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Theory article

Public understanding and scientific uncertainty: The communication of risk in the L'Aquila earthquake

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Abstract: On April 6, 2009, a magnitude 6.3 earthquake struck L'Aquila, Italy, causing extensive damage and loss of life, and raising significant issues around the communication of scientific risk. In the preceding weeks, increased seismic activity had alarmed the population, prompting authorities to seek expert advice. Public authorities reassured the population that the chances of a dangerous shock were slim. These assurances given by officials led many to remain in their homes when the earthquake struck. The subsequent legal actions against the scientists involved ignited a global debate on the responsibilities and challenges in scientific communication. This paper explores the complexities of conveying probabilistic risk information to the public and decision-makers. It highlights how different formats for presenting probabilistic data can significantly influence understanding and decision-making. In particular, it canvasses how the use of natural frequencies to convey probabilistic information makes it cognitively easier to understand and manipulate them, given how they make more salient and transparent the so-called base rate. However, the benefits of using natural frequencies decrease when dealing with low-probability, high-consequence (LPHC) events like major earthquakes, where even significant increases in relative probability remain small in absolute terms. Moreover, the paper investigates the social dimensions of earth science, examining the multifaceted role of scientists as both technical experts and social actors. The L'Aquila case exemplifies the need for integrating scientific accuracy with an understanding of its social implications. Effective risk communication must address cognitive limitations and the presence of social context to reach appropriate public behavioral responses. In order to achieve that, communication should be handled by actors that have specific expertise in its complexity.

Keywords: L'Aquila earthquake; risk communication; natural frequencies; earthquake prediction; experts-laypeople communication

1. Introduction

Time: April 6, 2009, 3:32am. Place: L'Aquila, regional capital of Abruzzo, central Italy. A magnitude 6.3 earthquake strikes the city and the surrounding area, leading to the death of 308 people and injuring around 1500, 202 of them seriously [1]. Around 100,000 buildings are damaged, and 67,000 people are left homeless [2].

Due to their random nature, earthquakes are typically unpredictable: it is impossible to know that a major shock is about to happen, making adopting preparedness* measures (e.g. evacuation) particularly difficult. However, in the weeks before the earthquake, seismic activity in L'Aquila had noticeably increased, alerting the population and the authorities, and spreading the fear that a major shock was nearing. Scientists were summoned to provide an expert assessment of the risks, and the population was reassured in light of their judgment.

In the aftermath of the disaster, legal actions against the scientists for their possible role in the catastrophe stirred a heated debate on the responsibilities of science. In this paper, it is not our intent to discuss the merits of the decisions made by the Italian tribunals. Instead, we would like to analyse the difficulties and the potential pitfalls that may arise when scientists must communicate their findings to the general public and to the decision-makers, who will in turn decide on some course of action based on the scientists' assessments. To do so, we will focus on the role of probabilities in scientific communication and on the limits of human cognition in dealing with them. In particular, we look at the debate around different formats to express probabilistic estimations of risk. This debate highlights that while some formats hinder a transparent understanding of the so-called base rate of a certain event, others allow an easier cognitive grasp of probabilistic data. This result has ample experimental research support [3–6]. However, it shows its limits when applied to cases (such as destructive earthquakes) where the event in question has very low probability to begin with, and where variations in probability, even if relatively ample, are still minimal in absolute terms.

After discussing the cognitive impact of data communication, we will return to L'Aquila. We will analyse one specific dimension that was sorely missed in communication before and after the earthquake, and we will elucidate its shortcomings in one crucial aspect, which is the dimension of the social impact of scientific communication.

Before delving deeper into our analysis, however, it is important to recall the unfolding of the events. What happened in the days before and after the earthquake has been subject to close scrutiny, and even now, with the benefit of insight, it remains a fairly complicated story.

2. L'Aquila 2009: The story of a communication failure

Abruzzo, located in central Italy, is a well-recorded hotspot for geoseismic activity. Historical record for L'Aquila city recalls 6000 victims due to earthquake in 1703 and 32,500 in 1912. In October 2008, an earthquake swarm began in the L'Aquila zone. The swarm continued for months, causing no discernible damage, due to the low intensity of the tremors, but significant distress in the population. One of those affected was G. Giuliani, a lab technician living in L'Aquila. His hobby was the monitoring of radon emissions, hoping to predict earthquakes. Radon is a radioactive, inert gas, whose

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[*] It is important to notice that *preparedness* and *prevention* denote two different concepts, as underlined by the terminology adopted for the ONU Sendai Framework for Disaster Risk Reduction.

levels have been consistently observed to fluctuate in correspondence with seismic activity. Despite being only one of a dozen physical parameters that have been observed to change before an earthquake, radon is one of the easiest to detect in air and fluid. Its role as a potential earthquake predictor has been proposed since the Tashkent earthquake of 1966. However, despite a considerable scientific interest that continues nowadays, the consensus is that radon anomalies cannot be used to forecast earthquakes with sufficient precision [7, 8]. Reasons for this consensus are that the frequent release of radon gas results in too many false alarms to make the system reliable and trustworthy for earthquake prediction, and the fact that radon gas dispersed in the air makes it complicated to pinpoint the exact epicentre. Despite these weak scientific grounds, Giuliani's radon observations continued during the swarm. On March 29, 2009 he informed L'Aquila authorities that a strong seismic event would occur "within a week, and probably centered upon Sulmona" (a city roughly 40 km from L'Aquila). Knowledge of his prediction spread through the population, causing disturbance and agitation. G. Bertolaso, Undersecretary of State and head of the national "Dipartimento di Protezione Civile" (Department of Civil Protection, DPC), announced that Giuliani would be prosecuted for instigating alarm in the public.

Intending to reassure the population, Bertolaso called a meeting of the "Commissione Grandi Rischi" (Major Risks Committee, CGR—a body of the DPC deputed to the provision of scientific assessments to ground public risk management) in L'Aquila on March 31, 2009. After one hour of meeting, B. de Bernardinis, political representative to the CGR and deputy of Bertolaso, announced on live television that the committee concluded that there is no reason for saying that a sequence of low magnitude shocks could be considered the precursor of a strong event. He then proceeded to tell viewers that they should "go home and have a glass of wine", because there was nothing to worry about. People's worries were assuaged by functionaries of the DPC who were instructed to tell them to "calm down and go home, everything is under control" [1]. Seven days after the meeting, a devastating earthquake struck. Three hours before the main shock, two perceivable but innocuous foreshocks (M_W 3.9 and 3.5, respectively) scared many inhabitants, prompting some of them to leave their houses to sleep in the cars. Many others, however, remained home, reassured by the institutional line that everything was normal.

After the disaster, in August 2009, a group of citizens who survived the event filed a criminal complaint against the DPC, accusing them and the CGR of negligent homicide, citing failure in their duties of prevention and preparedness. On October 22, 2012, an Italian tribunal condemned all of the accused to six years in prison, the payment of massive fines, and disqualification from public office. The motivation of the sentence was that they provided "[...] incomplete, imprecise and contradictory information on the nature, causes, dangers and future development of seismic activity in the area in question [...]" [9][†]. The story reported in many international media was that the scientists were accused of failing to predict the earthquake. Consequently, the reaction in the international academic community was outrage, with a quite shared opinion that "[t]he verdict [was] perverse and the sentence ludicrous" [12]. Many voices were raised against an obscurantist trial attacking science, one that was explicitly juxtaposed to the Inquisition trial to Galileo [13]. There were no reliable, scientifically validated methods for earthquake prediction [14], and therefore, failure in predicting the occurrence of an earthquake could hardly be considered a scientific failure. Conversely, primarily in Italy, this

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[†] "[...] informazioni incomplete, imprecise e contraddittorie sulla natura, sulle cause, sulla pericolosità e sui futuri sviluppi dell'attività sismica in esame", p. III, X, 2, 21. The sentence was commuted in appeal to 2 years for De Bernardinis, and full acquittance for the six scientific experts. This sentence was confirmed in the final instance of the trial [10, 11].

objection seemed to be retorted by the presence of Giuliani's "prediction". To many in the lay public there seemed to be, indeed, some scientific evidence that could support an early alarm.

However, it must be underlined that the trial was neither on science itself, nor on the possibility that the scientists had overlooked some relevant scientific evidence[‡]. Its central question was whether the public bodies conducted a proper risk assessment and adequately communicated it to the public [15]. Indeed, some voices in the public debate underlined that the verdict was to be considered "a judgment not against science, but against a failure of science communication" [16]. In that regard, the accused were found guilty in the first instance of the trial, and later in the appeal trial the scientific components of the CGR were acquitted, leaving only De Bernardinis with a reduced sentence.

3. The cognitive representation of risk

Science communication is a field fraught with potential faux pas. Even when the information conveyed is entirely accurate, there is always the potential for misinterpretation from the public. One of the most complex matters to keep in mind when dealing with scientific information is its probabilistic nature. One of the pillars of modern science is its inductive nature. Induction begins with observations that are specific and limited in scope, and proceeds to a generalized conclusion that is likely, but not certain, in light of accumulated evidence.

Among the instruments that scientists employ to convey the intrinsic uncertainty of their findings, a major role is played by probabilities. These are typically used to represent two distinct types of judgement. They can be used to represent the frequency with which some event is observed, when repetitions of the same event can be identified within a reference class; or they can be used to represent an overall assessment of the likelihood of some event.

However, uncertainty is not only a necessary dimension of scientific inference. When dealing with risk, it is also a component of the behavior of hazards, some of which tend to have an aleatory nature. In the risk sciences, probabilities are therefore used to represent two different, albeit related, uncertainties: the epistemic uncertainty of our inferential processes, which always carry some possibility of error, and the aleatory uncertainty of the phenomenon that these processes are trying to describe, that may or may not happen independently of our own ignorance about it.

Given the importance of probabilities in dealing with risk, it is particularly troubling that human cognition is not very well-suited to deal with probability in a precise manner. As human beings, we must continuously make decisions, even though the outcome of these decisions is often uncertain. The outcome of most of our decisions, from crossing the street to grocery shopping, from planning an investment to choosing a spouse or partner, is not entirely predictable. Risk and uncertainty are fundamental dimensions of our choices. It is therefore unsurprising that various fields of research have focused their attention on how people and institutions make decisions under conditions of uncertainty. This investigation has both normative and descriptive dimensions. On the normative side, the intention is to develop a theory of reasoning and decision-making under uncertainty that should constitute a model for human rationality. On the descriptive side, the early idea that "human beings are intuitive statisticians" [17] was soon called into question by research programs that showed how human reasoning often diverges from what, theoretically, should be the path to making the best[§] decisions.

[‡] The sizeable clamour over the possibility that Giuliani predictions were scientifically sound prompted publicly funded investigations. The conclusion of the scientific community was that they were not. This debate, however, did not play any role in the trial.

[§] Of course, this begs the question of what it means for a decision to be considered "best". An extended analysis of the issue is well

The work of psychologists like D. Kahneman and A. Tversky [18,19] has documented a significant divergence between how we reason in practice and the formal theories of probability and decision-making. Humans tend to use reasoning and decision heuristics that function as ”mental shortcuts” and are often conditioned by systematic and predictable errors, known in the literature as (cognitive) biases. Other researchers, such as cognitive scientist G. Gigerenzer, have highlighted how the use of heuristics during reasoning and decision tasks is often efficient and reasonably accurate [20], interpreting the divergence from theories of probability and rational decision-making as the effect of an excessively idealized and demanding theoretical and normative framework [21].

Recently, many efforts have been made to improve human reasoning under conditions of uncertainty based on these results from psychology, behavioral economics, and cognitive science. For example, the idea that one can positively influence decisions by working on the ”choice architecture”, i.e., the environment in which such decisions are made [22], and that the context in which a decision is made should be as ecologically compatible as possible with the functioning of human cognition [23] represent particularly significant research strands in terms of both academic discussion and potential benefits for public policies.

One of the main results of this discussion has concerned the characteristics with which information considered relevant for decision-making is presented, an aspect called “framing”. Decision-making depends on possessing information that is as complete and accurate as possible. However, presenting complete and accurate information is not enough to help people make better and more rational decisions. How such information is presented can play a crucial role in understanding the problem and in the decision-maker’s cognitive handling of it. This aspect is all the more critical when dealing with the expression of statistical and probabilistic information, which is not intuitive from a cognitive point of view and therefore requires additional effort to reach correct interpretations. Several formats can be used to communicate probabilistic information. Such formats differ in terms of easiness of cognitive handling and lead to different levels of understanding, which in turn materialize different behaviors. These elements must be taken into account when dealing with scientifically informed risk communication.

Suppose, for example, that we are healthcare professionals who are tasked to communicate the benefit of complying with a particular hygienic recommendation in order not to catch a specific disease. To do this, we rely on statistical data. We provide information on how many people get sick in a population that does not comply, compared to how many people get sick in a population that complies. One way we can do that is by using natural frequencies, i.e., the number of people with the disease in the two populations: we can say, for example, that 13 people out of 1000 in the compliant population caught the disease, versus 16 out of 1000 in the non-compliant one. Alternatively, we can express the information using absolute risk (AR), i.e., the number of people with the disease in a population divided by the amplitude of that population: 1.33% for the compliant population, 1.66% for the non-compliant. Finally, we can provide the relative risk (RR), i.e., the ratio between the two groups: 0.8. We could express the last two formats as well as absolute risk reduction (AAR) for compliance, in this case 0.033%, or relative risk reduction (RRR), 0.2 or 20% [24].

Even though these formats are numerically identical, they are not treated in the same way by human cognition. Several studies [3–5] have shown that reasoning based on data expressed in percentage format is particularly challenging for most people. On the contrary, performance improves

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beyond the scope of the present work.

when natural frequencies are used [6]. The reason is that natural frequencies underline and make more cognitively accessible one element necessary in calculations, which is the *base rate* of a particular event to occur. The base rate is the general prevalence of an occurrence, or the initial likelihood of an event occurring before considering additional information. Experimental evidence led to the general recommendation to privilege the use of natural frequencies over AR or RR when communicating risk probability, and to make the base rate as evident as possible in order not to incur the so-called base rate neglect [25].

Base rate neglect is a form of fallacious reasoning in which the general prevalence of a specific event is not taken into account when considering a probability outcome. Suppose, for example, that there are 100 people hospitalized with a specific disease. Observing that 50 of them have received the vaccine against that disease, and 50 did not, it is tempting to conclude that the vaccine is not effective, and that there is an equal chance to be hospitalized for vaccinated and unvaccinated people. However, that would mean that you are committing base rate neglect. If we are aware that the population of unvaccinated people is equal to 100, and the population of vaccinated people is equal to 100,000, we can safely conclude that it is much more probable to be hospitalized for an unvaccinated person, than for a vaccinated one. Therefore, making the base rate evident and cognitively accessible seems to be crucial for a proper evaluation of risk.

This facilitating effect of natural frequencies is a well-established result, over which there is general consensus. However, there are cases in which this advice is limited. When the base rate is very low, making it more transparent and cognitively salient does not translate into behavioral improvement. Not every event category allows for a meaningful construction of a base rate: some events are very rare and do not provide sufficient data to draw meaningful statistical conclusions on their occurrence. Yet, their relative infrequency does not mean that these events are necessarily irrelevant. Some of the situations that present negligible probability of occurring have disastrous consequences if they occur (those are the so-called low-probability high-consequence risk, LPHC). High-magnitude earthquakes fall into this category, and the cognitive analysis of how their risk is treated shows some limitations in the results presented so far[†].

The difficulties in incorporating very low probabilities in cognitive computation of risk emerged in cognitive research relatively early, even in Kahneman and Tversky's seminal paper on prospect theory [26]. As Stone and colleagues [27] (p. 388) would put it, "[...] the essential idea is that low probabilities are overweighted until they reach some "sufficiently low" probability, at which point they are given no weight at all." What this sufficiently low threshold is, of course, is difficult to determine, and would have to be defined subjectively, taking into account personal attitudes to risk. The fundamental problem revolves around the fact that the base rate for catastrophic events is (luckily enough) very low. As we have seen, there is a general consensus that communication formats that make the base rate explicit or easily obtainable are to be preferred, as they improve the understanding of risk. However, it is possible that, in cases where the base rate is so low that its increment fails to overcome that "sufficiently low" threshold, communications formats that are usually considered less efficient achieve a greater behavioral impact [27], and that this happens precisely *because* they mask the base rate. Emphasizing the base rate and striving for a risk representation that prefers absolute rather than relative risk is sound advice for most cases of risk communication. However, that advice could be reversed for LPHC

[†] It should be noted that earthquakes could not be interpreted as "low probability" events if a wider or temporal geographical perspective is employed. We thank an anonymous reviewer for this point.

[28]. The fact that the "occurrence of a seismic sequence may increase the probability with respect to the background as much as a thousand times, but the absolute probability still remains very low" [29] represents a challenge for cognitive tools of rational risk assessment[¶], because with such low probabilities, the likelihood for a warning to be a false alarm remains often greater than a real one.

Another aspect over which the communication of risk is fraught with open questions when dealing with LPHC is the role of the temporal framework in which to convey the information. The construal level theory (CLT) of psychological distance [30] states that distance in time from the present moment affects the mental representation of future events. When dealing with risk perception, this different representation has an impact: risk communicated in a "risk-per-day" frame feels more proximal and salient than one communicated in a "risk-per-annum" format. Therefore, the first framing leads to in increased risk perception and behavioral response [31]. This result, however, seems at odds with another framing effect: the ratio bias. The ratio bias is the tendency to interpret a low probability as more likely when presented with a ratio employing large numbers, such as 100/1000, than with an equivalent but small-numbered one, such as 1/10. These two effects seem to pull in opposite directions. Which statement is considered to convey a greater perceived risk: a probability framed as "10 people will have a car accident in a day" or one that reads "3650 people will have a car accident in a year"? The two theories presented so far have diverging predictions: for CLT, the first statement should convey more risk, while for ratio bias theory, this holds true for the second. Evidence suggests that ratio bias is stronger than CLT [32]. However, this may not be the case when the temporal framing exceeds the span of a life: communication of a risk spread over 500 years seems less relevant than one spread over 50 [33].

These limitations create additional difficulties for laypeople in reaching a meaningful understanding of seismic risk. This, in itself, is not a tragedy: difficult does not mean impossible. However, this is not the only issue that emerges when analyzing what can go wrong in risk communication. It should not be taken for granted that when a correct understanding of risk is reached, behavioral response follows suit and according to what is required to minimize danger.

4. The social dimension of earth science

We have so far seen some of the difficulties faced in the cognitive representation of risk in general, and seismic risk in particular. These difficulties, however, are not the only ones. Even if a correct understanding of risk is reached, that understanding does not necessarily translate into some corresponding behavioral response. The behaviors of individuals with low risk perception and those with high risk perception, in terms of following warnings and increasing preparedness, are not necessarily different, a phenomenon that has been called the "risk perception paradox" [34]. Three reasons have been proposed to explain this apparent conundrum. First, risk does not happen in isolation: other risks may push in different directions. An individual might understand the probability of a specific risk, but accept it due to a higher perceived benefit in not changing behaviors, or a higher perceived harm in changing them. For example, an individual might be more willing to focus on the risks (social, economic, and in terms of security) linked with evacuation, than on the risk of remaining in a place that has become increasingly dangerous. Second, an individual might understand the risk, but not think that they are the ones who are supposed to take the initiative, deferring the responsibility

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[¶] Such as Bayesian updating.

of acting to other players, such as institutions. This element is linked with another puzzling result: trust in authorities is positively linked with reduction in individual preparedness and willingness to act to change risk levels [35]. Third, an individual might have an adequate understanding and a consequent willingness to act, but lack the knowledge and/or the means necessary to act effectively on that willingness. An individual could understand the risk and be willing to act, but if they are uncertain about the appropriate course of action to take, they might deem it best not to act.

These issues delineate yet another level of complexity for risk communication. In the case of earthquakes, for example, effective communication has to keep in mind at least three layers of analysis, coming from three different scientific fields. The first is the layer of geology and engineering, which provides scientifically informed data and predictions. The second layer concerns cognition, to specify how and how accurately those data and predictions are going to be understood. The third is the behavioral layer, which analyzes whether and how that understanding translates into increased prevention, habit modification, or other change of conduct. These layers interact with each other, and each of them needs some form of technical expertise to be handled correctly. This expertise may include some amount of scientifically accurate information. However, scientific knowledge and technical soundness do not complete the framework of what is required to obtain an appropriate response in the population for phenomena such as a high-magnitude earthquake. The social aspect has to be taken into account.

The role of human cognition in understanding low-probability, high-impact risk, as well as the role of social, economic, and institutional factors in determining behavior responses, shows that effective communication regarding seismic risk cannot be limited to the accurate conveying of scientific seismic information. In some sense, the L'Aquila trial supports the claim that "earth science has become a social science" [36]. As N. Oreskes puts it (p. 254):

> "The case centered not on the matter of whether or not earthquakes can be predicted, but on political questions about the social obligations of scientists speaking in official advisory capacities, and epistemic questions about the appropriate manner in which risk assessments should be performed. The questions at stake were what information scientists should have offered the public, and how that information should have been communicated. They were not so much matters of scientific facts, but matters of how those facts were rendered and communicated."

In L'Aquila, just before the earthquake, there were two different kinds of risk, which had to be balanced against each other: seismic risk and the risk of public disorder. The seismic swarm and the (scientifically ungrounded) forecast of an imminent earthquake could have spread alarm through the population, causing problems in the management of the population, at least from a governance perspective. Perhaps in light of the fact that, despite the rise in relative probability after the swarm, estimates of absolute probability of a major shock remained very low, the actions of representatives and DPC prioritised public order. A meeting of CGR was called with the intent to reassure the population[‖]. CGR members strived to avoid making specific assertions concerning the occurrence of a major shock: the informative content that was provided to the decision-makers was that it was impossible to make

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[‖] In a phone call preceding the convocation, Bertolaso said that he intended to call the "leading earthquake experts" (*i luminari della scienza*) in order "to silence any imbecile and calm down conjectures, preoccupations, etc." (" [...] *in modo da zittire subito qualsiasi imbecille, placare illazioni, preoccupazioni, eccetera*") [9].

an accurate prediction of the future presence of an earthquake. However, the type of message that arrived to the public was one logically different: that from that impossibility, the presence of a future earthquake could be ruled out. The scientifically sound assertion of impossibility in predicting the occurrence of an earthquake resulted in the beliefs that there was some form of scientific assertion of a specific hypothesis, namely that no seismic shock would have followed [37]. It is unclear to which degree this was the idea of the authorities [38]: however, this reassuring belief led many in the population to a misplaced sense of safety. Somewhere in the communication chain, accurate scientific information got interpreted as a different claim, one that pushed both public and private decision-making to underestimating preparedness measures.

It is clear that, in contexts of risk management, scientific expertise ends up playing social and political functions beyond those purely epistemic, as it is used to ground collective decision-making. However, scientists may be experts in their own disciplines, but that expertise does not (and should not) necessarily imply other types of competences. As we have canvassed, communication of scientific results is a field ripe with difficulties and debates that remain open. Asking geoscientists, vulcanologists, and seismologists to be fully aware of the intricacies and the social impact of their scientific communication seems to place an excessive epistemic burden on their shoulders.

At the same time, it would be naive to negate that such an impact exists. This fact is increasingly recognised: even the UN Sendai Framework for Disaster Risk Reduction [39] recognizes the need for an integration between the competencies of all of the relevant stakeholders when risk is involved. However, directly including geoscientists in the engagement with citizens can result in inefficient communication and might even backfire. It is doubtful how much geoscientists can effectively interact directly in such a highly participatory approach. This doubt might be shared by the very same scientists, who could judge interactions with lay audiences as a "rather unknown territory", as a recent survey stated [40].

Moreover, the presence of different stakeholders requires enacting communications that differ in format, style, content, and delivery. Consider, for example, how a scientist who is asked to inform both decision-makers and the general public is tasked to perform two very different operations. On the one hand, the scientist has to provide decision-makers with tools that would inform large-scale decisions. These tools might be probabilities, cost-benefit analyses, impact evaluations, and other technical instruments. On the other hand, scientists engaging with the public do not need to provide tools that are usable as input to collective decisional processes, but rather individual ones that take into account behavioral processes. Being capable of managing both of those communication contexts, on top of a very specific technical expertise, is a gargantuan task. It would be much more effective, efficient, and impactful, rather to employ people with specific expertise in communication to perform it. In L'Aquila, in 2009, the main institutional actors were two: the political decision-makers and the geoseismic experts. There was a lack of a third component: some actor specifically expert in communicating scientific results, and if necessary conveying their complexity, to the public.

5. Conclusion

The L'Aquila earthquake and the subsequent trial underline the social impact that communicating geological risk has on the life of thousands of people. Moreover, as we have seen, the reception of risk communication in itself is full of thorny issues from a cognitive point of view. Geoscientists might not have the expertise and be inclined to take the responsibilities connected with the social and behavioral reactions to the expression of their knowledge, neither should it be required that they possess that expertise and inclination. That is the role of politics and communication.

The communication chain in L'Aquila lacked the employment of actors competent in the intricacies of public communication of risk. The study of disaster risk communication has evolved and markedly improved in the past twenty years, also due to the vast reverberation of events such as the 2004 Indian Ocean earthquake and tsunami, the 2005 hurricane Katrina, and the L'Aquila earthquake itself. Most of the efforts of risk communication revolve around the daunting task of describing and transmitting uncertainty in the most precise way. The involvement of various stakeholders, as well as inescapable trade-offs between economic, social, health, and political consideration make the determination of the "best answer" a very difficult, at best, and possibly impossible task. Some of the proposals that have been put forward rely on checklists to accurately address the ranking of salience of different frameworks (scientific, legal, moral, social, institutional, proprietary) through which the uncertainty inescapably linked to risk can be communicated [41]. Others highlight the importance of employing "honest brokers", specialists able to facilitate the understanding of the available scientific knowledge by non-expert stakeholders [42]. However, an overall satisfactory answer to the problem of communication in a high risk context remains to be found. In a time characterized by the increase of natural risks due to climate change, being able to effectively communicate scientific uncertainty to decision-makers and the population is a capital challenge.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare no conflict of interest.

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