journal of Geoethics and social Geosciences

Journal of Geoethics and Social Geosciences, 02, Special Issue, 2025; doi:10.13127/jgsg-51

HSIT system: Citizen Participation in Seismology for Data Collection and Enhanced Understanding of Earthquake Effects

Patrizia Tosi, Valerio De Rubeis, Paola Sbarra*

Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

Article history: received October 7, 2024; accepted November 12, 2024; published December 16, 2024

Abstract

Hai Sentito Il Terremoto (HSIT: Did You Feel the Earthquake?) is one of the longest-running citizen science projects on the web. Launched experimentally in 1996 and fully operational since 2007, HSIT has collected data on over 16,800 earthquakes felt in Italy through more than 1,500,000 questionnaires submitted by citizens. Of these, nearly 30,000 participants are registered with HSIT, ensuring continuous engagement across the national territory. The results of this collaboration are bidirectional: citizens contribute their experience of earthquake perception, forming a core dataset that provides localized information. In return, they receive real-time feedback on the earthquake's effects on their region, represented in macroseismic intensity using the Mercalli (MCS) and European (EMS) scales. This partnership enables seismologists to access high-resolution data for analyzing territorial responses to seismic events, including attenuation laws, identifying amplification and/or attenuation zones, and perception patterns based on urban characteristics and behavioral factors. Citizen involvement has expanded the scope of the investigation to include moderate-to-low magnitude earthquakes and distant areas affected by stronger quakes. Registered participants, in particular, gain awareness of earthquakes as ongoing, active phenomena, shifting from a perception of rare catastrophic events to a continuous focus on regional seismic risks. The HSIT project *bridges the gap between scientific knowledge and common understanding, fostering a shared experience of living in earthquake-prone regions with awareness and respect for associated risks and preventive measures.*

Keywords: Citizen Science; Open Science; Earthquake; Macroseismology; Web Survey

1. Introduction

Scientific research deals with specialized and complex topics, which are often challenging to communicate to a general audience. This cultural gap between the communicators and the public can lead to misunderstandings and distancing of non-experts. Scientific understanding of topics such as seismology, is crucial, including guiding citizens in behaviours and choices. In recent decades, with the availability of the internet, scientific communication has benefitted from this technological advance. However, challenges still exist, including the rise of pseudo-scientific fake news that promotes incorrect behaviours, causing harm to both health and the environment. Citizen Science and Open Science are activities that help bridge the cultural gap between different roles. Besides providing valuable data, these collaborations foster greater scientific awareness among citizens and create a better relationship with researchers, with significant ethical benefits.

The study of the effects of earthquakes on the urban environment and people is a significant research topic in both seismological and social fields. The discipline that deals with this, macroseismology, has a very long history, predating the use of seismic instruments. Since people directly observe the effects, this type of research has always benefited from the accounts of lived experiences provided by citizens. Macroseismology might seem outdated, given that instruments for measuring earthquake magnitude and ground shaking have overshadowed the estimation of intensity based on qualitative descriptions of effects. However, parameterizing data from pre-instrumental earthquakes is a fundamental activity for seismic hazard studies, and understanding contemporary earthquakes helps us to understand those of the past similarly. Moreover, the level of detail provided by intensity estimates at various locations or municipalities exceeds that of instrumental stations, which are necessarily distributed with lower density across the territory [Carletti and Gasperini, 2003].

For logistical feasibility reasons, not all earthquakes, even those felt by the population, are directly studied. Field surveys conducted by researchers and specialized technicians primarily focus on higher-magnitude events and areas near the epicentre, where the effects are permanent. Data collection campaigns are lengthy and detailed, as damage assessments require specific expertise and thorough inspections. For lower-magnitude earthquakes or in areas farther from the epicentre, the diagnostic effects of intensity are mostly temporary (vibrations, fear, displacement of objects), and the only way to obtain data is by gathering information from the population.

In past centuries, macroseismic postcards were used to gather information in less time. These were sent by mail and contained a request directed at local technicians and officials to collect information about the effects of the earthquake on the entire locality. An approximate statistic on the number of people or objects affected by a specific effect was often requested, quantified by the adjectives used in the descriptions of macroseismic scales, as the Mercalli-Cancani-Sieberg Scale (MCS, Sieberg [1930]) and the European Macroseismic Scale (EMS, Grünthal [1998]) to differentiate between the various degrees of intensity: few, many, most, or all. This request for indirect information did not guarantee data accuracy, highlighting the need to develop methods aimed directly at citizens to obtain a more detailed picture of the effects. The availability of the web has allowed for direct and rapid communication with those involved, significantly expanding the scope of macroseismic investigation. In locations that have suffered significant damage, expert surveys remain essential to assess the vulnerability of buildings. However, citizen contributions play a central role in many other places with lesser effects, thus transforming macroseismology into Citizen Science. These data are also valuable because they can potentially be geolocated and provide a more detailed picture of the effects on the territory than what can be obtained from instrumental data alone.

This article reviews the HSIT system [Sbarra et al., 2010; Tosi et al., 2015], which studies the effects of earthquakes felt in Italy and aims to make people understand the benefits of interaction between science and citizens.

2. The HSIT System

In December 1996, two of the authors (Tosi and De Rubeis) began an experiment based on crowdsourcing to request information about the effects of earthquakes through an online questionnaire published (Figure 1) on the website of the Istituto Nazionale di Geofisica e Vulcanologia (INGV, National Institute of Geophysics and Volcanology). The website gradually gained visibility, and starting from November 1997, it began receiving data, mostly related to the strong earthquakes of September

1997 between the Italian regions of Umbria and Marche. This project was likely the first attempt in the world by a research institute to rely on a web-based questionnaire directed at citizens to study the effects of an earthquake. The questionnaire contained questions similar to those found on macroseismic postcards regarding the effects felt across the entire municipality. The processing of data obtained from the online questionnaire was partly done manually. The results were published online, but the processing times could extend over several days.

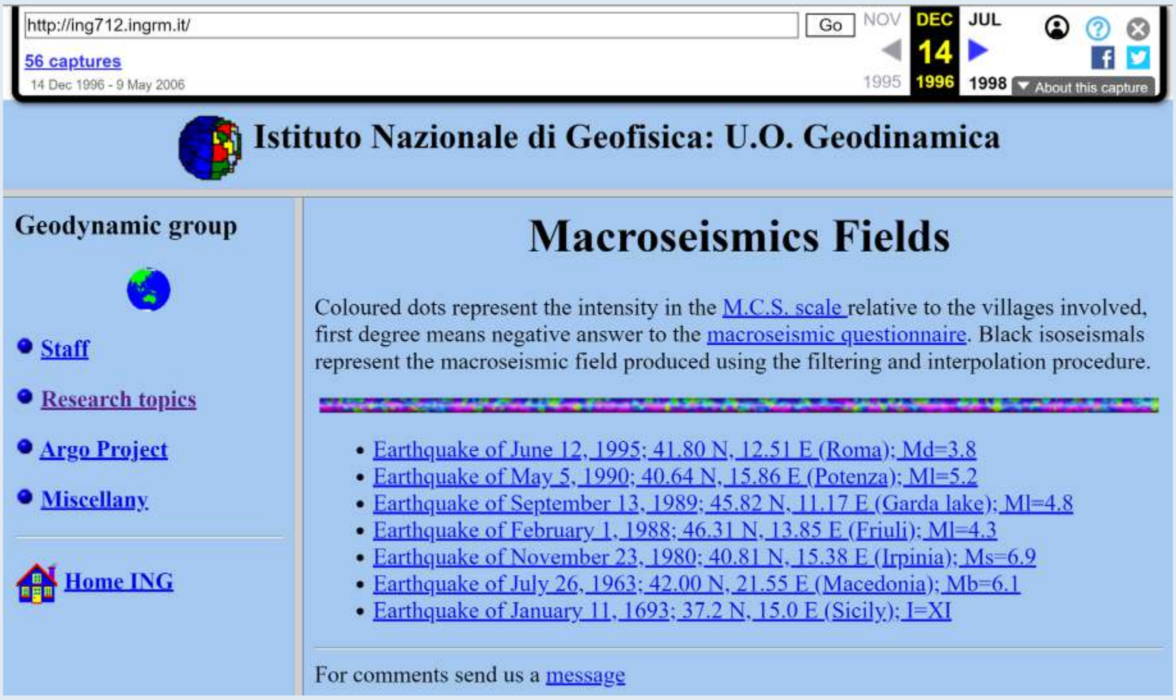

Figure 1. *Screenshot from December 1996 (https://web.archive.org/web/19961214032528/http://ing712.ingrm.it/, accessed 11 November 2024) of the Macroseismology page of the Geodynamics department of the Istituto Nazionale di Geofisica (a research institute that would merge into the current INGV in September 1999). Among the links is one to the interactive macroseismic questionnaire.*

In June 2007, the authors, with the help of a computer technician, created a new procedure [Sbarra et al., 2010; Tosi et al., 2015], implementing a dedicated website, "Hai Sentito Il Terremoto" (HSIT; https://www.hsit.it/, accessed 11 November 2024) with a renewed design. The website provides access to a questionnaire exclusively for individuals, allowing them to describe only the effects they personally felt or directly observed. Although this shift in focus might result in a partial view of the effects, it ensures more excellent reliability of the responses. The data processing is entirely carried out by automated procedures that estimate the macroseismic intensity through statistical analysis of the questionnaires received for each municipality. The results and the corresponding maps are published online in real-time, and updates with new data are continuous.

Since December 2008, users have been able to register for the "Info-earthquakes" service on the website. This feature of the HSIT system, when INGV instruments and technicians locate an earthquake, sends an e-mail to registered users notifying them that the event was characterized by magnitude and distance from the address provided such that it may have been felt locally [Sbarra et al., 2024]. The email contains an invitation to complete the questionnaire, even if the earthquake was not felt.

Registered users have access to a dedicated page where they can choose to:

- select the mode of receiving notifications (email or Telegram app);
- specify which and how many municipalities they want to receive notifications for (residence or others) and save the addresses;
- access the historical archive of all observations they provided to the HSIT website for each earthquake;
- change their password email, or delete their registration.

More than 29,000 users are nowadays registered on the HSIT website, representing 0.05% of the Italian population. However, there is significant variation across different municipalities: while almost half of the municipalities have no registered users, in others, the percentage reaches as high as 2.3% (Figure 2). The distribution of registered users across the territory is correlated with seismic activity, but a comparison with the map of maximum perceived intensity (Figure 3) highlights areas where other factors or conditions likely motivate registration, such as awareness of local seismic hazards or access to digital resources.

On the HSIT website's homepage, in addition to the data and maps for each earthquake, a dynamic map shows the reports received in the past hour. Here, site users can see the reports sent by citizens in real-time and visualize the area affected by a possible earthquake even before the INGV national seismic network locates it. In the case of a strong earthquake accompanied by damage in the epicentral area, reports from that area typically do not arrive immediately for obvious reasons. In this case, the map shows reports distributed around a central empty zone (*doughnut effect*, Bossu et al. [2018]), which contains the event epicentre and corresponds to the area where the effects were most severe. An example of this behaviour can be seen in the reports received 40 minutes after the magnitude 6.5 earthquake in Central Italy in 2016 (Figure 4).

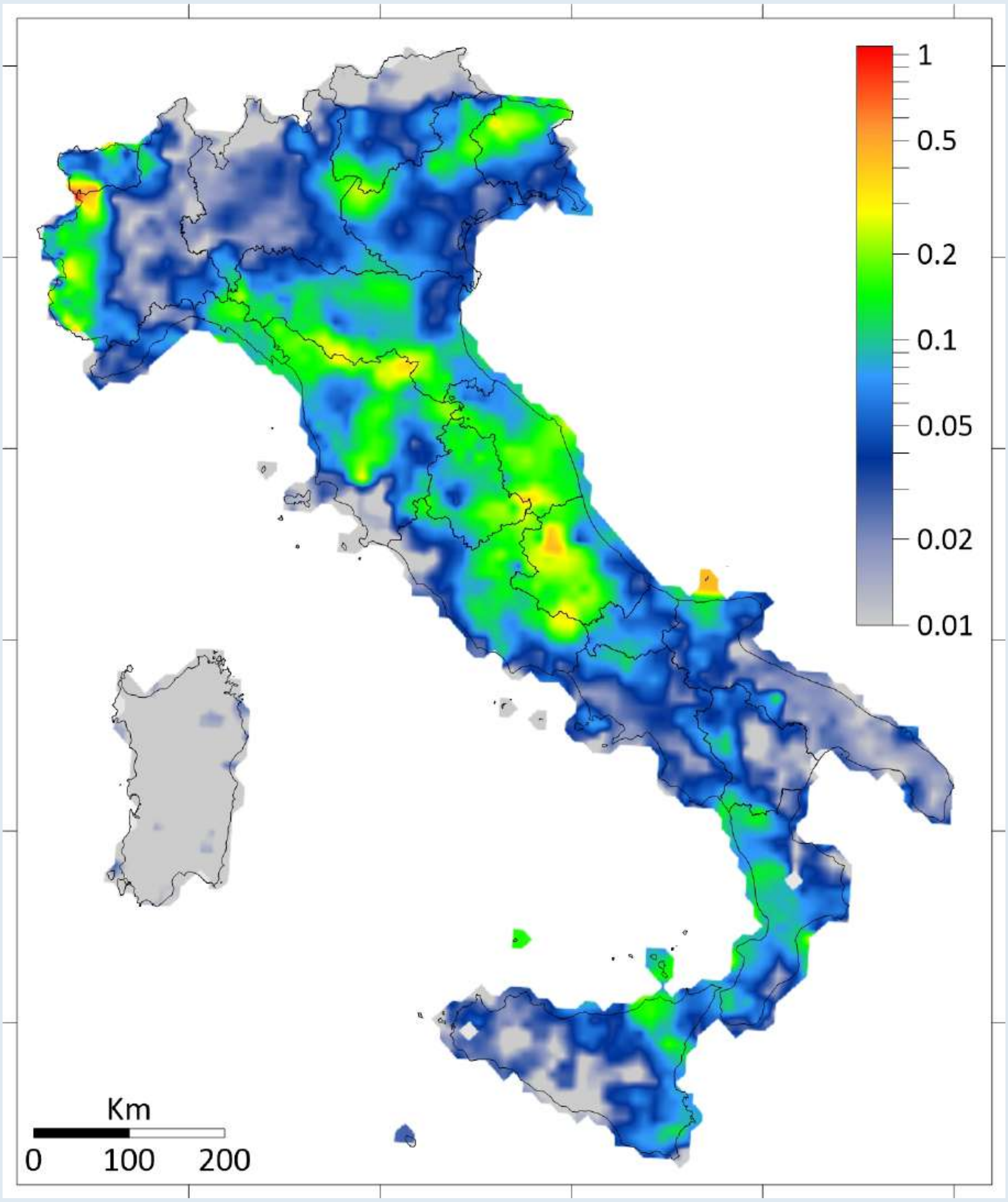

Figure 2. *Spatial average of the percentage of HSIT registered users relative to the population for each Italian municipality.*

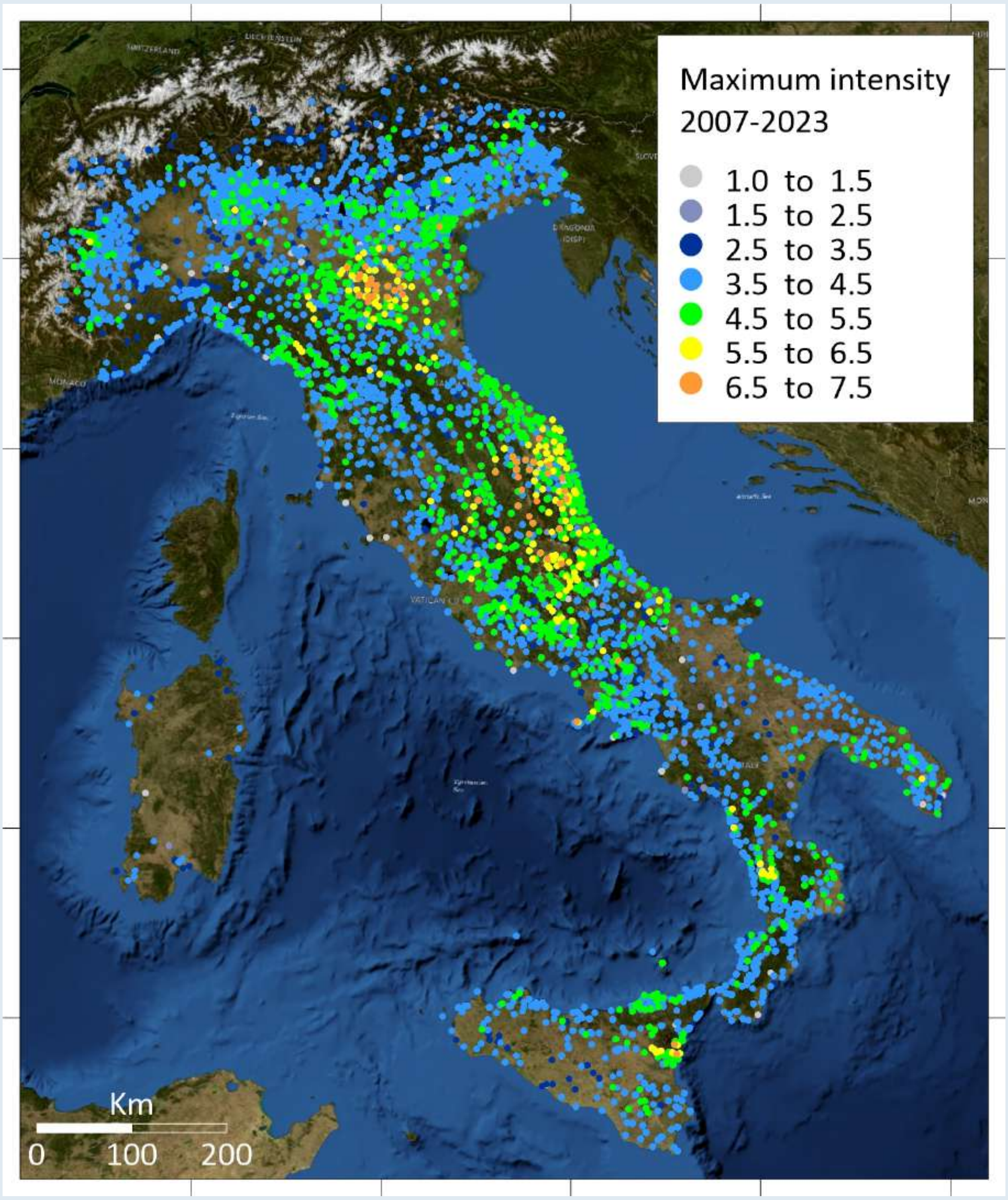

Figure 3. *Maximum municipal intensity estimated by the HSIT system with at least three questionnaires, for earthquakes occurring from June 2007 to December 2023.*

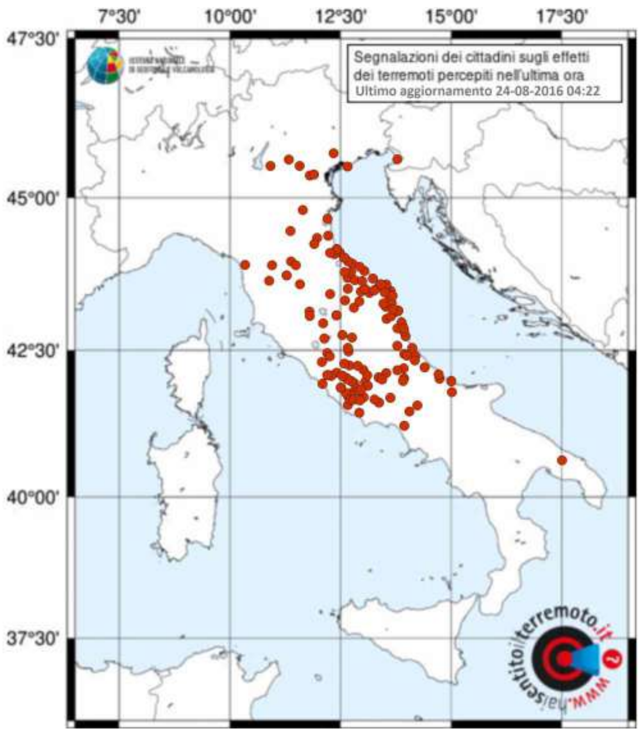

Figure 4. *Doughnut effect around the epicenter due to a lack of reports to the HSIT system 46 minutes after the occurrence of the earthquake on August 24, 2016, local time 03:36, Mw 6.0, depth 8 km in Central Italy.*

The estimation of macroseismic intensity is carried out by automated procedures that process the data obtained from the questionnaires. For each Italian municipality from which reports have been received, the procedure assigns an intensity based on the responses provided by citizens, constructing a probability distribution according to the diagnostic effects of each intensity level. The distribution mode resulting from all responses identifies the value of the macroseismic intensity [Tosi et al., 2015]. The automated procedures also check individual questionnaires. To make the intensity estimates more reliable, any questionnaires with contradictory or insufficient responses are discarded. On average, the procedure discards only 4% of the questionnaires based on these characteristics, demonstrating the reliability of the data provided by citizens.
In the invitation to complete the questionnaire that the HSIT system sends to registered users, there is a request to respond even if the earthquake was not felt.

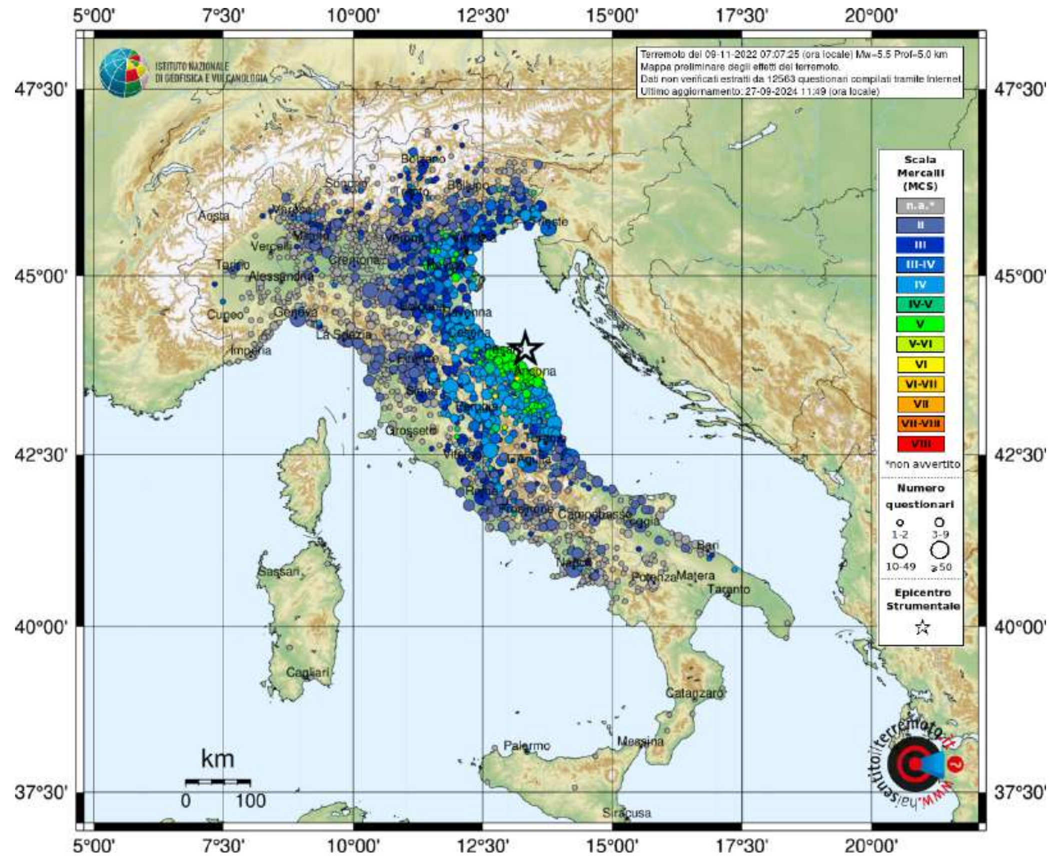

Figure 5. *Macroseismic intensities on the MCS scale for the earthquake of November 9, 2022, local time 07:07, Mw 5.5, depth 5 km, estimated by the HSIT system using over 12,000 questionnaires. The star indicates the epicenter.*

These reports, referred to simply as "not felt", are very useful for estimating macroseismic intensity, especially for the lower intensity levels, where the estimate is based on the percentage of people who felt the shaking. Before creating the group of registered users on the HSIT website, the percentage of "not felt" reports was 3%, similar to that of Did You Feel It (DYFI; Quitoriano and Wald [2020]). About half of all reports received are "not felt", to date. For low-magnitude earthquakes, requested reports represent almost all of the data, and in some cases, it turns out that the earthquake was not felt in any municipality. These earthquakes are 80% of magnitude ≤ 2.5 and represent 21% of the earthquakes displayed on the HSIT website [Sbarra et al., 2024].

The processing times for macroseismic questionnaires are relatively brief, with the initial map of the earthquake macroseismic intensity published approximately 20 to 30 minutes after the event. Specifically, during the initial 15-minute period, the system typically receives the first reports. After the epicentre location and magnitude are determined, email requests to complete the questionnaire are sent to registered users in the following minutes. Thus, about 20-30 minutes after the earthquake, the data is sufficient to process the results and publish the first maps online. Subsequently, the maps are updated as new reports arrive, with most submissions concentrated within the first 4 hours.

After more than 17 years of operation, nearly 1,600,000 questionnaires have been received, and the HSIT website provides maps for more than 16,000 earthquakes. Figure 5 shows an example of a macroseismic intensity map, using the Mercalli-Cancani-Sieberg scale (MCS), for the magnitude Mw 5.5 earthquake that occurred on November 9, 2022, off the coast of Ancona, obtained from the data of over 12,000 questionnaires. When enough data is available, the HSIT system produces maps showing the percentages of individual diagnostic effects, such as window vibrations, experienced fear, object displacement, or perceived noise (Figure 6), in addition to macroseismic intensity maps estimated using both the MCS scale and the European Macroseismic Scale (EMS).

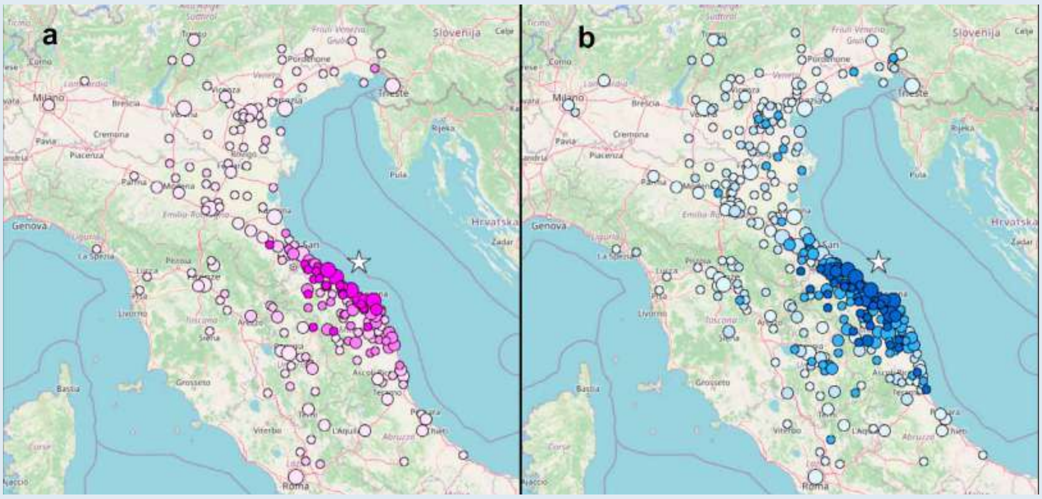

Figure 6. *Maps showing the percentage of observation or perception of individual effects during the earthquake of November 9, 2022, local time 07:07, Mw 5.5, depth 5 km. The colour intensity indicates the percentage of people who reported the effect relative to the total number of questionnaires received in the municipality (proportional to the size of the circle). a) Displacement of small objects, b) acoustic effect.*

Several comparisons have been made to verify the reliability of the intensity estimates, both with field-assessed intensities and with instrumental data (accelerometric network). Regarding the former, analyses show that the differences between the estimates are, in the vast majority of cases, within ±1 degree (Figure 7).
This variability is considered acceptable, as it is similar to that observed when comparing field surveys conducted by different groups of expert technicians (Figure 8). The comparison with instrumental data on peak acceleration, also shows a statistically significant correlation [De Rubeis et al., 2016; Sbarra et al., 2017], further supporting the high reliability of the data provided by citizens.

3. Scientific and Social Results

The analysis of HSIT data, collected through the direct collaboration of citizens, has highlighted the great potential of this type of data, which has allowed for deeper insights into earthquakes. Specifically, it has been possible to:

- correlate seismic perception with surface and deep lithology [Sbarra et al., 2012a];
- quantify the correction to be applied to macroseismic observations based on the position of the person concerning the building floor [Sbarra et al., 2012b];
- quantify the perception of seismic noise with the distance from the epicentre [Tosi et al., 2012];
- quantify the influence of the observer's situation (sleeping, stationary, moving, and whether outdoors or indoors) on the perception of vibrations produced by an earthquake [Sbarra et al., 2014];
- identify and quantify the correction to be applied to macroseismic observations based on building height (an effect not considered in macroseismic scales; Sbarra et al., 2015];
- study the frequencies that characterize diagnostic effects [Tosi et al., 2017];
- characterize the macroseismic fields in Italy for deep earthquakes originating in Greece, which propagate anomalously through the Hellenic slab, highlighting the role of the plate boundary between the Eurasian and African plates [Sbarra et al., 2017];
- determine the depth and magnitude of historical earthquakes through the analysis of attenuation curves of recent earthquakes [Sbarra et al., 2019 and 2023];
- quantify the percentage occurrence of individual diagnostic effects for intensity levels II to VI on the EMS scale [Sbarra et al., 2020];
- quantify how an earthquake is felt in stationary and moving vehicles [Sbarra et al., 2021];

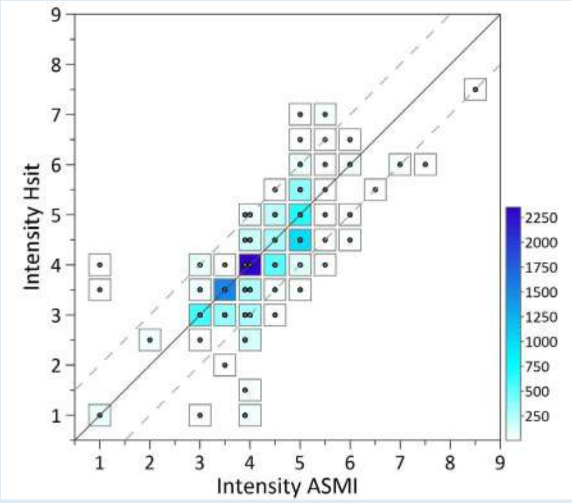

Figure 7. *Comparison between 331 intensity estimates for different earthquakes (occurring from 2009 to 2022) obtained by technicians directly in the field (ASMI data, Rovida et al. [2017]) and corresponding HSIT intensities. The color indicates the total number of questionnaires used to estimate the various HSIT intensities within the respective square. The lines represent the equality between intensities and the deviation of plus or minus one degree.*

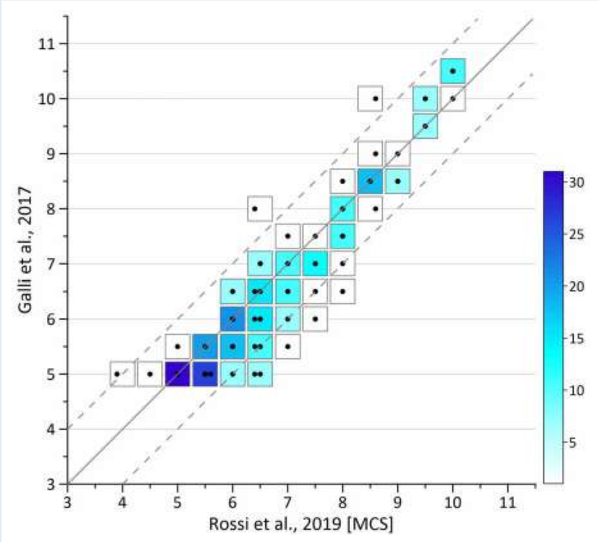

Figure 8. *Comparison of intensity estimates on the MCS scale made by different authors [Rossi et al., 2019; Galli et al., 2017] for the August 24, 2016 earthquake, Mw 6, in Central Italy. The colour indicates the number of localities included in the respective square.*

- quantify the natural frequencies of building vibrations and characterize the amplification-attenuation behaviour of different floors [Tosi et al., 2023];
- correctly estimate low intensities, considering the increase in the number of registered users [Sbarra et al., 2024].

In June 2024, the project "Do you remember past earthquakes?" (https://www.hsit.it/historicalquakes.html, accessed 11 November 2024) was launched to reconstruct maps of earthquake effects based on citizens' memories A recent study [Marreiros et al., 2023] demonstrated that online macroseismic questionnaires are an effective tool for data collection even years after the earthquake. So far, the HSIT system has received over 3,000 questionnaires related to a list of 14 selected notable Italian earthquakes, allowing the reconstruction of their macroseismic maps (Figure 9).

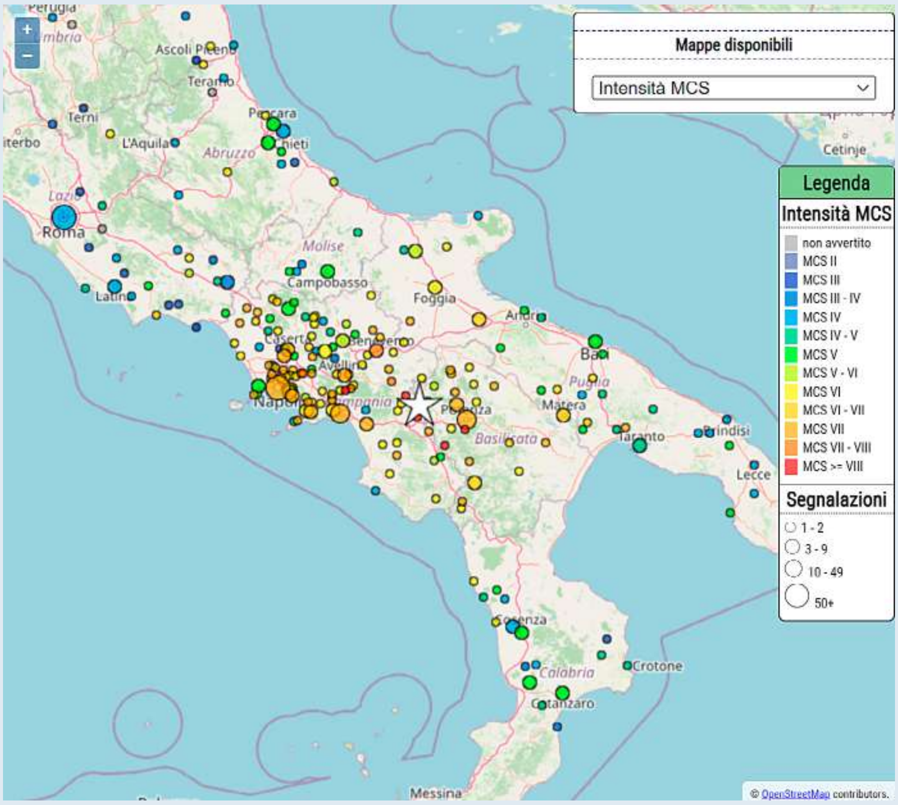

Figure 9. *Macroseismic intensities on the MCS scale for the earthquake of November 23, 1980, local time 19:34, Mw 6.8, depth 12 km, obtained from data derived from 897 questionnaires. The star indicates the epicentre.*

The project aims to compare the maps created using the online procedure [Tosi et al., 2015] with those derived from direct surveys conducted by expert technicians to identify the strengths and weaknesses of both methodologies. The project's outcome will lay the groundwork for establishing rules for future earthquakes to combine data into a single report.

Citizens are our "research instruments"; their collaboration has allowed us to investigate certain aspects of seismic wave propagation more deeply. For this reason, in many of our scientific articles, citizens are mentioned in the acknowledgements section, where we typically recognize all those who contributed to the research work in addition to the authors.

4. Citizen Science and Open Science

The HSIT system relies on the voluntary contributions of citizens, thus falling under the category of Citizen Science. Within this field, various levels of public participation have been identified. For example, the work of Bonney et al. [2009] distinguishes three types of approaches:

- contributory (citizens provide data);
- collaborative (citizens provide and analyse data);
- co-created (citizens provide, analyse, and interpret data).

Based on this classification, HSIT adopts the contributory approach without involving citizens in data analysis. This choice is not limiting, but in the authors' opinion, ensures the accuracy of the results, as the data are reviewed and analysed exclusively by researchers from an official institution. Mainly after strong earthquakes, incorrect information regarding the perceived intensity or magnitude of the event can sometimes spread on social media, potentially causing fear and confusion among citizens [Crescimbene et. al., 2023]. For this reason, it is essential to have the authoritative voice of a national institution as the source of information on sensitive topics such as earthquakes, which can cause damage and disruption to the population.

It is a common experience (also known in the scientific community as the Gutenberg-Richter Law) that the higher the magnitude, the less frequent the seismic event. Additionally, the media extensively cover destructive earthquakes, while smaller ones are often neglected or only addressed locally. These factors create the impression that strong earthquakes occur far from one's area, fostering a false sense of security. When a catastrophic event does occur in one's region, people are generally unprepared, and survivors often perceive the experience as the result of a malicious nature, from which no defence is possible. In deep destruction, there is also a sense of rejection of one's homeland, which can lead to a feeling of displacement. These reactions likely stem from the vast difference between the timescales of human activities and geological phenomena: it takes only a few generations to forget past events [De Rubeis et al., 2015]. In the authors' opinion, the HSIT email notifications, even for very low-magnitude earthquakes that might have been felt locally, help to maintain the memory of seismic risk in the place where one lives. Indeed, only a systematic approach consistent with the timescales of seismic evolution, scientifically conducted, can foster the awareness needed to reverse the fatalistic mindset, laying the groundwork for proactive actions aimed at reducing the severity of the effects of strong earthquakes on human-made structures. This action is part of building and strengthening earthquake awareness, a fundamental part of our relationship with the natural environment.

An essential aspect of the HSIT system is the online publication of results [Tosi et al., 2007] as soon as they are produced, making them available to everyone and increasing transparency in the data acquisition process. It is also possible to download the data of individual questionnaire responses and the estimated macroseismic intensities per municipality from the entire HSIT database [De Rubeis et al., 2022; Sbarra et al., 2022]. Additionally, the data is managed according to FAIR principles, meaning it is Findable, Accessible, Interoperable, and Reusable [Wilkinson et al., 2016]. In detail, all data used or produced by the HSIT system are findable because they have an associated Digital Object identifier (DOI) and are listed on the official database portal of the INGV (https://data.ingv.it/, accessed 11 November 2024); they are accessible because they are freely downloadable by everyone without registration (https://www.hsit.it/download.html, accessed 11 November 2024); they are interoperable because the data are available in various formats including the ASCII format; they are reusable because they are released under the CC BY license that allows sharing and reuse under the attribution term. In scientific research, our data have been used, in different contexts, e.g. by Mak et al. [2015] and Gizzi et al. [2020]. Moreover, the FAIR characteristics create a positive feedback loop, making citizens more willing to provide data and feel more engaged. In Citizen Science, it is important to consider both the extent of the contribution provided by citizens and the accessibility of the results. In many cases, scientific results are only disseminated through specialized literature. At the same time, in the HSIT system, data and maps are published on the website to show the distribution of earthquake effects across the territory, thereby stimulating scientific knowledge. For this reason, citizens are also involved as consumers of the results, initiating a process of immediate scientific communication and dissemination, which is of great value.

All the points mentioned position the HSIT system within Open Science, which UNESCO, in its recommendations regarding the adoption of Open Science [UNESCO, 2021], defines as:

Open science is defined as an inclusive construct that combines various movements and practices aiming to make multilingual scientific knowledge openly available, accessible and reusable for everyone, to increase scientific collaborations and sharing of information for the benefits of science and society, and to open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community.

For Open Science, citizen participation is therefore both a tool and a goal. Similarly, HSIT, based on citizens' input, provides them with awareness and helps build a seismic culture [Ortega et al., 2017; De Rubeis et al., 2015]. Both concepts of participation and awareness are often cited within the framework of Active Citizenship, which in recent years has become an essential element of citizenship education [European Commission/EACEA/Eurydice 2017]. Although usually applied to political issues, these concepts should be extended to any interaction between individuals and society, regardless of the topic.

5. Concluding Remarks

A project based on the real-time publication of results derived from data provided by citizens involves the possibility of errors and the dissemination of incorrect information. The utility of the HSIT website relies on the reliability of the data provided by citizens. Fortunately, reviews of past data show that the vast majority of the information is accurate. Nevertheless, the data are subjected to preliminary checks to identify and, if necessary, discard doubtful questionnaires with conflicting answers. Another type of error encountered is the incorrect assignment of the earthquake to which the questionnaire refers. It mainly occurs when an intense sequence of aftershocks follows a medium-to-high magnitude earthquake. It is understandable, given the emotional response caused by the strongest shock, which distracts attention from selecting the correct event, especially since the event is presented in a list along with many others occurred in just a few hours. To mitigate this issue, high intensities estimated from fewer than three questionnaires undergo additional verification, and in cases of doubt, they are not displayed on the map until further data are available.

Another potential source of error, although very rare, concerns the location and magnitude of the earthquake. An interesting episode in this regard revealed citizens' opinions about the HSIT system. On the night of June 2, 2015, an event with a very low magnitude (Ml=0.9) occurred in Sicily. Still, the automatic system assigned it a magnitude of Mw=5.0, the magnitude of an event that occurred a few seconds later in another country. Such an event could have caused significant damage in Sicily. Although the error was corrected by INGV technicians within a couple of minutes, the HSIT system had already sent thousands of emails to its subscribers, indicating the incorrect magnitude. Citizens close to the epicentre who had not felt any effects probably realised the error immediately. However, those who were farther away but had friends or relatives in the epicentral area understandably felt concern or even anxiety. The map of the earthquake intensity, available on the HSIT website about 30 minutes after the event, quickly showed that the earthquake had not been felt and that the magnitude had been overestimated. The final map showed that 98% of the approximately 400 reports indicated "not felt," equivalent to the first degree on the Mercalli scale. In this instance, registered users demonstrated the reliability of their reports, as only 2% of citizens reported feeling a slight tremor, likely influenced by erroneous information. The following morning, an informational email was sent to all subscribers, and a statement was posted on the website's homepage to acknowledge the error and apologize for any inconvenience caused. Few people expressed dissatisfaction with what had happened, while most of those who sent us responses were very understanding. They categorize the error as an unforeseen situation that could happen at any time and express gratitude for our seriousness and transparency. They also encouraged us to continue our research, reaffirming their willingness to collaborate. This feedback highlighted citizens' appreciation for the HSIT system, both for its usefulness in disseminating information about earthquake effects in Italy and for its demonstrated transparency. We believe registering on the HSIT site is the best way to sustain citizen involvement over time. Registered users receive notifications for earthquakes that have just occurred in their area of interest. Currently, notification occurs about 20 minutes after the earthquake event, but in the near future notifications to registered users will arrive after about 5 minutes using data provided by automatic localisation.

Acknowledgment. Completing this work was only feasible with the voluntary contributions of numerous citizens in Italy who were responsible for compiling HSIT macroseismic reports. These reports provided us with invaluable data on the effects of earthquakes, both those that were felt and those that were not. The authors wish to thank Mario Locati for the intensity comparison between the HSIT and ASMI catalogues and Diego Sorrentino for information technology architecture of http://www.haisentitoilterremoto.it (accessed 11 November 2024) and for software development. HSIT infrastructure benefitted from the funding of the INGV-DPC 2022–2024 agreement (Annex A).

References

Bossu R., Landès M., Roussel F. and Steed R., (2018). Felt reports for rapid mapping of global earthquake damage: the doughnut effect?. Seismological Research Letters, 89(1), 138-144. https://doi.org/10.1785/0220170129

Bonney R., Ballard H., Jordan R., McCallie E., Phillips T. et al., (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Online submission. http://files.eric.ed.gov/fulltext/ED519688.pdf (accessed 11 November 2024).

Carletti F. and Gasperini P., (2003). Lateral variations of seismic intensity attenuation in Italy. Geophysical Journal International, 155(3), 839-856. https://doi.org/10.1111/j.1365-246X.2003.02073.x

Crescimbene M., Todesco M., La Longa F., Ercolani E. and Camassi R., (2023). The whole story: Rumors and science communication in the aftermath of 2012 Emilia seismic sequence. Frontiers in Earth Science, 10, 1002648. https://doi.org/10.3389/feart.2022.1002648

De Rubeis V., Sbarra P., Sebaste B. and Tosi P., (2015). Earthquake ethics through scientific knowledge, historical memory and societal awareness: The experience of direct Internet information. Geological Society, London, Special Publications, 419, 103-110. https://doi.org/10.1144/SP419.7

De Rubeis V., Sbarra P., Tosi P. and Sorrentino D., (2022). Hai Sentito Il Terremoto (HSIT) —macroseismic intensity database 2007–2021, version 2 [Dataset]. https://doi.org/10.13127/HSIT/I.2

European Commission/EACEA/Eurydice, (2017). Citizenship Education at School in Europe - 2017. Eurydice Report. Luxembourg: Publications Office of the European Union. https://data.europa.eu/doi/10.2797/536166

Galli P., Castenetto S. and Peronace E., (2017). The macroseismic intensity distribution of the October 30, 2016 earthquake in central Italy (Mw 6.6). Seismotectonic implications. Tectonics, 36, 2179-2191. https://doi.org/10.1002/2017TC004583

Gizzi F.T., Kam J. and Porrini D., (2020). Time windows of opportunities to fight earthquake under-insurance: Evidence from Google Trends. Humanities and Social Sciences Communications, 7, 61. https://doi.org/10.1057/s41599-020-0532-2

Mak S., Clements R.A. and Schorlemmer D., (2015). Validating intensity prediction equations for Italy by observations. Bulletin of the Seismological Society of America, 105(6), 2942-2954. https://doi.org/10.1785/0120150070

Ortega J., Vasconcelos G., Rodrigues H., Correia M. and Lourenço P.B., (2017). Traditional earthquake resistant techniques for vernacular architecture and local seismic cultures: A literature review. Journal of Cultural Heritage, 27, 181-196. https://doi.org/10.1016/j.culher.2017.02.015

Quitoriano V. and Wald D.J., (2020). USGS "Did You Feel It?"—Science and lessons from 20 years of citizen science-based macroseismology. Frontiers in Earth Science, 8, 120. https://doi.org/10.1111/j.1365-246X.2005.02808.x

Rossi A., Tertulliani A., Azzaro R., Graziani L, Rovida A. et al., (2019). The 2016-2017 earthquake sequence in central Italy: macroseismic survey and damage scenario through the EMS-98 intensity assessment. Bulletin of Earthquake Engineering, 17, 2407-2431. https://doi.org/10.1007/s10518-019-00556-w

Rovida A., Locati M., Antonucci A. and Camassi R., (2017). Archivio Storico Macrosismico Italiano (ASMI) [Dataset]. Istituto Nazionale di Geofisica e Vulcanologia (INGV). https://doi.org/10.13127/asmi

Sbarra P., Tosi P. and De Rubeis V., (2010). Web-based macroseismic survey in Italy: Method validation and results. Natural Hazards, 54, 563-581. https://doi.org/10.1007/s11069-009-9488-7

Sbarra P., De Rubeis V., Di Luzio E., Mancini M., Moscatelli M. et al., (2012a). Macroseismic effects highlight site response in Rome and its geological signature. Natural Hazards, 62, 425-443. https://doi.org/10.1007/s11069-012-0085-9

Sbarra P., Tosi P., De Rubeis V. and Rovelli A., (2012b). Influence of observation floor and building height on macroseismic intensity. Seismological Research Letters, 83(2), 261-266. https://doi.org/10.1785/gssrl.83.2.261

Sbarra P., Tosi P. and De Rubeis V., (2014). How observer conditions impact earthquake perception. Seismological Research Letters, 85(2), 306-313. https://doi.org/10.1785/0220130080

Sbarra P., Fodarella A., Tosi P., De Rubeis V. and Rovelli A., (2015). Difference in shaking intensity between short and tall buildings: known and new findings. Bulletin of the Seismological Society of America, 105(3), 1803-1809. https://doi.org/10.1785/0120140341

Sbarra P., Tosi P. and De Rubeis V., (2017). Role of African–Eurasian plate setting in the felt areas of intermediate-depth earthquakes: an investigation using crowdsourced data. Terra Nova, 29(1), 36-43. https://doi.org/10.1111/ter.12245

Sbarra P., Burrato P., Tosi P., Vannoli P., De Rubeis V. et al., (2019). Inferring the depth of pre-instrumental earthquakes from macroseismic intensity data: a case-history from Northern Italy. Scientific Reports, 9(1), 15583. https://doi.org/10.1038/s41598-019-51966-4

Sbarra P., Tosi P., De Rubeis V. and Sorrentino D., (2020). Quantification of earthquake diagnostic effects to assess low macroseismic intensities. Natural Hazards, 104, 1957-1973. https://doi.org/10.1007/s11069-020-04256-6

Sbarra P., Tosi P., De Rubeis V. and Sorrentino D., (2021). Is an earthquake felt inside a car?. Seismological Society of America, 92(3), 2028-2035. https://doi.org/10.1785/0220200347

Sbarra P., Tosi P., De Rubeis V. and Sorrentino D., (2022). Hai Sentito Il Terremoto (HSIT) - Macroseismic Questionnaire Database 2007-2021, version 2 [Dataset]. https://doi.org/10.13127/HSIT/Q.2

Sbarra P., Burrato P., De Rubeis V., Tosi P., Valensise G. et al., (2023). Inferring the depth and magnitude of pre-instrumental earthquakes from intensity attenuation curves. Natural Hazards and Earth System Sciences, 23(3), 1007-1028. https://doi.org/10.5194/nhess-23-1007-2023

Sbarra P., Tosi P., De Rubeis V. and Sorrentino D., (2024). The importance of on-request reports for the correct assessment of low macroseismic intensities: the experience of "Hai Sentito Il Terremoto". Natural Hazards, 1-16. https://doi.org/10.1007/s11069-024-06869-7

Sieberg A., (1930). Scala MCS (Mercalli–Cancani–Sieberg). Geologie der Erdbeben. Handbuch der Geophysik, 2, 552–555.

Tosi P., De Rubeis V., Sbarra P. and Sorrentino D., (2007). Hai sentito il terremoto (HSIT) [Dataset]. https://doi.org/10.13127/HSIT

Tosi P., Sbarra P. and De Rubeis V., (2012). Earthquake sound perception. Geophysical Research Letters, 39(24). https://doi.org/10.1029/2012GL054382

Tosi P., Sbarra P., De Rubeis V. and Ferrari C., (2015). Macroseismic intensity assessment method for web questionnaires. Seismological Research Letters, 86(3), 985-990. https://doi.org/10.1785/0220140229

Tosi P., De Rubeis V. and Sbarra P., (2017). Frequency ranges and attenuation of macroseismic effects. Geophysical Journal International, 210(3), 1765-1771. https://doi.org/10.1093/gji/ggx201

Tosi P., De Rubeis V. and Sbarra P., (2023). Earthquake perception data highlight natural frequency details of Italian buildings. Earthquake Spectra, 39(2), 1240-1254 https://doi.org/10.1177/875529302311641

UNESCO, (2021). Recommendation on Open Science, Published by the United Nations Educational, Scientific and Cultural Organization, Paris, France, code SC-PCB-SPP/2021/OS/UROS. https://doi.org/10.54677/MNMH8546

Wilkinson M.D., Dumontier M., Aalbersberg I.J., Appleton G., Axton M. et al., (2016). The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3, 160018. https://doi.org/10.1038/sdata.2016.18

*Corresponding author: **Patrizia Tosi**

e-mail: patrizia.tosi@ingv.it