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# USING AGENT-BASED SIMULATION TO ANALYSE THE EFFECT OF BROADCAST AND NARROWCAST ON PUBLIC PERCEPTION: A CASE IN SOCIAL RISK AMPLIFICATION

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## ABSTRACT

Individuals often use information from broadcast news (e.g. media) and narrowcast news (e.g. personal social network) to form their perception on a certain social issue. Using a case study in social risk amplification, this paper demonstrates that simulation modelling, specifically agent-based simulation, can be useful in analysing the effect of broadcast and narrowcast processes on the formation of public risk perception. The first part of this paper explains the structure of a model that allows easy configuration for testing various behaviours about which the empirical literature cannot make definitive predictions. The second part of this paper discusses the effect of personal social network and the role of media in the dynamics of public risk perception. The results show the undesirable effect of the extreme narrowcast process in society and a media that simply broadcasts the average public risk perception.

## 1 INTRODUCTION

Individuals often need to make sense of a certain social issue and form their perceptions about the issue. Their perception is likely to be influenced by past experience and information received from various secondary sources such as media and personal social network. In this paper, we refer to non-personal communication between a source and wider part of the society as *broadcast*, and personal communication between an individual and his/her immediate neighbours in the social network as *narrowcast*. We are interested in understanding how broadcast and narrowcast processes affect the formation of public perception, especially in the context of social risk amplification.

Most individuals, consciously or subconsciously, seek to manage risk. Studies show that the public do not necessarily perceive risk in the same way that experts do. Hence, public risk perception has been an important issue for many organizations and has become an important part of risk management. Although a risk event such as a nuclear accident, food poisoning or zoonosis is real, the perception of a society of the same risk event varies. The risk perception often affects the real risk. For example, during SARS outbreak, people reduced their travel which reduced the probability of the spread of SARS. On the other hand, in a flash crowd, the risk perception can make the real risk more imminent. It has become clear that public risk perception is a social phenomenon affected by social processes, not just the psychology of individuals. The *Social Amplification of Risk Framework* (SARF) (Kasperson et al. 1988) is the most commonly used framework to describe how a society responds to risk, and in particular how a society amplifies or attenuates risk through social processes.

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The use of simulation modelling, in particular *agent-based simulation* (ABS), in theorizing about a phenomenon in a society has gained popularity. Classic examples include theorizing about how segregation may occur in a reasonably tolerant society (Schelling 1971), describing the emergence of wealth inequality in a simple society (Epstein and Axtell 1996) and theorizing about how rebellion of a subjugated population emerges against a central authority (Epstein 2002). However, when we search on the use of computer simulation in public risk perception, there is a scarcity in the literature. Two examples that we can find from the literature are Burns and Slovic (2007) and Busby and Onggo (2012). Both of them use system dynamics. Burns and Slovic (2007) simulate the intensity of investigation, media coverage, public risk perception, diffusion of fear and community intervention to examine how a community responds to a terrorist attack. Busby and Onggo (2012) show that when actors in a society correct for other actors' apparent risk amplifications and attenuation, instead of simple-mindedly correcting their own risk beliefs, it can have a polarizing effect on risk beliefs in the society, and can produce residual worry and loss of demand for the associated products and services. The clear limitation of both studies is that their assumptions about group homogeneity means that they cannot reveal the consequences of diversity within groups. Yet, on controversial risk issues, beliefs are highly likely to differ even within quite cohesive sections of society.

This paper presents an ABS model that allows us to theorize about risk perception in a society comprising lay people, risk experts, media and a risk manager. We demonstrate how we use the model to investigate the effect of social networks, memory of past encounters with other members in the society and behaviour of news media on the dissemination of risk perception in the society.

The remainder of this paper is organized as follows. Section 2 provides an overview of social risk perception and, in particular, the social amplification of risk framework. Section 3 explains the structure of the model. Section 4 and Section 5 discuss the effect of social network structure and the role of media, respectively, on the dynamics of public risk perception. Finally, Section 6 concludes our paper.

## 2 SOCIAL AMPLIFICATION OF RISK

Risk has been defined in many ways but there seems to be a consensus that a risk is defined as a product of the probability of a risk event and the magnitude of its effect. Risk perception is a subjective assessment of risk by an individual or a group of individuals. The subjectivity of individuals is confirmed in a review by Boholm (1998) who compared a number of risk studies involving similar questionnaires being given to people from different countries, and argued that risk perception was a socially and culturally constructed conception. The consequence of risk perception being not simply a personal construct but also a social and cultural construct is that there is an interaction between an individual perception at the micro level and the emerging public perception at the macro level.

Kasperson et al. (1988) introduced the social amplification of risk framework (SARF) based on an observation about the discrepancy between the risk as perceived by the public and the risk as assessed by experts. They posited that a risk event was processed by individuals and some social stations (such as experts, media, and social network) in which the risk event interacted with psychological, social and cultural processes that could amplify or attenuate public risk perception. The risk perception affects the risk behaviour which may have a real social or economic impact on the society. It is this impact that causes concern to many policy makers and risk managers.

Two of the key questions that researchers have tried to answer are how the social stations (risk managers, risk experts, media, social networks) communicate risks to the public and how the individuals react to the communicated risk. The literature on these two questions is extensive. The review by Boholm (1998) highlighted the variations in individuals' responses to a number of risk events. This is partly due to the variations in how risk is communicated through media and the role assumed by the media (Bakir 2010). Bakir further highlighted that the impact the media had on public risk perception varied. In addition to the variation in media communicated risk, the impact of media cannot be easily isolated from other communication channels because media communicated risk is not digested in isolation by individuals. They may discuss it with other individuals in their social networks. This has been shown in a number of empirical studies, such as Scherer and Cho's (2003) and Muter et al's (2013). With the ease of getting information from online media, the interplay between narrowcast and broadcast communications has become more intertwined. Ashlin and Ladle (2006) showed how a scientific risk (species extinction) could be skewed in the 'blogosphere' and indicated how easily accessible, low quality broadcast media might encourage public distrust in risk managers or risk experts. Researchers such as Busby and Onggo (2012) showed how the public could easily question the risk communicated by authoritative individuals or institutions using less scientific arguments. The authority of risk managers and risk experts can further be undermined when they contradict one another. Research has shown that experts are not immune to subjectivity. For example, the review done by Bradley (1991) found that doctors' decision making and prescribing behaviour varied and in some cases could be attributed to the characteristics of the prescribing doctors (instead of the illness and patients). To take another example, in his review, Mitchell (1995) found that the personal characteristics of managers influenced their risk perception in making risky buying decisions. From the perspective of SARF, the variations in the risk communicated by the authorities may be interpreted negatively by the public (such as inconsistency or lack of transparency). This could affect their trust to the authorities.

The above studies show that the dynamics of public risk perception are affected by the interactions between key actors such as individuals (lay persons), media, risk experts and risk managers (authorities). Hence, a model that can represent these interactions appears essential for public risk analysis. If policy makers need to understand how risk events such as an outbreak of avian influenza will develop they need to understand 1) how public opinion will develop in response to news, to expert commentary in the public domain, and to the communications of the authorities; and 2) how this developing opinion will co-evolve with the behaviour that it induces.

## 3 AGENT-BASED SIMULATION (ABS) MODEL

The model is implemented using Repast Simphony (http://repast.sourceforge.net/). The model comprises four types of agent (risk manager, risk expert, media and individual) and a risk event generator. The individuals form a social network among themselves, and so do the risk experts. The experts can gather information about individuals experiencing a risk event, make their assessments of the real risk and communicate their assessment to the manager. The manager can see the public risk perception and can obtain risk assessment from experts. The manager will then broadcast his/her communicated risk through the media to the individuals. The media can also gather information from the individuals and broadcast media's communicated risk to the individuals.

### 3.1 Risk Manager

A risk manager represents an individual, or an institution, that, has a legal responsibility or an interest in managing the risk perception in a society. In this model we only include one risk manager because we are interested in the interaction between one institution and the society in which the institution is interested. Hence, the impact of two competing or conflicting managers on public perception dynamics is beyond the scope of this model.

Figure 1 shows that a risk manager regularly consults experts' assessment on real risk, public risk perception and public consumption. Based on this information, the risk manager will make a decision on the level of risk to be communicated to the public. The model implements a number of rules that a risk manager may use, for example:

- relay the average of experts' risk assessment (simplest rule)
- communicate experts' risk assessment but include the uncertainty factor to represent experts' subjectivity

- attenuate experts' risk assessment when public is amplifying and vice versa (Busby and Onggo 2012)

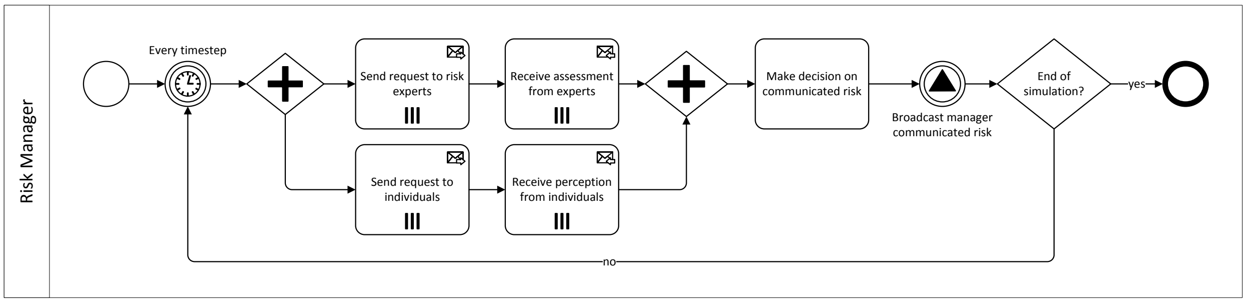


Figure 1: Risk manager's behavior.

Figure 1 uses BPMN to represent agent's behaviour (Onggo and Karpat 2011; Onggo 2012). A circle with a single thin line boundary signifies an event that triggers a process (i.e. start event). A circle with a thick line boundary represents an end event, i.e. an event that marks the end of a process. Any other events are called intermediate events and they are represented by circles with a double thin line boundary. It is common to add an icon to add more information about an event. For example, a timer icon signifies event that is triggered at certain times and a signal icon (triangle) signifies broadcast messages. A rounded rectangle represents an activity. To add more information, an icon can be added to the activity. For example, an envelope icon signifies an activity that sends or receives message(s) (depending on the direction of the arrow in the icon). The multiple bars icon indicates a multi-instance activity. For example, in Figure 1 the manager may send request to and receive information from a number of experts. A diamond represents a decision point that controls the sequence flow in a process. A plus icon indicates a parallel gateway in which parallel sequences are initiated at the fork point and multiple sequences are synchronized at the merge point.

### 3.2 Risk Expert

The role of a risk expert in this model is to make an assessment of the real risk based on the information s/he has (for example, the number of individuals experiencing a specific risk event and the level of public consumption of some good or service that has become hazardous). A risk expert can communicate his/her assessment to a risk manager and to the media.

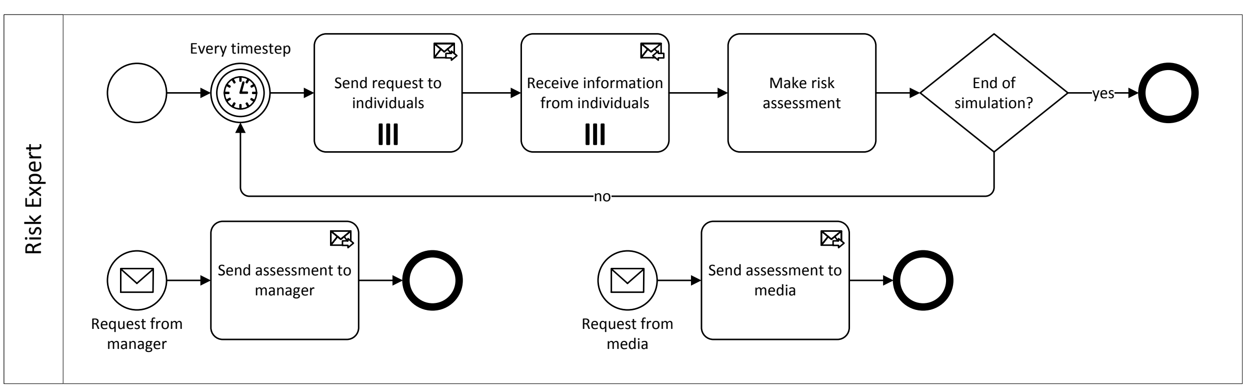


Figure 2: Risk expert's behavior.

The behaviour of an expert can be represented in three sub-processes as shown in Figure 2 (due to space constraint, the line boundaries of the sub processes are not shown). The sub process at the top shows that an expert regularly obtains information from a sample of individuals and makes a risk assessment. The sub-processes at the bottom are triggered whenever an expert receives a request from a risk manager and media, respectively.

### 3.3 Media

The behaviour of media in this model depends on the role it assumes. We have implemented a number of behaviours to reflect different media roles. However, regardless of its role, the activities of media represented in the model are always the same (Figure 3). The media regularly retrieves information from the public and experts, processes the information and communicates the processed information to the public. How the information is processed depends on the role assumed by the media, for example:

- take the average of public risk perception and communicate it (a public-following role)
- as above but add a random noise to represents the uncertainty from its sources (a public-following role with awareness of uncertainty)
- communicate the middle point between public risk perception and risk assessment from experts (a public-leading media role)
- select certain subset of individuals in the sample to amplify (or attenuate) the average public risk perception (biased reporting role)

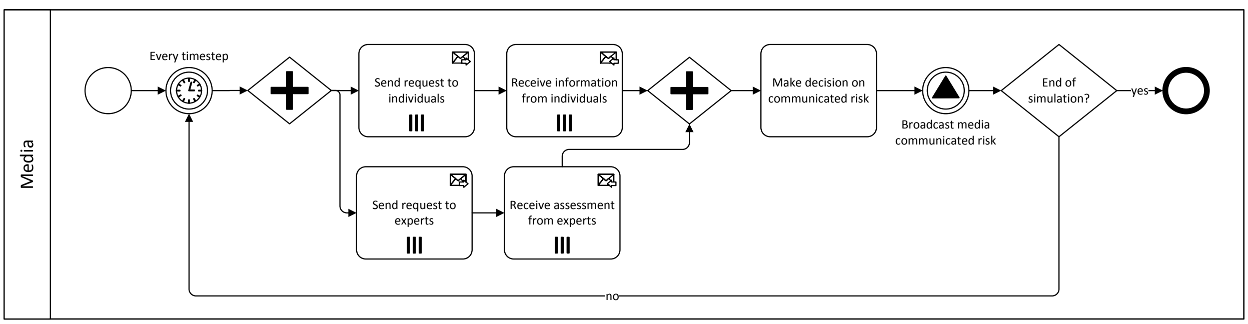


Figure 3: Media's behavior.

### 3.4 Individual

This agent type represents a member of the public who is concerned with the risk that is being studied. Each agent may represent an individual or a group of individuals (such as a nuclear family or an extended family) that has the same collective behaviour. For simplicity, we represent a completely cohesive group of individuals as one individual in the model. If the perceived risk of an individual is above a certain threshold, the individual stops consuming. Depending on the context, an individual may believe that reducing consumption can reduce the risk (for example, in the case of SARS outbreak, reducing travel may reduce the risk of getting infected); on the other hand, an individual may believe that increasing the consumption may reduce his/her risk (for example, in the case of a bank run, an individual may believe that by getting his/her saving as quickly as possible will reduce his/her risk of not having any money at all). The bank run case exemplifies that the objective of each individual is often in conflict with the objective of a risk manager which creates an interesting dynamics.

The behaviour of an individual is shown in Figure 4. The top sub-process shows that an individual receives information from a risk manager (broadcast), media (broadcast) and his/her social network neighbours (narrow cast). The individual will decide his/her risk perception based on these sources of information. We have implemented a number of updating rules. The one used in this paper will be explained in the next section. The four sub-processes at the bottom are triggered by a request from the risk manager, a risk expert, the media and a neighbour, respectively.

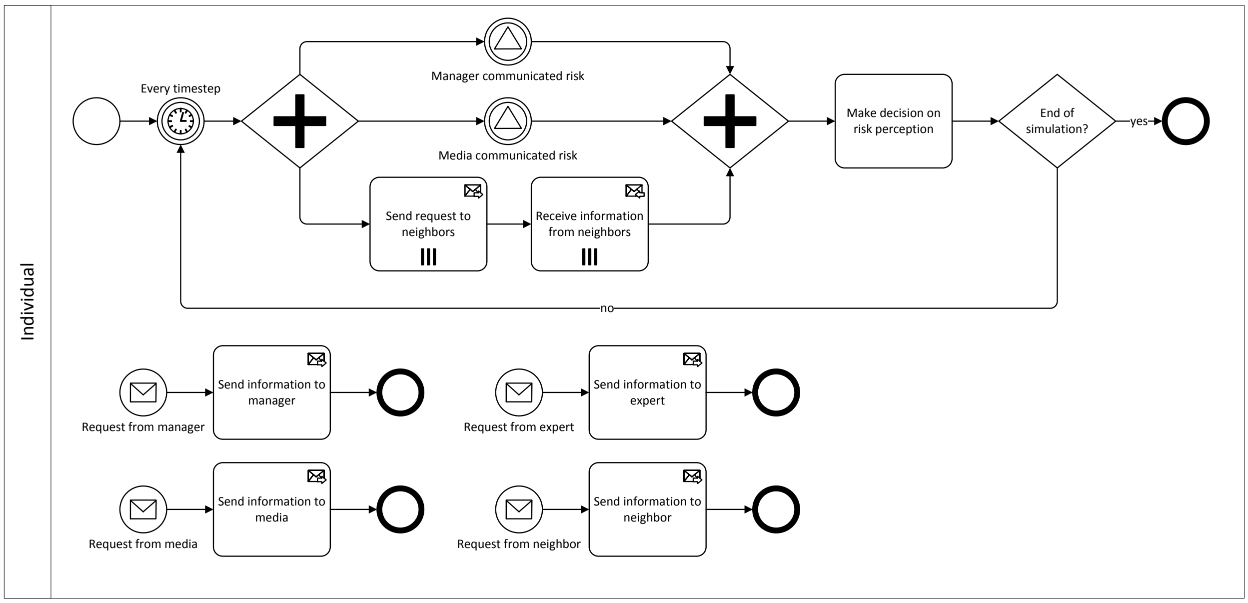


Figure 4: Individual's behavior.

### 3.5 Risk Event Generator

The model has one component that generates risk events for individuals with a predefined probability. The probability will increase at prescheduled outbreaks. The advantage of ABS is that we can use the exact number of individuals experiencing a risk event as a measure of objective risk, which may be unknown in some contexts in the real world. Since the objective risk is often not unknown, we should only use the objective risk given in the model for appropriate analyses (such as comparison between different scenarios); it should not be used as a factor affecting risk perception in the model, especially in cases when such an objective risk is unknown in the real world.

## 4 EFFECT OF NARROWCAST INFORMATION FROM SOCIAL NETWORKS

In this section, we discuss the effect of narrowcast information from social networks on the formation of public risk perception. In this experiment, we disable the media, experts and manager so that the formation of public risk perception will depend solely on the individuals and their social network. Likewise, the effect of consumption on real risk is disabled to cut the interplays between the real risk and perceived risk. The initial risk perception among individuals is initialized to be the same as the real risk (from the risk event generator) with some small uniformly distributed variations to represent a well-informed initial population. As the simulation progresses, an individual changes their risk perception based on the following rule.

```
Let nHigher = #encounters in which neighbour risk perception is higher than mine
Let nLower = #encounters in which neighbour risk perception is lower than mine
Let nSimilar = #encounters in which neighbour risk perception is similar to mine
Let nTotal = nHigher + nLower + nSimilar
Let neighbourRiskPerception = risk perception of a neighbour selected at random
Let myRiskPerception = my risk perception
if (neighbourRiskPerception is higher than myRiskPerception) {
```

```
   change myRiskPerception to neighbourRiskPerception with a probability of
      nHigher/nTotal
   nHigher = nHigher + 1
}
else if (neighbourRiskPerception is lower than myRiskPerception) {
   change myRiskPerception to neighbourRiskPerception with a probability of
      nLower/nTotal
   nLower = nLower + 1

}
else {
   nSimilar = nSimilar + 1
}
```

The exception to the rule is when an individual experiences a risk event. In this case, his/her risk perception will change to 100%. This behaviour is based on the assumption that risk perception refers to what the individual thinks about the probability of a risk event that happens to him/her. This risk perception level will not change for 10 time steps to represent the time it takes for the individual to start considering the perception of other individuals again.

We set the number of individuals to be 1,000. The simulation duration is 1,000 time steps. The probability of an individual to experience a risk event is 1 in 10,000. In this experiment, we compare a lattice 1D network structure in which each individual is connected to two other individuals and a small world network generated using Repast's `WattsBetaSmallWorldGenerator` function with beta = 0.25 (the probability of an edge being rewired randomly) and degree = 8 (the number of edges connected to each vertex). Figure 5 shows the result based on the average of 100 simulation runs on each scenario.

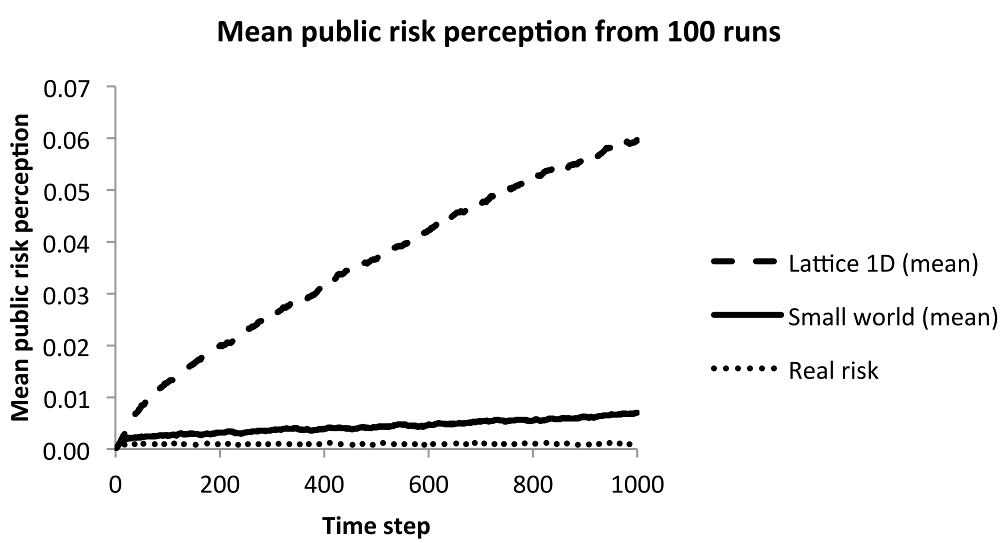


Figure 5: Effect of social network on public risk perception without any outbreak.

The result shows that the mean of public risk perception is significantly higher when each individual forms a lattice 1D network than a small world network. Lattice 1D network represents an extreme network structure in which each individual involves in an extremely narrow communication. When an individual experiences a risk event, s/he can influence his/her two neighbours more easily. Subsequently, the two neighbours can influence their other neighbour more easily too. As a result, the spread of higher risk perception level is faster in a Lattice 1D network. This is not the case for the small world network because each individual is connected to more neighbours. Unless there is a massive outbreak to a specific cluster, the spread of higher risk perception level will not be as fast. The extremely narrow communication can also trigger a polarity in the society as shown in Figure 6. Figure 6 shows the mean of the standard deviation of risk perceptions among individuals in the society over time (this is different from the standard deviation of mean public risk perception).

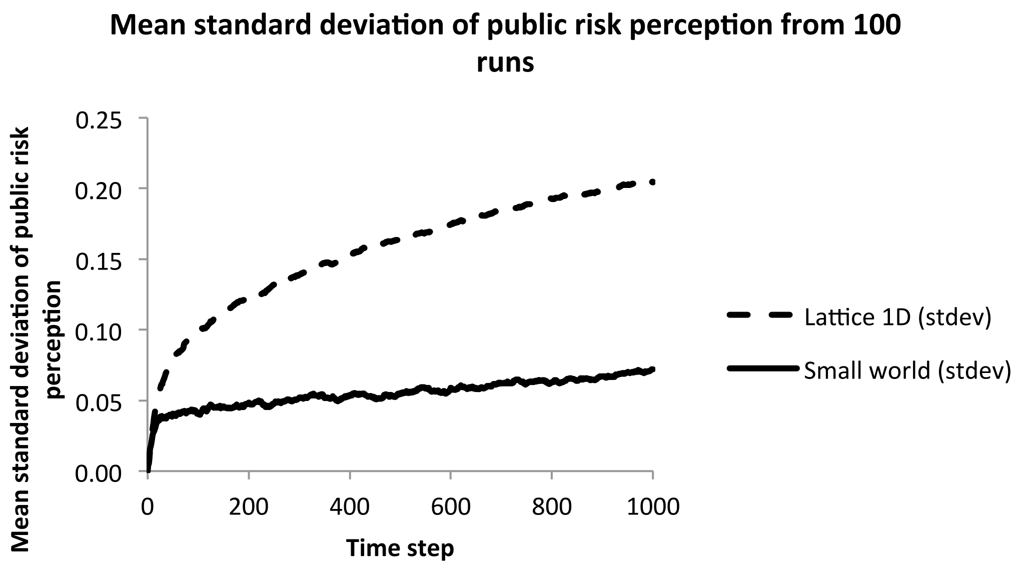


Figure 6: Effect of social network on polarity in public risk perception without any outbreak.

In the next experiment, we introduce an outbreak to happen at time step 100 for a duration of 10 time steps, during which the probability of an individual to experience a risk event surges to 1 in 100. We are interested in the effect of the two social network structures on the formation of public risk perception after the outbreak has ended. The result based on the average of 100 simulation runs on each scenario is shown in Figure 7.

The result shows a significant difference between the two social network structures. In Lattice 1D network, during an outbreak the public risk perception surges but when the outbreak has ended the public risk perception keeps increasing. This is because the outbreak increases the number of people experiencing the risk event. The increased number of people experiencing the risk event provides more starting points for the spread of the their risk perception at the end of the outbreak. Hence, the spread is faster in comparison to the case when there is not any outbreak. A society with the small network structure, on the other hand, shows more resilience. As long as the number of people experiencing the risk events still represents a minority in the population, the perception from the majority will have enough power to bring the mean public risk perception down to the pre-outbreak level after some delays. The same explanation applies to the difference in the polarisation. An outbreak in the Lattice 1D structure amplifies the polarisation in the society as we can see from comparing the mean standard deviation in Figure 6 and Figure 8. On the other hand, the small world network shows more resilience. Although the outbreak causes polarisation in the society, once the outbreak has ended, the polarisation in the society goes down to a level that is not significantly higher than the one before the outbreak.

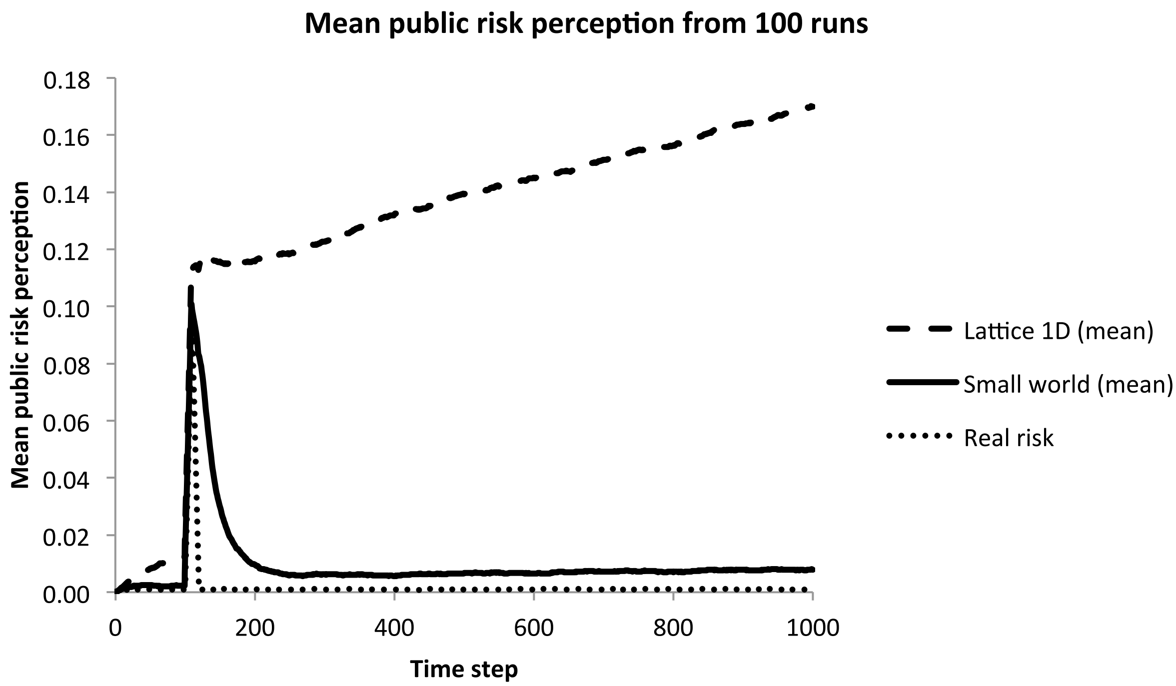


Figure 7: Effect of social network on public risk perception with an outbreak.

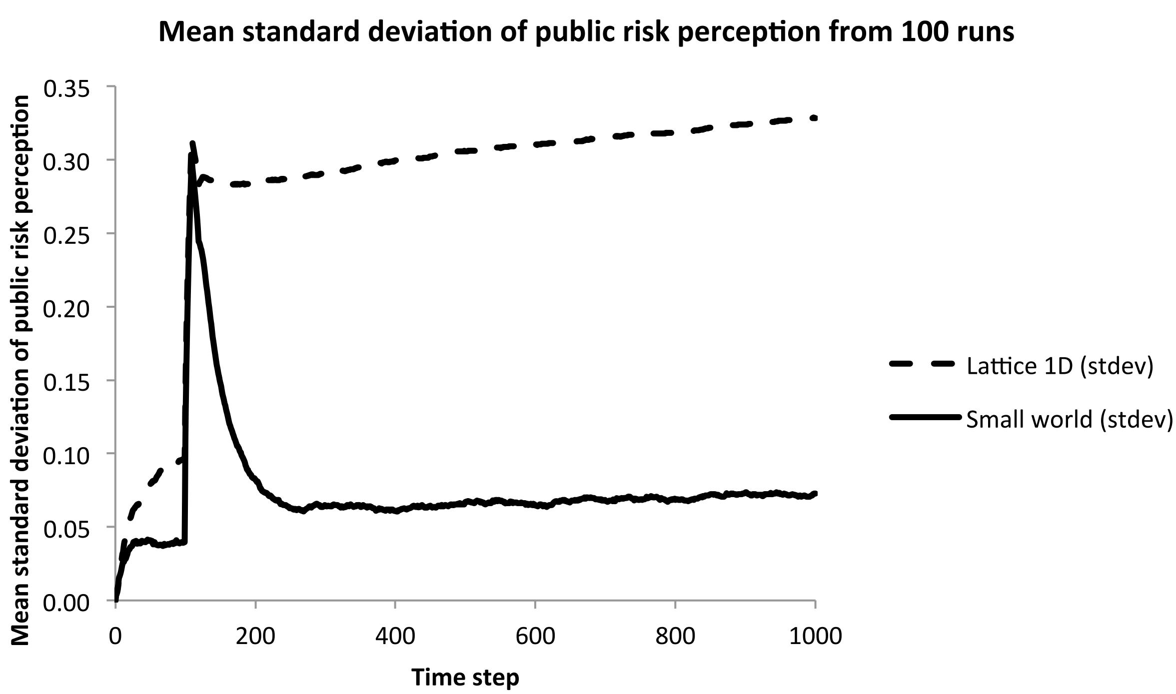


Figure 8: Effect of social network on polarisation in public risk perception with an outbreak.

## 5 THE EFFECT OF BROADCAST FROM MEDIA

This section studies the interplay between broadcast (through a media) and narrowcast (word-of-mouth between connected individuals). In addition, we will also compare how three different media roles affect the formation of public risk perception. The first role is referred to as "media as an objective institution" in which the media always broadcasts the real risk (i.e. the proportion of people experiencing the risk event). Unlike the first role, in the second role, the media softens its broadcast by taking the average of the real risk and the public risk perception. We refer to this role as "media as a leader". The objective is to gradually bring the public risk perception closer to the real one. This role could be used when the public is likely to distrust the media if the media communicates a significantly different risk level than the public risk perception. These two roles assume that the real risk is known. This assumption is acceptable for the objective of this experiment. The final role is referred to as "media as a follower". In this case, the media always broadcast the public risk perception, probably in order to win the heart of the public.

We use the same configuration as the previous experiment. We assume that all individuals put significantly more weight on the risk communicated through their social network than the one through media. The weight that an individual places on the media's communicated risk varies and it follows a uniformly distributed random number between 0 and 0.05. This setting represents a society that does not trust the media but still takes into account the media's communicated risk in constructing their risk perception. The result based on 100 simulation run is shown in Figure 9. The baseline result without media from Figure 7 is copied to Figure 9.

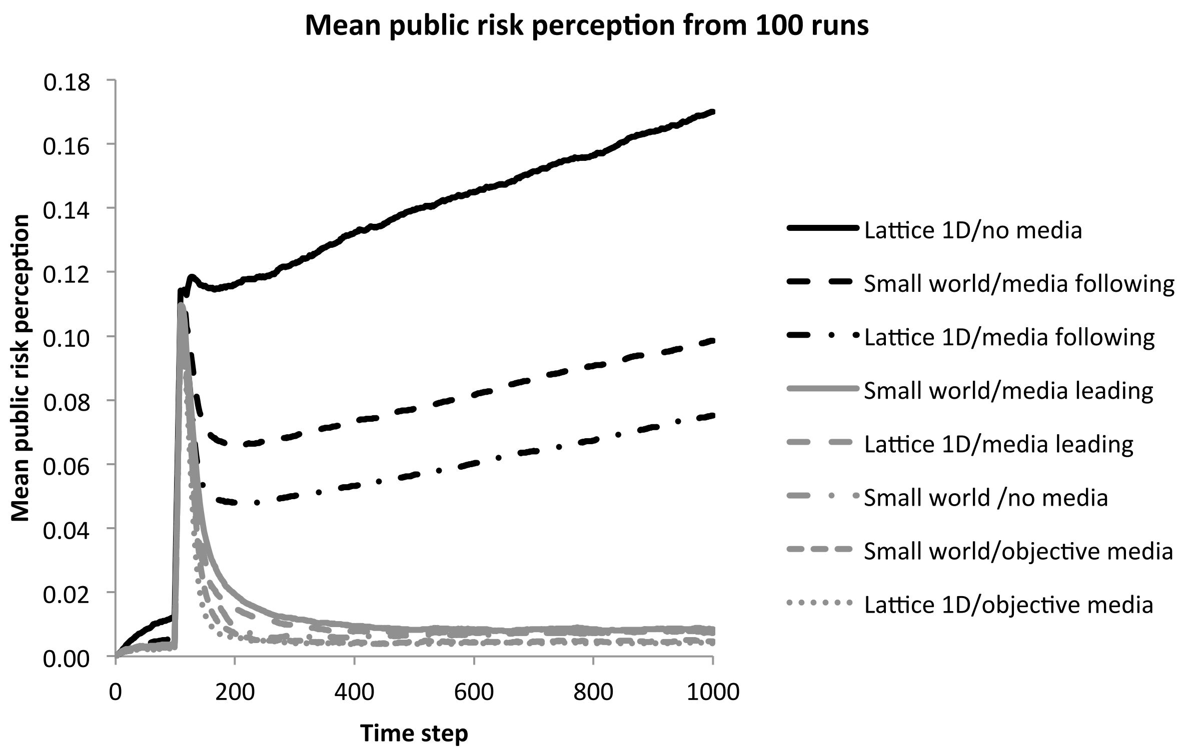


Figure 9: Effect of different media roles on public risk perception with an outbreak.

The result shows that when the media follows the public, the public risk perception is amplified regardless of the social network structure. This result is interesting because it implies that even in a society that trusts their social network significantly more than the media, this macro behaviour can emerge. The reason is that although the media does not significantly affect the individuals directly but they continuously influence all individuals. The individuals who have lower risk perception than the population mean will slightly amplify their perception. On the other hand, the individuals who have higher risk perception than the population mean will attenuate their risk perception slightly. At the same time, individuals who have adjusted their perception may influence other individuals through their social network. Hence, the media influences individuals in two ways directly and indirectly through other individuals in their social network. If we look at the small world network scenario, we can see that the society is better off without any media than having a media that assumes a following role. The scenarios when the media assumes a leading role and an objective role show how effective media is in helping the society to take a responsible view on the risk perception, even if they do not necessarily put a lot of trust in the media. The media can still continuously influence the individuals to make small adjustment to their risk perception.

Bakir (2010) highlighted the need to study the impact of mediated risk at the micro and macro levels. This section has demonstrated, using a simple model, a number of possible public risk perception dynamics caused by the interplays between risk perception decision at the individual level and the aggregate public risk perception as communicated by the media. Hence, ABS is a suitable for such analysis as evident in this example and numerous other studies that use ABS to investigate the interactions between micro level's behaviours and the emerging behaviour at the macro level (for example, Schelling 1971; Epstein and Axtell 1996; Epstein 2002).

## 6 CONCLUSIONS

We have highlighted that the use of simulation modelling in social risk research is lacking. This paper has demonstrated that simulation modelling, in this case, agent-based simulation, is a useful tool to analyse the formation of risk perceptions in a society. Using a simple model, this paper has shown the impact of narrowcast information exchange through social networks and broadcast exchange through a media that assumes different roles in its relationship with the public. The model has enabled us to understand that an extremely narrow communication may exacerbate the amplification (or attenuation) of risk perception and create the polarization of risk perception in a society. The model has also shown that the role of media can be important even in a society that trusts their social networks significantly more than the media. Although social amplification of risk is chosen for the case study, the agent-based simulation used in this paper can be used to analyse a more general social process that is affected by the interplays between broadcast and narrowcast communications.

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