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The effectiveness of flood risk communication strategies and the influence of social networks—Insights from an agent-based model

Toon Haer*, W.J. Wouter Botzen, Jeroen C.J.H. Aerts

Institute for Environmental Studies (IVM), VU University Amsterdam, De Boelelaan 1087, 1081HV Amsterdam, The Netherlands

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ABSTRACT

Flood risk management is becoming increasingly important, because more people are settling in flood-prone areas, and flood risk is increasing in many regions due to extreme weather events associated with climate change. It has been proposed that appropriately designed flood risk communication campaigns can stimulate floodplain inhabitants to prepare for flooding, and encourage adaptation to climate change. However, such campaigns do not always result in the desired action, and the effectiveness of communication in raising flood risk awareness and improving flood preparedness has hardly been studied. We evaluate different flood risk communication strategies, using an agent-based modelling approach, which is especially suitable for examining the effect of communication on each individual, and how flood risk communication can propagate through an individual's social network. Our modelling results show that tailored, people-centred, flood risk communication can be significantly more effective than the common approach of top-down government communication, even when tailored communication reaches fewer individuals. Furthermore, communication on how to protect against floods, in addition to providing information about flood risk, is much more effective than the traditional strategy of communicating only about flood risk. Another main finding is that a person's social network can have a significant effect on whether or not individuals take protective action. This leads to the recommendation that flood risk communication should aim at exploiting this natural amplifying effect of social networks, for instance, through the use of social media.

1. Introduction

The severity and frequency of floods is expected to increase in many regions around the world as a result of climate change (IPCC, 2012) and economic and population growth in flood-prone regions (Jongman et al., 2012). It is becoming increasingly important to communicate the risks of flooding to communities living near rivers and coasts (IPCC, 2012), and to motivate those at risk to better prepare for flooding (Botzen and Van den Bergh, 2009; Kunreuther and Michel-Kerjan, 2011; Poussin et al., 2014). Although the importance of flood risk communication is widely acknowledged, little is known about the effectiveness of flood risk communication, as is apparent from a literature review on flood risk perceptions by Kellens et al. (2013). It is only recently that several studies have attempted to fill this gap, by applying questionnaires to analyse the effect of different risk communication strategies on risk perceptions and intentions to prepare for flooding (Botzen et al., 2013; De Boer et al., 2014a,b). These studies

show that information tailored to the specific needs of an individual has an important influence on risk perceptions. Moreover, they find that risk communication can stimulate individuals to take measures that reduce flood risk, such as structural flood risk mitigation measures, flood-adapted building use, deployment of flood barriers, and/or purchase of flood insurance (Botzen et al., 2013; De Boer et al., 2014a,b).

Risk communication is commonly done by governments and organisations who disseminate information about floods in a top-down manner through guidelines, information brochures, media campaigns, and internet websites, which individuals may or may not read or receive (Fekete, 2012). Examples are the flood zone maps that delineate flood-prone areas and their flood probabilities provided by the Federal Emergency Management Agency in the United States (www.fema.gov) and the flood maps produced for the European Union Floods Directive. To a lesser extent, information on coping responses is provided, such as the effectiveness of the measures that people can take to protect themselves against floods. A recent study on communication strategies in England, the Netherlands, and Flanders showed that top-down government campaigns have not been very successful in motivating people to

* Corresponding author.
E-mail address: toon.haer@vu.nl (T. Haer).

take protective measures against flooding (INTERREG, 2013). These campaigns were partly ineffective because they did not address the different attitudes that people have towards flooding because of their cultural differences and local circumstances (Burningham et al., 2008; Martens et al., 2009).

The need for people-centred risk communication, which focuses on the specific needs of different people, as opposed to a one-size-fits-all government campaign, was acknowledged by the IPCC (2012) to be a key factor in disaster risk reduction. In particular, local risk perceptions and local framing of risk should be included in communication processes. According to the IPCC (2012), risk communication should achieve the aims of both informing people about their particular risk and engaging the stakeholders in the identification of possible solutions. While the traditional top-down approach offers little opportunities for this, individual or community-based approaches can address the heterogeneous needs of individuals, and offer a means to provide tailored information on risk perception and coping measures (Bier, 2001; Martens et al., 2009; Terpstra et al., 2009). By providing tailored information, people are then enabled to assess their own risk situation, and are provided with the means to make informed decisions on the appropriate actions to take (Kellens et al., 2013).

Furthermore, there is a growing recognition in the scientific literature of the role of an individual's social network and social context in decisions about protecting against risk (Bubeck et al., 2013; Figueiredo et al., 2009; Kunreuther et al., 2013; Lara et al., 2010; Lo, 2013; Van der Linden, 2015). For example, both Lo (2013) and Bubeck et al. (2013) found that, in addition to risk perception, the expectations and adoption of flood risk reduction measures in the social networks of individuals are important determinants of individual flood preparedness. Kunreuther et al. (2013) found similar results in a laboratory experiment, where the major driver of an individual to invest in disaster risk reduction was the average investment level of his/her neighbours. Moreover, Van der Linden (2015) found that an individual's actions towards extreme weather risks amplify throughout his/her social network. Lara et al. (2010) found clear evidence for the relation between social involvement and the willingness to take action against floods. These studies show that social networks not only serve as a stimulus for taking action, but also convey information.

An improved understanding of the effectiveness of flood risk communication, as well as of the influence of a person's social network on this effectiveness, can provide valuable insights for flood risk management policies. This study examines both of these themes by applying an agent-based model, as advocated by Martens et al. (2009). This method is especially suitable for modelling the interaction between social networks on a micro-scale (household) level, and for analysing the emerging flood risk reduction and diffusion of information on a meso- or macro-scale (An, 2012). Although these models are only an approximation of the full complexity of human behaviour, agent-based models are

especially useful for disentangling specific behavioural processes, as is of interest here. While agent-based models have previously been applied to investigate the diffusion of information (e.g. Macy and Willer, 2002; Rahmandad and Sterman, 2008), and flood risk management (i.e. Dawson et al., 2011; Filatova, 2013), we present here the first application specifically for flood risk communication purposes. The theoretical basis for individual flood-preparedness decisions is provided by Protection Motivation Theory (Rogers, 1983).

Protection Motivation Theory, shown schematically in Fig. 1, has become an important socio-psychological model of individual flood risk-preparedness decisions (Bubeck et al., 2012; Grothmann and Reusswig, 2006; Koerth et al., 2013; Poussin et al., 2014). For the study presented here, it offers a useful framework to analyse how flood risk communication, as a form of verbal persuasion, can influence a person's threat or coping appraisal, and how flood preparedness is affected. Communicating for instance the probability of a flood, as is done by the FEMA flood maps in the United States, aims to change people's threat appraisal. Communicating about the costs and the effectiveness of certain protection measures aims to change people's coping appraisal. We estimate the effectiveness of communication strategies by the implementation rates of different disaster risk-reducing measures. Moreover, the influence of the social network is estimated by including and excluding social networks of agents. By investigating different general types of flood risk communication strategies, the results can be used for making recommendations for the overall design of flood risk communication campaigns.

2. Methods

We developed an agent-based model to capture the effectiveness of flood risk communication and the influence of social networks. The applied modelling software is NetLogo V 5.2.0 (Wilensky, 1999). The model simulates how and when households take protective action and it evaluates the effectiveness of different flood risk communication strategies. Each simulation runs for 7 years with time-steps of 1 year and each stochastic simulation run is repeated 100 times. The 7-year period represents a realistic period for flood risk communication campaigns in the Netherlands, such as the 'The Netherlands lives with water' campaign (INTERREG, 2013). The model is applied to households in the outer-dike areas in the Rotterdam-Rijnmond region, shown in Fig. 2. The case-study area serves as an example from which we derive specific results for the region, and more general lessons that are transferable to flood-prone regions around the world. Different social, cultural and political conditions in other regions may imply that flood risk communication campaigns produce different results. To facilitate the reproducibility of the model, a technical description is given in supplement A following the ODD (Overview, Design concepts, Details) protocol by Grimm et al. (2010, 2006).
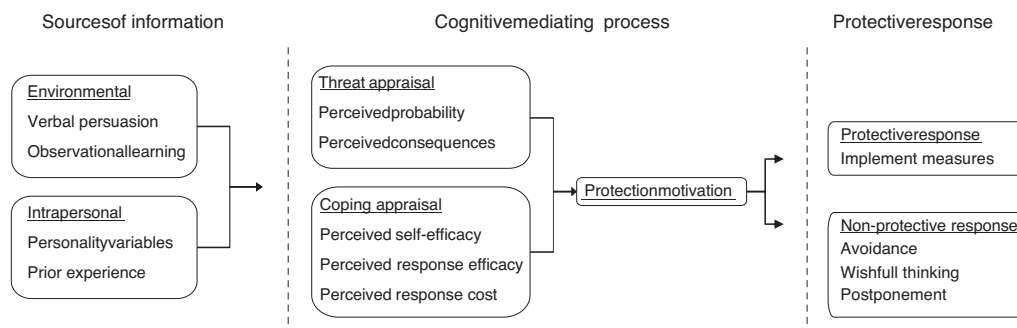

Fig. 1. A schematic overview of Protection Motivation Theory, adapted from Rogers (1983) and Bubeck et al. (2012).