The O.R.E. (Opinions on Risky Events) Model

We have a population of L agents (if not differently specified, we will assume usually $L = 1000$). Each agent i is characterized by an opinion O_i. For the sake of simplicity, we model opinions as the subjective probability that the disaster will actually take place, without taking into account the magnitude of the possible consequences, which would add further unnecessary complexity to the model. What is more, there is a huge variation between disasters in which probability and consequences are extremely difficult to predict, such as earthquakes, and disasters like floods in which weather forecasts and location-specific features make risk calculation less haphazard. Opinions vary between 0, which can be expressed as "I am certain that nothing is going to happen", and 1, which means "I am certain that the disaster will happen". At the onset of the simulation, opinions are randomly assigned to agents, and they are updated on the bases of the interplay between internal characteristics of the agents and three different sources of influence.

Initial conditions – At the beginning of every iteration of the dynamics, the agents are randomly assigned an opinion between 0 and 1, always with uniform distribution. Also the internal variables are randomly distributed, but the distribution is not necessarily uniform, and it will be specified in each case. Opinions evolve, but individuals' internal variables remain constant over time. The institutional information I is set at the start of the dynamics and never changes.

Characteristics of the agents

Each individual agent is described by two parameters: risk sensitivity and trust. Risk sensitivity is an integer variable which can assume three possible values, $R_i \in \{-1, 0, +1\}$. Risk sensitivity affects the tendency to inform others about the potential danger, B_i. This means that agents who perceive the risk as more probable will also tend to talk about it more, thus sharing their worries with others. People tend to transmit information that is in accordance with their initial risk perception, neglecting opposing information [Popovic et al. (2020)]. This, in turn, can lead to an amplification of the initial risk perception of the group, even if the original information supported the opposite view; it also fuels polarization between different groups.

Trust is a real number varying between 0 (minimum trust) and 1 (maximum). When trust is 0 or close to it, the information received will not produce any change in the initial opinion because the source will be considered untrustworthy and its message will be discarded. On the contrary, when trust is high the influence of the source and its effect on the opinion will be equally high.

Trust plays a key role in risk perception [Flynn et al. (1992)]. People having trust in authorities and experts tend to perceive fewer risks than people not having trust, and this e#ect is higher when people have little knowledge about an issue that is important to them. In his critical review of the literature, Siegrist confirms the importance of trust, but he concludes that it varies by hazard and respondent group therefore it is not possible to define a single way in which trust interacts with risk perception [Siegrist (2019)]. In this study we distinguish between trust in institutions and in other individuals. We define trust in institutions as T_i and trust in peers as P_i

$$T_i = 1 - P_i \qquad (1)$$

This assumption is important because it allows us to distinguish the e#ect of trust in two major sources of information about risk, and to model the interplay between inter-individual trust and trust in official communication [Slovic (1993)]. Studies on misinformation [Lewandowsky et al. (2012)] and the link between conspiracist ideation, worldviews and rejection of science seem to suggest that individuals with low trust in government and experts tend to selectively believe to people with the same views [Lewandowsky et al. (2013)]. A recent study on institutional trust and misinformation about the Ebola outbreak in DR Congo shows that participants in the survey with low levels of trust in government institutions and the information they communicated held widespread beliefs about misinformation, and more than 88 per cent of the surveyed participants had received this information from friends or family [Vinck et al. (2019)].

Processes of social influence

We define three ways in which social influence may unfold. The first consists of peer-to-peer communication among agents communicating with each other in a horizontal and reciprocal way. The second kind of influence happens through vertical institutional communication, which spreads unilaterally from the institution to the individuals.

The impact of media on the population in the a#ermath of disasters is well-known [Vasterman et al. (2005); Holman et al. (2014)], therefore we also model media influence, as neutral, alarming or reassuring depending on the way in which institutional information is reported. Media influence is also unidirectional, i.e., broadcast from the media source to the agents (in this model we do not consider social media).

TABLE 1:

Variable	*Description*	*Notes*
Oi	Opinion	Real number; evolving
Ri	Risk sensitivity	Integer; constant
Bi	Tendency to communicate	Real number; constant
Ti	Trust towards institutions	Real number; constant
Pi	Trust towards peers	Integer; constant

Table 1 presents the main variables defining agents' internal and external behavior, together with their main features.

Algorithm of the dynamics

Step one - Information from the institutional source At each time step, the Institution informs each and every agent about the official risk evaluation I, which is a real variable between 0 and 1, being I= 0 the minimum risk information (i.e., no risk at all), and I = 1 the maximum (i.e., catastrophic event to happen with probability of 100%). We will call this variable institutional information. Agents use this information to update their opinions about the communicated risk I according to their internal variables. An individual i modifies its opinion $Oi(t-1) \equiv Ooi$ following the same rule adopted in Deffuant model [Deffuant et al. (2000); Abelson (1964)]:

$$Ooi \rightarrow Oi = Ooi + Ti(I - Ooi) \qquad (2)$$

The updated opinion Oi is further processed according i's risk sensitivity:

$$\begin{aligned} Oi &\rightarrow (1 + Oi)/2 && \text{if } Ri = +1 \\ Oi &\rightarrow Oi && \text{if } Ri = 0 \qquad (3) \\ Oi &\rightarrow Oi/2 && \text{if } Ri = -1 \end{aligned}$$

Risk sensitive individuals will overestimate the institutional information, therefore considering the hazard as more likely, whereas less sensitive agents will underestimate it. A third category, unbiased individuals, will not process the information any further and the opinion about risk will remain unchanged.

Step two - Information exchange among peers In each simulation round a pair of agents is picked up at random. Let us define j as the "speaker" and i as the "listener" (the symmetrical interaction where i is the speaker and j the listener will take place in the same way), i, and Oi and Oj their opinions before the interaction takes place, respectively. Now, the probability Πx that a determinate player x communicates its opinion to the opponent is

$$\Pi x = Ox^{(1/Bx)} \qquad (4)$$

because we assume that given the same opinion, agents with higher tendency to communicate are more likely to speak, but given the same tendency to communicate the more worried agents will also speak more often.

If the speaker decides not to share its opinion Oj (according previous equation, this happens with probability 1 − Πj) with the listener, the latter's opinion Oi does not change. If instead agent j actually shares its opinion, agent i will change its own according to a rule of the same kind of Eq (2):

$$Oi \rightarrow Oi + Pi(Oj - Oi) = Oi + (1 - Ti)(Oj - Oi) \equiv O'i \qquad (5)$$

The listener considers its risk sensitivity and updates again its opinion:

$$\begin{aligned} O'i &\rightarrow (1 + O'i)/2 && \text{if } Ri = +1 \\ O'i &\rightarrow O'i && \text{if } Ri = 0 \\ O'i &\rightarrow O'i/2 && \text{if } Ri = -1 \end{aligned} \qquad (6)$$

The construction of risk perception - Step three After L rounds (so that on average each player has interacted once per time step), the information exchange ends, and the opinions of the agents become their opinions at time t.

Media influence – As a starting point, we assume that in principle media can report the institutional information in three ways: in a reassuring way, in an alarming way and in a neutral way, i.e., reporting the information without any changes. In this paper we model such effect in a rather simplified manner, leaving a proper refinement for future works: for a discussion about the role of media in disaster preparedness and agenda setting see Barnes et al. (2008) and Moeller (2006).

Therefore, we implemented the effect of media influence in the model as follows. Every time an agent receives the institutional information, we assume that with equal probability such information can be distorted towards alarmism, reassurance, or left unaltered:

$$\begin{aligned} I &\rightarrow I' = \text{random number } \in (0, I/2) && \text{with probability } 1/3 \\ I &\rightarrow I' = I && \text{with probability } 1/3 \\ I &\rightarrow I' = \text{random number } \in ((I+1)/2, 1) && \text{with probability } 1/3 \end{aligned} \qquad (7)$$

End of simulation – Every iteration lasts enough to achieve a final state, i.e., a configuration where the dynamics has become constant and the global configuration of the system is stable, that is, the opinions of all the agents do not change anymore. All the simulation results are averaged over 2000 independent realizations (i.e., iterations) for each given condition, unless differently specified.