survey, Hai Sentito Il Terremoto (HSIT) by INGV - Istituto Nazionale di Geofisica e Vulcanologia [22], and Report an Earthquake by the Swiss Seismological Service at ETH Zurich. These models were tailored to the specific context of Marrakech and the distinctive characteristics of our target population.

The survey was developed using the Google Forms platform and was delivered and advertised through the Global Geopark Network media channels. Additionally, in order to reach as many conference participants as possible, an official email was sent by the conference organizers to all registered attendees. The survey was first released on March 2, 2024, and responses were accepted until April 30, 2024.

3.1. Survey structure

The final survey consists of 52 questions divided into four main sections: personal information (6 questions), professional background (part of the 6 above), experience of the earthquake in Marrakech (40 questions, across 9 thematic subsections), and knowledge and awareness of earthquakes (6 questions). The section on earthquake experience includes questions on the respondent's location at the time, perception and sensation of the tremor, immediate reaction, observed effects on people, animals, environment, and buildings, emergency relief, and lasting memories of the event.

The questionnaire was written in English, the working official language of the UNESCO Global Geoparks Network. Therefore, the respondents were able to understand the questions correctly. The average completion time was estimated to be between 5 and 15 min. Only a subset of questions regarding demographic information, perceived shaking, and position during the earthquake were mandatory.

The survey was predominantly composed of closed-ended questions, complemented by open-response options (e.g., "Other") to facilitate the collection of qualitative insights. Multiple-choice formats were employed where appropriate to enhance clarity and consistency in responses. To ensure respondent confidentiality, all responses were gathered anonymously. The complete survey is available in the supplementary material.

3.2. Methodological validity

The survey enables the rapid and large-scale data collection on individual experiences. Through this approach, we adopt a descriptive-analytical strategy aimed at systematically documenting the respondents' personal characteristics, professional background, reactions to the earthquake, and levels of earthquake awareness. Given the observational nature of the study and the characteristics of the target population, this descriptive approach allows for a structured and coherent analysis of patterns emerging from the collected responses.

4. Results

We received 180 completed questionnaires. More than 50 % of these forms (n = 100) were completed within the first 5 days of the survey's release date (March 2–6, 2024). The remaining responses came in sporadically later, with nearly all arriving within the first ten days of April 2024.

In general, the respondents answered all the questions, providing more than 8900 data. In this study, we focused only on considering and presenting the results regarding the emotional and behavioural reactions of the Global Geoparks community attending the 10th International Conference on UNESCO Global Geoparks in Marrakech. The analysis of findings from the questions on the effects of the earthquake on buildings, objects, and the environment will be presented and discussed in another specific paper.

Even if released six months after the seismic event, the survey appears to be consistent, as almost all respondents declared that they still have memories of the earthquake they felt in Marrakech, answering "yes" to the specific question Q49. "Months after the event, do you still have any memory of the earthquake?" (section "Memory of the earthquake" of the questionnaire; see supplementary material). This first result is in accordance with the "flashbulb memory" mechanism [23]: vivid, detailed and long-lasting memories of a significant and highly emotional event, such as those related to disasters from geological hazards. Factors related to flashbulb memory have been documented for earthquakes such as the 1989 Californian earthquake [24], the 1999 Marmara earthquake [25], and the 2008 Sichuan earthquake [26]. Intrusive memories among survivors of the 2016–2017 Central Italy earthquakes have been

documented twenty months after the seismic events [27].

4.1. Respondents

Of the 180 respondents, 57 % were male (n = 102) and 43 % were female (n = 78) (Table 1). We received feedback from participants across 40 countries worldwide. Although most responses came from Europe, a significant number also originated from North and South America and Asia.

Age is mainly concentrated in three decades, each representing about a quarter of the respondents: 35 to 44 (26 %; n = 47); 45 to 54 (25.5 %; n = 46); 55 to 64 (24 %; n = 43). 17 % (n = 31) claim to be between 25 and 34 years old, while the remaining 7 % (n = 13) are over 64 years old. The absence of any respondents under the age of 25 indicates that most Conference participants are university graduates. The specific question pointed out that 15.5 % (n = 28) hold a Bachelor's degree, 48 % (n = 87) hold a Master's degree, and as many as a third are PhDs (33 %; n = 60). 62 % of the respondents (n = 111) were geoscientists including people with a geological education. However, even those who state that they have no geoscience education (38 %; n = 69) hold positions in bodies or administrations (geoparks, regions, provinces, municipalities, non-profit organizations, government agencies, private companies) with responsibilities about land management, operating within existing or aspiring UNESCO Global Geoparks, or who are interested in the UNESCO Global Geopark model.

4.2. Emotional reactions during the earthquake

At the time of the main shake, 85 % of respondents (n = 153) were awake, and the remaining (n = 26) who were sleeping were awakened by the earthquake. It is noteworthy that a number of respondents (n = 14) accurately describe what they were doing (e.g., "We were on a drink and planning something to eat"; "I was walking in the city on the way to my hotel"; "I was eating in a restaurant"), attesting to the fact that those moments were well etched in the survey participants' memories.

Given that the earthquake occurred at the end of a conference day (11:11 p.m. local time), most respondents—members of the UNESCO Global Geoparks community gathered in Marrakech—were generally in small groups, either dining at restaurants or cafés, walking around, or participating in work-related meetings. At the time of the earthquake, however, the majority (76 %; n = 136) were indoors, while the remaining 24 % (n = 43) were outside, either near buildings or in open areas without surrounding structures.

The question Q22. "What did you feel during the earthquake?" was conceived to obtain information about reactions to the shaking. The answers were divided into 9 categories. Most of the respondents experienced a type of "fear" as 68.4 % (n = 123) declared that they felt extremely, very or somewhat frightened.

In terms of gender, the category "very frightened" (n = 41) is represented almost equally by females (54 %; n = 22) and males (46 %; n = 19). By contrast, an appreciable difference concerns the category "extremely frightened". Among the 21 respondents who had this reaction to the earthquake, 81 % (n = 17) were women aged between 25 and 64, with no particular concentration of a specific age range, apart from a slight prevalence for the 35–44 age group (n = 6). The "extremely frightened" category also does not seem to be significantly affected by professional skills. Again, the sample can be divided into two approximately equal parts between geoscientists (including people with geoscience education) and people with no geoscience education (10 and 11, respectively). When the overall reactions of women and men are compared, women experience more fear than men (Fig. 2).

Considering the two most frightened categories (extremely frightened, very frightened), the age range that experienced the greatest fear was 35–44 years old, followed by the range 25–34. Overall, therefore, we can show that the younger groups in our population sample were those who were most frightened by the earthquake. Conversely, those who were less frightened seemed to be members of the 45–54 age group, followed by the 55–64 age group. (Fig. 3).

Another possibly significant factor that has been analysed is the past experience with earthquakes (question Q21. "Was this your

Table 1
Characteristics of 180 respondents to the online survey.

	N	%
Gender		
Female	78	43.3
Male	102	56.6
Age		
<25	0	0.0
25–34	31	17.2
35–44	47	26.1
45–54	46	25.6
55–64	43	23.9
>64	13	7.2
Education		
Geoscientific	111	61.6
Other (no geoscientific)	69	38.3
Previous experience of earthquake		
Yes	108	60.6
No	70	39.3

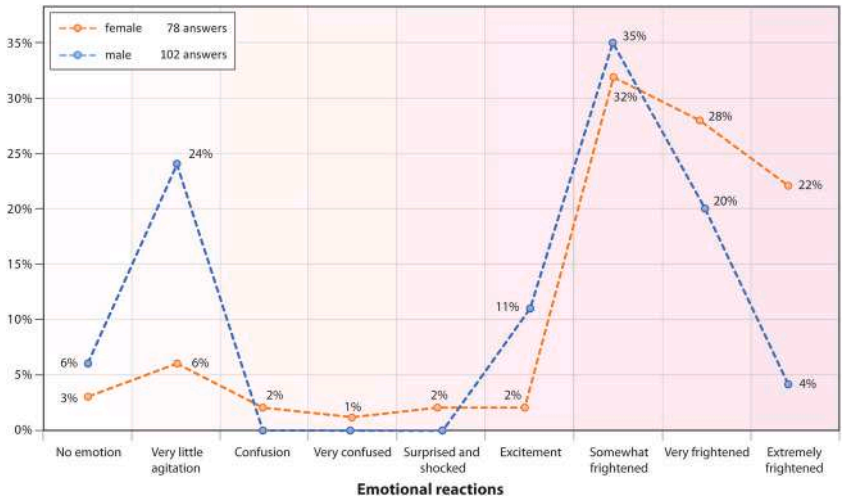


Fig. 2. Gender difference in emotional reactions to the earthquake. Answers to question Q22. What did you feel during the earthquake.?.

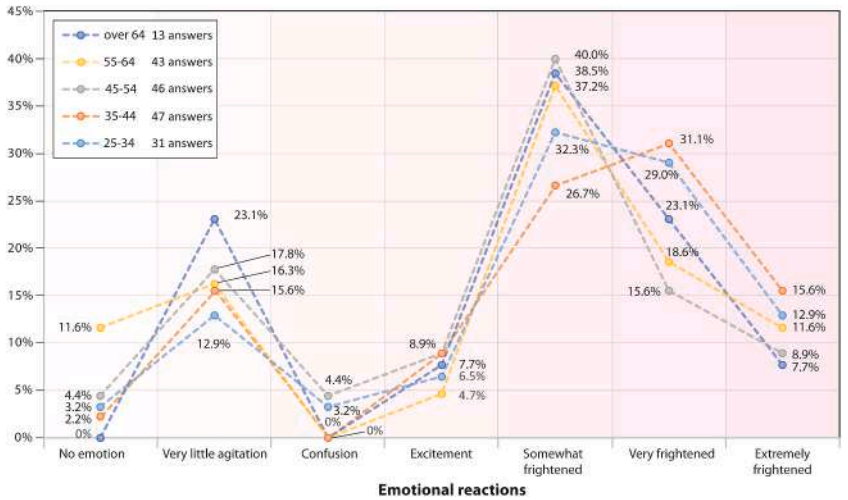


Fig. 3. Age group's differences in emotional reactions to the earthquake. Answers to question Q22. What did you feel during the earthquake.?.

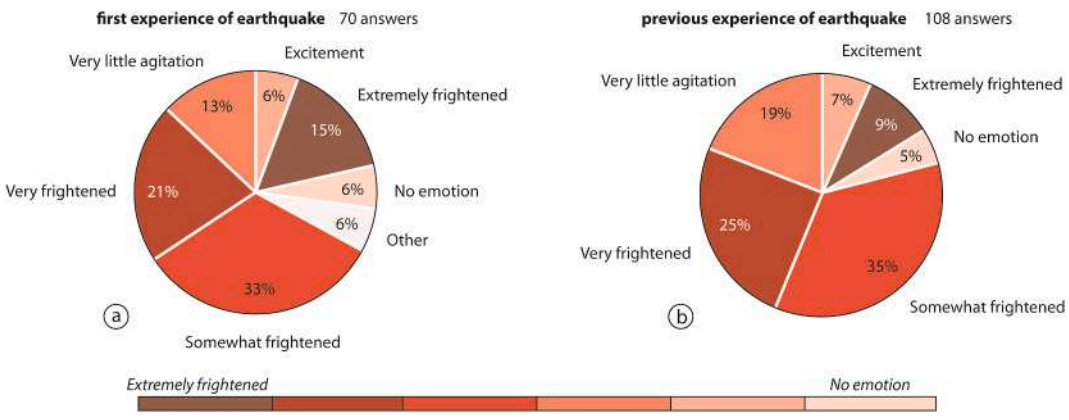


Fig. 4. Emotional reaction comparison between respondents who experienced the Al Haouz earthquake as their first experience of an earthquake (a) and respondents who had previous earthquake experience (b). Answers to question Q22. What did you feel during the earthquake.?.

first experience with an earthquake?"). 108 (60 %) respondents said they had experienced earthquakes before, while 70 (40 %) said the earthquake they felt in Marrakech was their first. Emotional reactions between the two groups differ mainly in the "extremely frightened" category with 15 % (11 out of 70) from those who experienced an earthquake for the first time versus 9 % (10 out of 108) from those who had previous earthquake experience (Fig. 4).

Considering the total number of answers, the emotional reactions from geoscientists and from people without geological education do not differ much, except for the "extremely frightened" category with percentages of 9 % and 16 %, respectively (Fig. 5). The "somewhat frightened" category also shows significantly different results (39 % vs. 26 %).

4.3. Behaviour during the earthquake

The question Q23. "How did you react to the earthquake?" was included in the survey to obtain information on the behavioural reactions of the Global Geoparks community during the earthquake. The possible answers were listed in five categories (plus the open-answer "other"; see the questionnaire in the supplementary material). The closed-answer "I moved away from walls and buildings" was designed to be addressed to those who were outside at the time of the main shock, and who were in a considerable number (compare the percentage of this answer with that of the answer to the question Q8. "Where were you during the earthquake?"; see chapter above *Emotional reactions during the earthquake*).

Fig. 6a shows the overall results. Approximately 25 % of the answers are concentrated on three categories ("I ran outside"; "I moved away from walls and buildings"; "I moved to a doorway"). 10 % of respondents "dropped and covered" and 17 % "took no action". Analysing the answers of females and males separately (Fig. 6b and c), it is noticeable that among females, the percentage of answers "I ran outside" rises (36 %), and fewer women acted by dropping and covering themselves (6 %). On the contrary, among men, the percentage of those running outside decreases significantly (17 %), while the category "I dropped and covered" increases slightly (13 %).

Answers to the same question (Q23. "How did you react to the earthquake?") from geoscientists and people without a geological background were also taken into consideration (Fig. 7). The results indicate that the percentage of answers "I dropped and covered" and "I ran outside" are comparable, and indeed non-geoscientists have a slightly higher percentage of answers "I dropped and covered" than geoscientists. Non-geoscientists also have a lower percentage of answers "I moved to a doorway" (17 % vs. 24 %).

In addition, the behavioural reactions of the survey respondents according to their country of provenance were investigated to check for possible differences in actions during the earthquake. We compared countries that provided the most replies (more than 9), selecting two from countries prone to earthquakes (Japan and Italy) and three from low seismic countries (Brazil, France, Germany) (Fig. 8). The highest percentage of response "I dropped and covered" came from Japan (45 %), which also shows the highest percentage (33 %) of "moving to a doorway". In contrast, nobody from Germany followed the "drop and cover" behaviour, while many Germans "ran outside" (46 %), followed in the ranking by the Italian respondents (33 %).

4.4. Basic knowledge of earthquakes

As for the sample population to which the questionnaire was addressed, the section dealing with basic earthquake knowledge and general seismic concepts is of particular significance. The first question is about the possibility of predicting an earthquake. Of the four possible answers (multiple answers could be indicated), most respondents indicated "No, you can only determine the hazard of an area", which is the correct answer (57 %; Fig. 9a). The percentage of this answer rises considerably when isolating the answers from geoscientists (70 %; Fig. 9b). Among non-geoscientists, the percentage of this answer drops (36 %; Fig. 9c), while the answer "I do not know" rises significantly (30 %).

The second question in this section still regards the possible location of earthquakes (Q44. "Is it true that earthquakes always occur

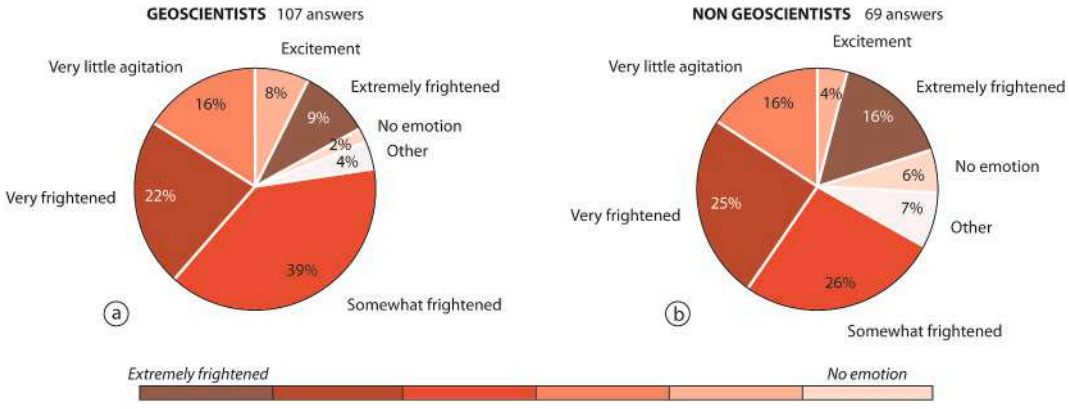


Fig. 5. Emotional reaction comparison between respondents who are geoscientists or people with geoscience education (a) and respondents who have no geoscience education (b). Answers to question Q22. What did you feel during the earthquake.?.

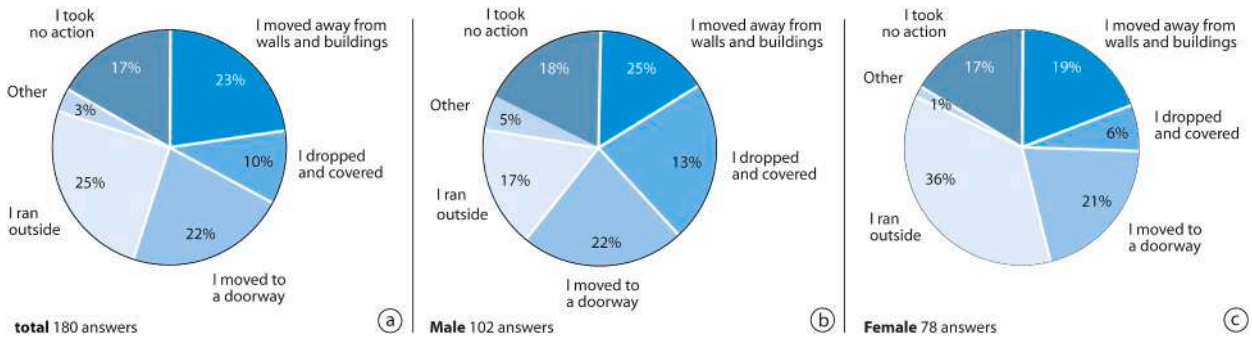


Fig. 6. Proportion of different behaviours undertaken as a first response to the earthquake for total respondents (a), male (b), and female (c). Answers to question Q23. How did you react to the earthquake.?.

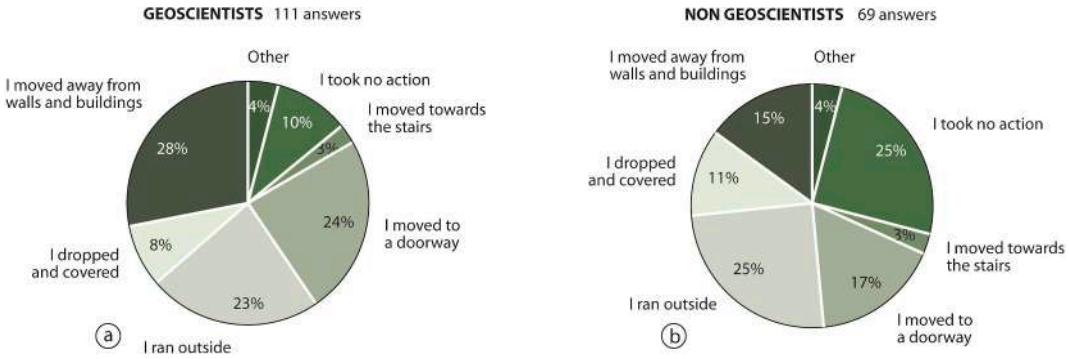


Fig. 7. Behavioural response comparison between respondents who are geoscientists or people with geoscience education (a) and respondents who have no geoscience education (b). Answers to question Q23. How did you react to the earthquake.?.

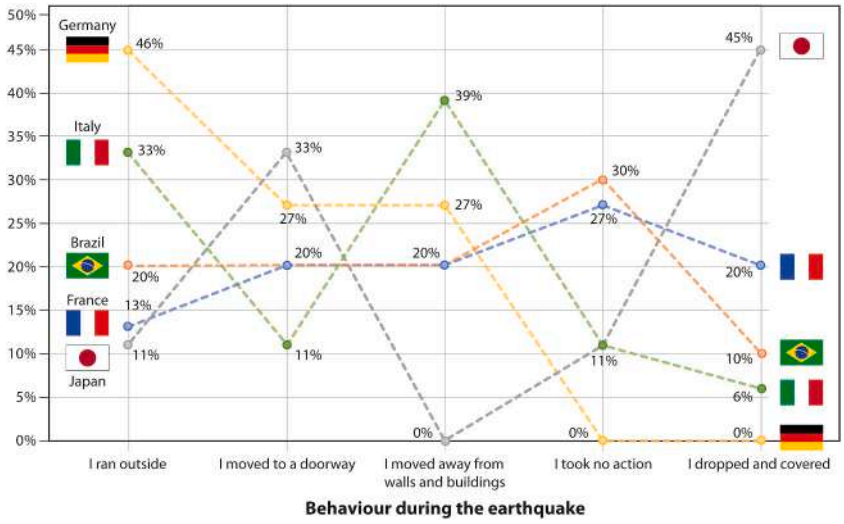


Fig. 8. Behavioural response comparison among countries prone to earthquakes (Japan, 9 answers; Italy, 18 answers) and countries with low seismicity (Brazil, 10 answers; France, 16 answers; Germany, 11 answers). Answers to the question Q23. How did you react to the earthquake.?.

in the same areas?). For this question, it was not possible to indicate multiple answers, and the suggested answers do not include all possible cases (e.g. intraplate earthquakes). Consequently, a considerable percentage of responses falls into the "Other" category (12 %; Fig. 10a), where respondents expressed objections that the question was not properly asked or specified different contexts where earthquakes may occur. However, the majority of respondents (56 %) indicated the answer we considered correct ("Yes, earthquakes always occur in the same areas …"). This percentage is raised by isolating the answers from geoscientists (66 %), while the same

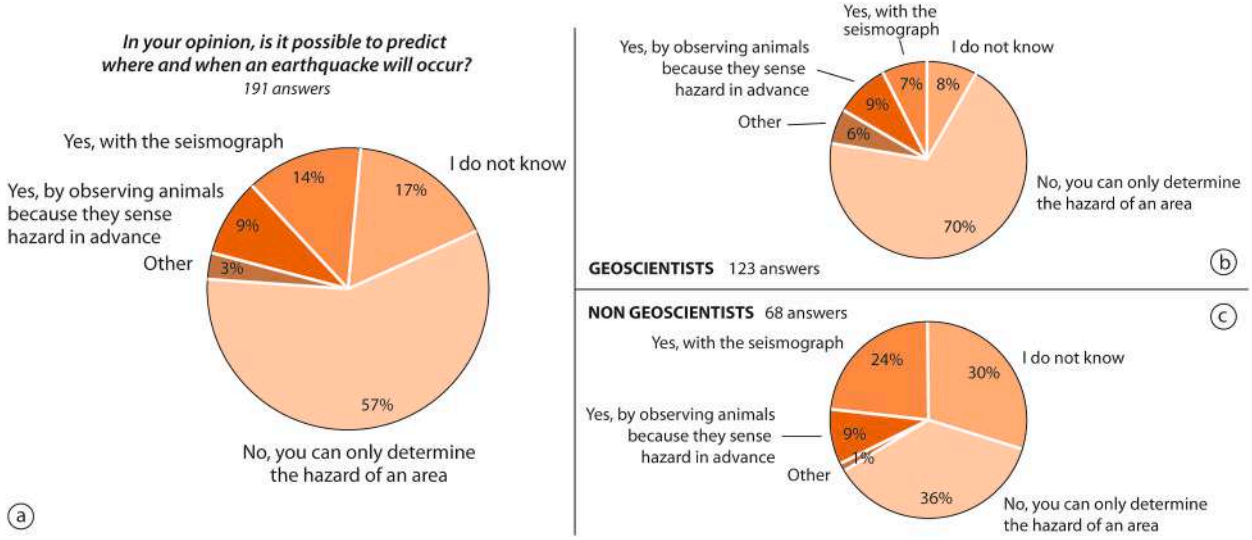


Fig. 9. Proportion of different answers about the possibility of predicting an earthquake for total respondents (a), geoscientists or people with geoscience education (b) and people without geoscience education (c). Answers to question Q43. In your opinion, is it possible to predict where and when an earthquake will occur? (multiple answers can be indicated).

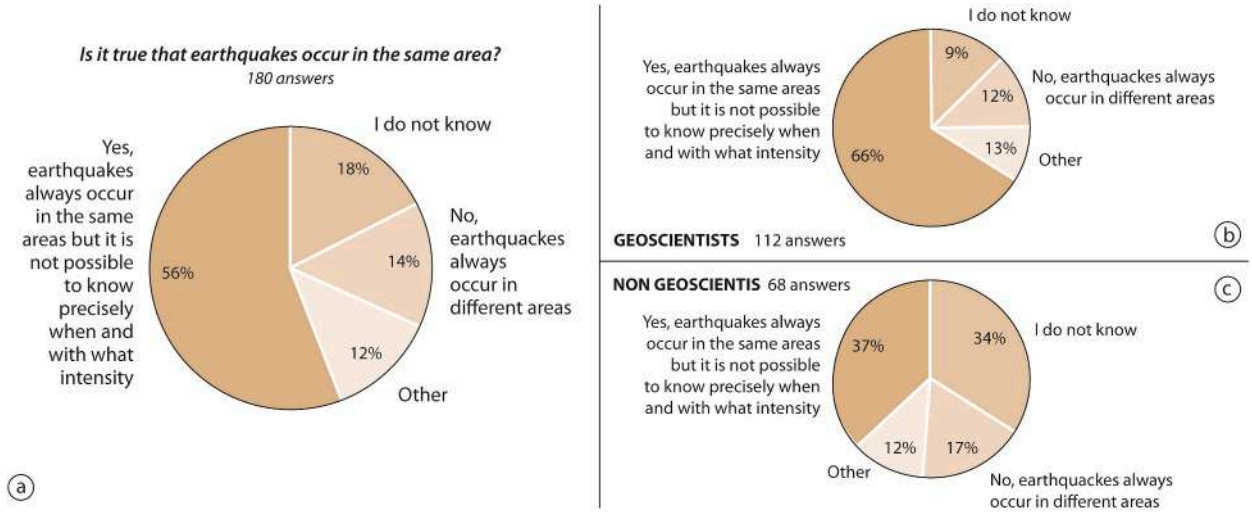


Fig. 10. Proportion of different answers about the possible location of earthquakes for total respondents (a), geoscientists or people with geoscience education (b) and people without geoscience education (c). Answers to question Q 44. Is it true that earthquakes always occur in the same areas.?.

percentage is considerably lowered among non-geologically educated (37 %), and at the same time the percentage of "I do not know" answers is greatly increased (34 % vs.18 % of the total responses) (Fig. 10b and c).

Two further questions were asked to find out whether the correct behaviour during an earthquake was known (question Q46. "Do you know how to behave properly during an earthquake?") and, if so, whether those who knew the correct behaviour actually followed it during the Marrakech earthquake (question Q47. "If you know the proper behaviour, did you follow it during the earthquake in Marrakech?"). Almost all geoscientists claim to know the correct behaviour to adopt during an earthquake (94 %; Fig. 11a). Even for non-geoscientists, the result is good (80 %; Fig. 11b). The self-assessment regarding the earthquake they felt in Marrakech indicates that although they know the correct behaviour to adopt, a significant number of geoscientists did not follow it completely during the earthquake (34 % Fig. 12a). Similar feedback is also shown for non-geoscientists (Fig. 12b), suggesting that some non-geoscientist respondents who did not know the proper practices during an earthquake behaved at least partially correctly.

A further question, crucial for the community to which the questionnaire was addressed, explored respondents' awareness of the distinction between seismic hazard and seismic risk (Q48. Do you know the difference between seismic hazard and seismic risk?). The majority of respondents (66 %) answered in the affirmative (Fig. 13a). In this question, the difference between responses from geoscientists and those without a geological background is very clear and significant. Among geoscientists, the affirmative responses in

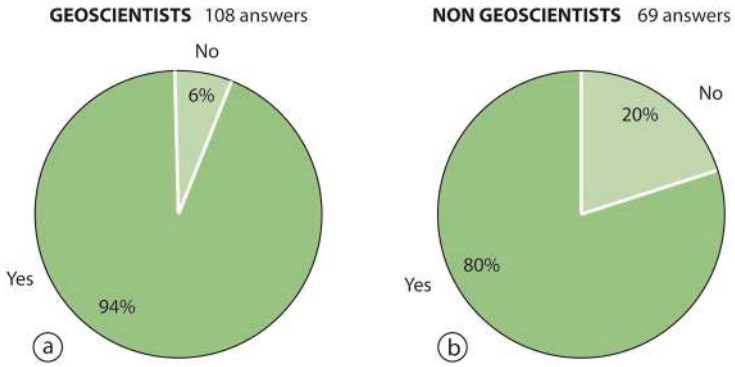


Fig. 11. Self-assessment of the knowledge of correct behaviour to follow during an earthquake. Comparison between responses from geoscientists or people with geoscience education (a) and people with no geoscience education (b). Answers to question Q46. Do you know how to behave properly during an earthquake.?.

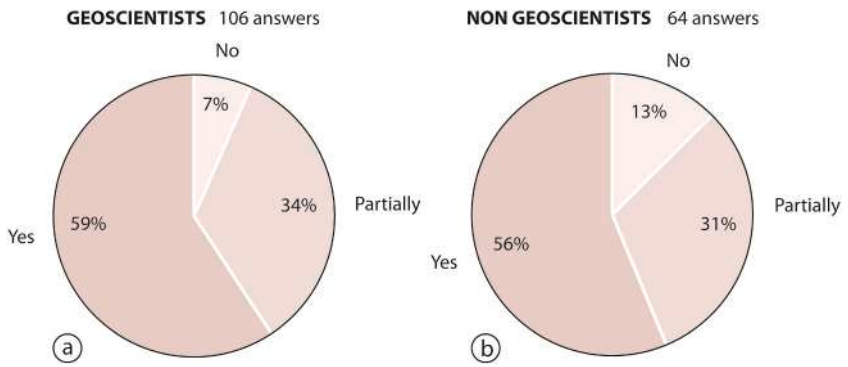


Fig. 12. Self-assessment of the behaviour followed during the Al Haouz earthquake. Comparison between responses from geoscientists or people with geoscience education (a) and people with no geoscience education (b). Answers to question Q47. If you know the proper behaviour, did you follow it during the earthquake in Marrakech.?.

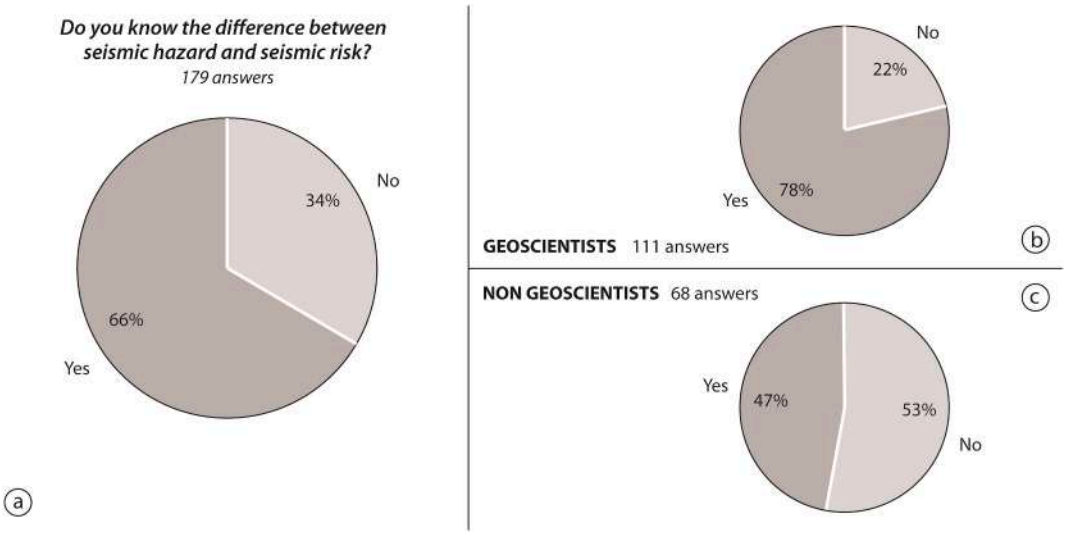


Fig. 13. Self-assessment on awareness of the concepts of seismic hazard and risk from total respondents (a), geoscientists or people with geoscience education (b) and people with no geoscience education (c). Answers to question Q48. Do you know the difference between seismic hazard and seismic risk.?.

fact rise to 78 % (Fig. 13b), while they decrease considerably to 47 % among other survey respondents/congress participants without a geological background (Fig. 13c).

5. Discussion

Our study seeks to investigate the emotional reactions and behavior of the Global Geoparks community who experienced the earthquake that struck Morocco in September 2023 in Marrakech. Demographic factors, including gender, age, professional background, previous experience of earthquakes, and regional provenance, that could have influenced people's reactions to the seismic shaking have been examined.

5.1. Reactions and behaviours during the earthquake

The emotion that was reported as the most experienced by respondents (almost 7 out of 10) during the earthquake was fear. The finding that women experienced more fear than men is consistent with previous studies on earthquake disasters showing that emotional reactions are influenced by individual differences such as gender [3–7,28].

The data analysis showed that age difference does not seem to influence significantly the reaction to the shaking, although a tendency in the younger age groups (25–34 and 35–44 age groups) to react with more fear can be highlighted. Other papers (e.g., Ref. [6]) have pointed out that the feeling of greater fear due to the earthquake was mostly recorded in younger age groups. Our population sample is completely over 25 years old, and therefore the concept/factor of "youth" in our case can only be relative and not comparable with the other examples in literature that included ages down to 18 or below [6,7].

Past experience with earthquakes has been significantly correlated with a lower level of fear [6,7]. Our study does not clearly show this direct connection, except partially for the category with the highest level of fear ("extremely frightened"). Jon et al. [29] pointed out that the experience of earthquakes did not teach people how to react and behave properly in subsequent earthquakes.

Professional skills and educational background seem to have had little influence on emotional reactions to the earthquake and still need to be carefully examined in order to be considered as significant individual differences. Gender instead seems to be the most relevant as a significant individual difference. In fact, in our survey, gender also significantly influenced behaviour during the earthquake. Among the behaviour categories, the most noticeable difference between men and women can be observed in the category "ran outside from building" (17 % vs. 36 %). Conversely, behaviour "dropped and covered" was followed by 13 % of men and 6 % of women.

The direct association between earthquake shaking intensity and response behaviour has been documented [4]: for earthquakes of strong shaking intensity (USGS CDI$\geq$6.6), the propensity of persons to run outside the buildings is very high. Bernardini et al. [30] determined that evacuation or physical movement usually begins from approximately intensity MMI 5. Therefore, our results concerning this topic for the 2023 earthquake felt in Marrakech (MMI = 6.5-6.0) would seem to confirm previous studies.

Similarly, higher levels of expressed fear (very/extremely frightened) were also associated with respondents' propensity to evacuate the building quickly [4,6]. However, this conclusion is more controversial, and, for example, Lindell et al. [7] have found that the level of emotional reaction did not strongly determine the action taken by people during an earthquake.

Regarding this possible correlation, the analysis of the results of our survey seems to confirm that those who had felt feelings of fear had a greater impulse to evacuate the building they were in at the time of seismic shaking. Fig. 14 highlights the comparison between emotional reactions and behaviours. Frightened people (somewhat, very, and extremely frightened) show the highest percentages in the "ran outside" category (35 %, 24 %, and 33 %, respectively). Furthermore, frightened people have the lowest percentages of the behaviour category "dropped and covered" (5 % for somewhat and extremely frightened; 10 % for very frightened), even though these are closer to the percentages of the other reaction categories, apart from the "excitement" category which shows the highest percentage (33 %).

As to be expected, the respondents who felt "very little agitation" and "no emotion" are those who took no action (38 % and 22 %, respectively). It should be noted that the "extremely frightened" category has a "no action" percentage (19 %) not too much lower than the previous ones, indicating that in some cases fear exerts a freezing effect on movement/action [5,7,31,32]. Moreover, the study by Sun and Liu [33] indicated that a stronger fear reaction resulted in a greater probability of self-protective action. Further researches seem necessary to examine the relationship between the feeling of fear and the development of safety behaviours during earthquakes.

5.2. Safety practices during earthquakes

The prevailing internationally recommended appropriate protective action to take during an earthquake is to "drop, cover and hold on''. This practice is generally accepted by countries with a high seismic hazard/risk, including Chile, Japan, New Zealand, Turkey, and the USA, which have carried out and continue to carry out public campaigns to raise awareness on the correct behaviour to adopt during an earthquake (e.g., www.shakeout.org, www.earthquakecountry.org, www.civildefence.govt.nz). The "Drop, Cover, and Hold On" protective procedure seems to be the best strategy to reduce injuries and deaths during earthquakes and is replacing other possible safety actions including building evacuation, sheltering in doorways, and the highly debated "Triangle of Life" advice (www.earthquakecountry.org/dropcoverholdon). However, exceptions to the "Drop, Cover and Hold On" rule may apply in countries with non-engineered, mud-brick constructions. In this case, moving quickly outside the building into an open space could be recommended as a safety action [34].

In terms of earthquake-resistant construction, Morocco is a very uneven country with vast rural areas with mud-brick buildings,

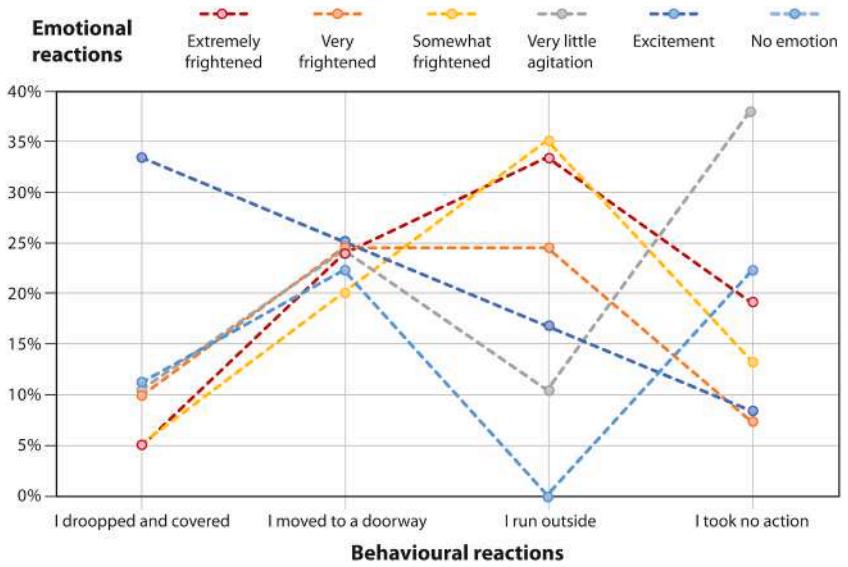


Fig. 14. Emotional reaction profiles associated with behavioural reactions.

and cities with modern buildings designed according to the Moroccan paraseismic regulations [35,36]. The city of Marrakech includes both these differences, with an old historic town centre and modern outer districts. As mentioned above, due to the distance from the epicentral area, the Al Haouz earthquake hit Marrakech with an intensity of 6.5–6.0 on the Modified Mercalli Intensity Scale, meaning slight to considerable damage to buildings depending on their construction characteristics.

Almost all studies on injuries caused by earthquakes have shown that movement during strong earthquakes increases the risk of injury, whether inwards to seek shelter under furniture, or outwards from buildings [4]. Based on the above considerations, it can therefore be argued that even in Marrakech during the Al Haouz earthquake the most recommendable protective action was probably the "Drop, Cover, and Hold On" procedure.

Our study highlighted that the prevailing behaviour was to run outside buildings and that, in general, the impulse to physical movement was the outstanding feature (Fig. 6). These results are consistent with the earlier papers that documented that flight from buildings is the high-frequency response and that compliance with official recommendations of proper behaviour is generally low (Alexander, 1995; Zhou et al., 2018; [4,30]). Overall, about 70 % of the respondents to our survey reported improper behaviour for their own safety during the earthquake in Marrakech, i.e. they "ran outside", "moved to a doorway" or "took no action" (Fig. 6). It should be emphasized that responses falling into the category "moved away from walls and buildings", which were considered as coming from people who were outside buildings during the seismic shock, were assessed as being part of safe behaviours. As already said, even though response behaviour to the earthquake did not follow the recommended procedure(s), none of the UNESCO Global Geoparks Conference participants who responded to the survey was injured.

Although the Global Geoparks community is aware of the correct behaviour to adopt during an earthquake (88 %; Fig. 11), those who put the appropriate procedure (drop, cover and hold on) into practice were a small minority (10 %; Fig. 6). Professional skills derived from a geological education did not favourably influence safety behaviour(s), as the completely tested population sample gave uniform responses in this respect. The emotional dimension therefore seems to be more important in personal emergency management than the scientific aspect knowledge.

A further point for discussion may derive from the analysis of behaviours according to the countries of provenance of the respondents. Participants from Japan provided the best performance in terms of correct behaviour ("dropped and covered"). Japan is highly prone to earthquakes, and the Japanese population has developed a deep-rooted understanding of seismic hazard due to historical experience of devastating earthquakes, cultural emphasis on resilience and adaptability, and, most notably, participation in regular earthquake drills and public awareness campaigns to educate community to highly effective disaster reduction practices (e.g., www.jishin.go.jp; www.bousai.go.jp; https://www.bousai.metro.tokyo.lg.jp/content/e_book_04/guide-english/pdf/guide-english.pdf; www.jma.go.jp). As a result, the Japanese are probably much more prepared to act correctly during earthquakes, than Europeans and all other populations worldwide.

5.3. The role of the UNESCO Global Geoparks community

Since natural hazards can have negative impacts on human communities, as well as on natural and cultural heritage, UNESCO Global Geoparks promote awareness of geological hazards, including earthquakes. Within one of their main focus areas, Geological Hazards Risk Reduction, several UNESCO Global Geoparks developed educational activities for local people and visitors providing scientific information on the earthquake process and on best response strategies for building more resilient communities (e.g., [37–39]). UNESCO Global Geoparks have been very active in organising events (workshops, seminars, drills, etc.) for the International

Day for Disaster Risk Reduction, which is celebrated every year on October 13 (https://webarchive.unesco.org/web/20220328144140/https://en.unesco.org/commemorations/disasterreductionday#ugg).

Geological structures and landforms as well as damaged or destroyed buildings and infrastructures linked to the earthquake process have been identified of geo-educational and geotourism interest (e.g. Ref. [40–42]). Exhibition/interpretative centers and geosites about seismic hazard and risk were set up in a number of UNESCO Global Geoparks (e.g. Itoigawa and Muroto in Japan, Bohol Island in Philippines, Lesvos and Vikos-Aoos in Greece, Terras de Cavaleiros in Portugal, Kula-Salihli in Turkey, Tabas in Iran).

Nevertheless, the findings of our study highlighted the discrepancy between knowledge and action. In fact, despite a high level of geological expertise within the surveyed group (62 % are geoscientists), only 10 % followed the recommended safety protocol, revealing a critical gap between knowledge and actual behaviours during the seismic event. In our case study, emotional responses, such as fear, appeared to override professional training. Therefore, further actions must be undertaken for developing targeted educational initiatives that enhance comprehension and promote informed decision-making within the UNESCO Global Geoparks. These earthquake preparedness programs must be undertaken not only aimed at the local communities living in Geoparks but also, and primarily, at the teams of the Geoparks, including geoscientists as well as staff without geological education.

Global Geoparks from earthquake-prone territories should further develop initiatives starting from the regular training on earthquake topics and seismic disaster preparedness for their managers and teams, including exercises aimed at reducing injury and increasing survivability. Our study underscores the significance of incorporating stress resilience training into earthquake preparedness programs, even for experts, empowering individuals to maintain composure and follow safety protocols during high-stress events.

Concurrently, Global Geoparks should promote good practices addressed to the communities living in their territories for improving education and communication on seismic disaster risk reduction. It is crucial for geoscientists, and Geoparks staff in particular, to clearly define and communicate seismic hazard and seismic risk as different concepts.

As evidenced by the above-cited example of Japan, education is of crucial importance for earthquake disaster prevention and the achievement of this goal should be supported by science-based dissemination of tools and initiatives targeted to a broad audience. A good starting point could be example from the Japan Meteorological Agency that uses an illustrated version of the MMI Intensity Scale as a prescriptive tool to suggest that at higher intensity levels safety behaviours, as “drop, cover and hold on”, are recommended (https://www.jma.go.jp/jma/en/Activities/intsummary.pdf). As it is important to start training and education at an early age, earthquake awareness programs can benefit from a playful learning approach, as well as the use of serious games, whereas audiovisual products represent the best way to promote risk awareness and education of the general public (Musacchio et al., 2016; [43]). Social media should also be used as an essential communication tool for the young generation to convey correct information on seismic processes and the concepts of correct seismic prevention practices.

All documentation and information disseminated through the possible different channels (printed leaflets and guidelines, online platforms and websites, educational television programs, face-to-face seminars and training) should use scientifically correct but straightforward language that is easy to read and understand for people of all cultural levels. Messages should be targeted and adapted to different social groups to meet different needs, as well as to peculiarities in each country due to the geological, cultural and historical background, and construction techniques. As the communication process is a complex issue, the delivery on seismic hazard and risk should involve geoscientists but should also benefit from the input of experts in other disciplines, such as engineering, communication, sociology and psychology.

It was emphasized that regular reminders on earthquake preparedness are necessary to enable people to not only be aware of but to actually adopt best practices before, during and after an earthquake (Tekeli-Yesil et al., 2020). Disaster preparedness should become a common topic that would increase community resilience. The best result should be achieved if risk communication becomes a two-way process in which the public and risk communicators are engaged in a dialogue rather than acting as receivers and senders [44,45].

Within the UNESCO Global Geoparks programme, the global and regional (e.g., European, Asia-Pacific; www.globalgeoparksnetwork.org/organization/working-groups) networks working groups on geohazards may play a valuable role in coordinating communication on earthquake knowledge and exchanging experiences on seismic hazard awareness and disaster mitigation strategies. Overall, these activities will build important capacities and contribute to creating more resilient communities, with the knowledge and skills to respond effectively to potential geological hazards in Geoparks, territories of outstanding natural and cultural value.

6. Limitations

Although the data collection process and the methodology used for the analysis allow for a structured and coherent assessment, some limitations must be acknowledged. First, respondents constitute a specific and specialized group, which may limit the generalizability of the findings. Nonetheless, their domain-specific expertise reinforces the reliability and relevance of the collected data. Second, the delay between the event and the distribution of the survey may have affected the accuracy of respondents’ recollections, potentially introducing recall bias. However, this temporal distance may also help mitigate immediacy-related distortions in emotional perception, allowing for a more reflective answer.

Finally, the voluntary nature of participation may have skewed the dataset toward individuals with stronger emotional reactions or greater professional interest in the subject, who may have been more likely to respond. This introduces a potential self-selection bias as well as response bias, since participants may have provided answers that reflect their motivations or expectations rather than their actual experiences.

Nevertheless, these limitations do not undermine the internal consistency of the findings, which remain valuable for investigating

and understanding human reactions to the 2023 Al Haouz earthquake.

7. Conclusions

Our study investigated the emotional and behavioural responses of the UNESCO Global Geoparks community attending the 10th International Conference in Marrakech during the 2023 Al Haouz earthquake. The main findings include.

- Prevalence of fear: fear was the dominant emotion experienced during the earthquake. Women reported experiencing more intense fear than men did. Prior earthquake experience and a professional background in geoscience had limited impact on emotional reactions.
- Prevalence of flight from buildings: running outside buildings was the most common behaviour during the earthquake, and the impulse to the physical movement was the most prominent feature observed. Only a small percentage of respondents followed the recommended "drop, cover, and hold on" procedure. Again, fear seems to have a decisive influence on behaviour during the earthquake.
- Discrepancy between knowledge and action: while most respondents were aware of the recommended safety procedure ("drop, cover, and hold on"), a majority did not follow it during the earthquake, instead opting for less safe behaviours.
- Need to improve training on earthquake process and seismic hazard/risk: despite the educational focus of UNESCO Global Geoparks' educational focus on geological hazards, including earthquakes, the Conference attendees demonstrated a gap between knowledge and practice. This highlights the need for Geoparks to strengthen training and drills for their own teams and to promote further effective earthquake preparedness strategies within their communities. Our findings suggested that emotional responses could override knowledge in emergency situations, emphasizing the importance of practical training and drills in addition to scientific knowledge.

In summary, this study contributes to a deeper understanding of how emotions influence behavior during seismic events and has served as a real-world assessment of earthquake preparedness within the UNESCO Global Geoparks community, highlighting the need for enhanced training efforts.

CRediT authorship contribution statement

Giuseppe Ottria: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Alessandro Ellero:** Writing – review & editing, Visualization, Methodology, Formal analysis, Conceptualization. **Chiara Frassi:** Writing – review & editing, Visualization, Methodology. **Alessia Amorfini:** Methodology, Funding acquisition, Conceptualization. **Ilaria Rosani:** Writing – review & editing, Methodology. **Mattia Benato Cortecci:** Writing – review & editing, Methodology, Formal analysis.

Funding

This research was funded by the Apuan Alps Regional Park-UNESCO Global Geopark within the framework of the memorandums of understanding with the National Research Council of Italy (Institute of Geosciences and Earth Resources, Pisa) and the Department of Earth Sciences at Pisa University, respectively.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to express our sincere gratitude to Nickolas Zouros, Setsuya Nakada and Charalampos Fassoulas for their critical review of the questionnaire, which greatly contributed to enhancing both its content and effectiveness. We also wish to thank Driss Achball for spreading the survey and all those who responded to the survey, providing valuable information for the critical analysis of the results. Special thanks to Hassan Ouanaimi for his contribution to the discussion on the geological significance of the seismic event. We also acknowledge the two anonymous reviewers for their valuable comments.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2025.105597.

Data availability

Data will be made available on request.

References

[1] UNDRR United Nations Office for Disaster Risk Reduction. The human cost of disasters: an overview of the last 20 years (2000-2019), 2020. Available at: https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019.

[2] CRED Centre for Research on the Epidemiology of Disasters. Disasters in numbers: a significant year of disaster impact, 2024. https://files.emdat.be/reports/2023_EMDAT_report.pdf.

[3] J.D. Goltz, L.A. Russell, L.B. Bourque, Initial behavioral response to a rapid onset disaster: a case study of the October 1, 1987 Whittier narrows earthquake, Int. J. Mass Emergencies Disasters 10 (1) (1992) 43–69.

[4] J.D. Goltz, H. Park, G. Nakano, K. Yamori, Earthquake ground motion and human behavior: using DYFI data to assess behavioral response to earthquakes, Earthq. Spectra 36 (3) (2020) 1231–1253, https://doi.org/10.1177/8755293019899958.

[5] G. Prati, V. Catufi, L. Pietrantoni, Emotional and behavioral reactions to tremors of the Umbria-Marche earthquake, Disasters 36 (3) (2012) 439–451.

[6] G. Prati, E. Saccinto, L. Pietrantoni, C. Pérez-Testor, The 2012 northern Italy earthquakes: modeling human behavior, Nat. Hazards 69 (2013) 99–113.

[7] M.K. Lindell, C.S. Prater, H.C. Wu, S. Huang, D.M. Johnston, J.S. Becker, H. Shiroshita, Immediate behavioral responses to earthquakes in Christchurch, New Zealand and Hitachi, Japan, Disasters 40 (1) (2016) 85–111.

[8] R. Kimura, S. Ohtomo, N. Hirata, A study on the 2016 Kumamoto earthquake: citizen's evaluation of earthquake information and their evacuation and sheltering behaviors, J. Disaster Res. 12 (6) (2017) 1117–1138, https://doi.org/10.20965/jdr.2017.p1117.

[9] B. Delcaillau, M. Amrhar, M. Namous, E. Laville, K. Pedoja, O. Dugué, Transpressional tectonics in the marrakech high atlas: insight by the geomorphic evolution of drainage basins, Geomorphology 134 (3–4) (2011) 344–362.

[10] M. Sébrier, L. Siame, E.M. Zouine, T. Winter, Y. Missenard, P. Leturmy, Active tectonics in the Moroccan high atlas, compt, Rendus Geosci. 338 (1–2) (2006) 65–79.

[11] A. Ellero, M.G. Malusà, G. Ottria, H. Ouanaimi, N. Froitzheim, Transpressional structuring of the high Atlas belt, Morocco, J. Struct. Geol. 135 (2020) 104021.

[12] W.L. Yeck, A.E. Hatem, D.E. Goldberg, W.D. Barnhart, J.A.T. Jobe, D.R. Shelly, P.S. Earle, Rapid source characterization of the 2023 M w 6.8 Al Haouz, Morocco, Earthquake, Seism. Rec. 3 (4) (2023) 357–366.

[13] K. Huang, G. Wei, K. Chen, N. Zhang, M. Li, L. Dal Zilio, The 2023 Mw 6.8 Morocco Earthquake: a lower crust event triggered by mantle upwelling? Geophys. Res. Lett. 51 (2024) e2024GL109052.

[14] D. Cheloni, N.A. Famiglietti, C. Tolomei, R. Caputo, A. Vicari, The 8 September 2023, MW 6.8, Morocco earthquake: a deep transpressive faulting along the active high Atlas mountain belt, Geophys. Res. Lett. 51 (2) (2024) e2023GL106992.

[15] A. Nouayti, L.E. Moudnib, D. Khattach, M. Zeckra, N. Nouayti, O. Saadi, K. Elhairechi, B. Oujane, H. Iken, Seismic synthesis of the Al Haouz earthquake of September 8th, 2023 by integrating gravimetric and aeromagnetic data from the western high Atlas in Morocco, Model. Earth Syst. Environ. 10 (2024) 6639–6658, https://doi.org/10.1007/s40808-024-02148-3.

[16] F. Carboni, M. Occhipinti, R. Lanari, F. Medina, T.E. Cherkaoui, R. Gaspari, C. Faccenna, C. Chiarabba, M. Porreca, Strain partitioning and fault interaction during the 2023 Mw 6.8 Al-Haouz earthquake, Western High Atlas, Morocco, J. Struct. Geol. 195 (2025) 105394.

[17] A. Qarbous, Y. Timoulali, C. Hoepffner, A. Chalouan, L.A. Ouzzaouit, F.Z. Allaki, K. Bargach, Update on the Compressional tectonic evolution of the Tizi n'Test Fault zone (western high Atlas) and its Relation to the Al-Haouz Earthquake of 8 September 2023, Bull. Seismol. Soc. Am. (2025), https://doi.org/10.1785/0120240212.

[18] M.G. Malusà, A. Ellero, G. Ottria, Tectonics of the Mw 6.8 Al Haouz earthquake (Morocco) reveals minor role of asthenospheric upwelling, Tectonophysics 891 (2024) 230533, https://doi.org/10.1016/j.tecto.2024.230533.

[19] D.J. Wald, V. Quitoriano, C.B. Worden, M. Hopper, J.W. Dewey, USGS "Did You Feel It?" Internet- based macroseismic intensity maps, Ann. Geophys. 54 (2011) 688–709, https://doi.org/10.4401/ag-5354.

[20] Y. Amara, I. Hanine, J. Salim, M. Gartoum, K. Mouhadi, M. Kadiri, Assessment of post-traumatic stress disorder in survivors of the Al Haouz earthquake, SAS J Med 10 (9) (2024) 957–961.

[21] Z. El Maataoui, B. Bensaleh, H. Kisra, Assessment of post-traumatic stress disorder in children and adolescents surviving the El Haouz earthquake: a study of 69 cases, Sch Acad, J Biosci 12 (9) (2024) 285–290.

[22] P. Tosi, V. De Rubeis, P. Sbarra, D. Sorrentino, Hai Sentito Il Terremoto (HSIT), Istituto Nazionale di Geofisica e Vulcanologia (INGV), 2007, https://doi.org/10.13127/hsit.

[23] R. Brown, J. Kulik, Flashbulb memories, Cognition (The Hague) 5 (1) (1977) 73–99.

[24] U. Neisser, E. Winograd, E.T. Bergman, C.A. Schreiber, S.E. Palmer, M.S. Weldon, Remembering the earthquake: direct experience vs. hearing the news, Memory 4 (4) (1996) 337–357, https://doi.org/10.1080/096582196388898.

[25] N. Er, A new flashbulb memory model applied to the Marmara earthquake, Appl. Cogn. Psychol. 17 (2003) 503–551, https://doi.org/10.1002/acp.870.

[26] J. Qiu, H. Li, Q. Zhang, L. Huang, Y. Guo, S. Tu, T. Wang, D. Wei, Electrophysiological evidence of personal experiences in the great Sichuan earthquake impacting on selective attention, Sci. China Ser. C Life Sci. 52 (2009) 683–690, https://doi.org/10.1007/s11427-009-0076-6.

[27] A. Massazza, H. Joffe, E. Parrott, C.R. Brewin, Remembering the earthquake: intrusive memories of disaster in a rural Italian community, Eur. J. Psychotraumatol. 13 (1) (2022) 2068909, https://doi.org/10.1080/20008198.2022.2068909.

[28] J.D. Goltz, Status and power differentials in the generation of fear in three California earthquakes, Int. J. Disaster Risk Reduct. 16 (2016) 200–207.

[29] I. Jon, M.K. Lindell, C.S. Prater, S.-K. Huang, H.-C. Wu, D.M. Johnston, J.S. Becker, H. Shiroshita, E. Doyle, S. Potter, J. McClure, E. Lambie, Behavioral response in the immediate aftermath of shaking: earthquakes in Christchurch and Wellington, New Zealand, and Hitachi, Japan, Int. J. Environ. Res. Publ. Health 13 (2016) 1137, https://doi.org/10.3390/ijerph13111137.

[30] G. Bernardini, R.M. Lovreglio, E. Quagliarini, Proposing behavior-oriented strategies for earthquake emergency evacuation: a behavioral data analysis from New Zealand, Italy and Japan, Saf. Sci. 116 (2019) 295–309.

[31] L.B. Bourque, L.A. Russell, J.D. Goltz, Human behavior during and immediately after the earthquake, in: P.A. Bolton (Ed.), The Loma prieta, California, Earthquake of October 17, 1989: Public Response, Professional Paper 1553-B. United States Geological Survey, Washington, DC, 1993, pp. 3–22.

[32] A. Massazza, C.R. Brewin, H. Joffe, Feelings, thoughts, and behaviors during disaster, Qual. Health Res. 31 (2) (2021) 323–337, https://doi.org/10.1177/1049732320968791.

[33] L. Sun, X. Liu, Unpacking immediate public behavioral responses to earthquakes: a study focusing on the role of fatalism and fear, Earthq. Spectra 39 (4) (2023) 2173–2192, https://doi.org/10.1177/87552930231189701.

[34] GeoHazards International, Developing messages for protective actions to take during earthquake shaking. https://4649393f-bdef-4011-b1b6-9925d550a425.filesusr.com/ugd/08dab1_49df199bcf44453f939c5777fa75c18a.pdf, 2018.

[35] Ministère de l'Habitat et de la Politique de la Ville. Le Règlement de Construction Parasismique (RPS 2000), 2011. https://www.mhpv.gov.ma/wp-content/uploads/2018/03/reglement-parasismique-2000.pdf.

[36] OECD. OECD Review of Risk Management Policies in Morocco, OECD Publishing, Paris, 2017. https://doi.org/10.1787/9789264276482-en.

[37] I.B.O. Agastya, E.T. Paripurno, B. Prastistho, H. Murwanto, J.D. Prasetya, A.R.B. Nugraho, Model media learning for disaster risk reduction in the Batur UNESCO global Geopark, International Journal of Geoheritage and Parks 12 (2024) 353–366.

[38] C. Fassoulas, M. Watanabe, I. Pavlova, A. Amorfini, E. Dellarole, F. Dierickx, UNESCO global Geoparks: living laboratories to mitigate natural induced disasters and strengthen communities' resilience, in: L. Antronico, F. Marincioni (Eds.), Natural Hazards and Disaster Risk Reduction Policies. Geographies of the Anthropocene Series Books, Il Sileno Edizioni, Rende (CZ), Italy, 2018, pp. 175–197.
[39] X. Mir Pellicer, A.S. Aytaç, A. Amorfini, in: S. Delaby (Ed.), Geohazards in European Geoparks, Akademisyen Publishing, Ankara, 2024. https://doi.org/10.37609/akya.1159.
[40] N. Zouros, S. Pavlides, N. Soulakellis, A. Chatzipetros, K. Vasileiadou, I. Valiakos, K. Mpentana, Using active fault studies for raising public awareness and sensitisation on seismic hazard: a case study from lesvos petrified forest Geopark, NE Aegean Sea, Greece, Geoheritage 3 (2011) 317–327, https://doi.org/10.1007/s12371-011-0044-y.
[41] P. Migoń, E. Pijet-Migoń, Natural disasters, geotourism, and geo-interpretation, Geoheritage 11 (2) (2019) 629–640, https://doi.org/10.1007/s12371-018-0316-x.
[42] P. Iqbal, D.A. Wibowo, P.D. Raharjo, H. Lestiana, E. Puswanto, The great sumatran fault depression at west Lampung district, Sumatra, Indonesia as geomorphosite for geohazard tourism, GeoJournal of Tourism and Geosites 47 (2) (2023) 476–485, https://doi.org/10.30892/gtg.47214-1046.
[43] S. Solarino, M. Amaral Ferreira, G. Musacchio, R. Rupakhety, H. O'Neill, S. Falsaperla, V. Marta, M. Lopes, C. Sousa Oliveira, What scientific information on the seismic risk to non-structural elements do people need to know? Part 2: tools for risk communication, Ann. Geophys. 64 (3) (2021) SE322, https://doi.org/10.4401/ag-8439.
[44] Z. Gurabardhi, J.M. Gutteling, M. Kuttschreuter, An empirical analysis of communication flow, strategy and stakeholders' participation in the risk communication literature 1988–2000, J. Risk Res. 8 (6) (2005) 499–511.
[45] G. Musacchio, S. Falsaperla, A.E. Bernhardsdóttir, M.A. Ferreira, M.L. Sousa, A. Carvalho, G. Zonno, Education: can a bottom-up strategy help for earthquake disaster prevention? Bull. Earthquake Eng. 14 (2016) 2069–2086, https://doi.org/10.1007/s10518-015-9779-1.