THE CHANGING LANDSCAPE OF EARLY WARNING SYSTEMS

Promoting Effective Decision Making and Action in Disasters

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HARVARD FXB
CENTER FOR HEALTH & HUMAN RIGHTS

HARVARD T.H. CHAN
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Key Messages

1. Early warning systems are critical in protecting populations in disaster-prone areas from harm.
2. Hong Kong has well-established warning systems for climate-related disasters, however the role of human decision making in engagement with protective action is less clear.
3. Action-oriented warning signals channelled through a trusted source, such as the HKO, are vital to improving disaster preparedness and response.
4. Engaging social media avenues to disseminate real-time information and directions will support broader accessibility and faster response in complex disasters.

Early warning systems are critical to protecting populations from harm during disasters. The recent Sendai Framework for Disaster Risk Reduction highlights a need to increase the availability of and access to early warning systems as a priority target.[1] A number of nations, including Hong Kong, have already established highly developed early warning systems. However, the changing landscape of communication technologies has created both opportunities and challenges for people as they navigate a greater number of information networks, and a higher frequency of messaging.

This policy brief provides an overview of the interaction between social media, disaster preparedness, and strategic decision-making. Recommendations on how to communicate information in ways that optimise protective action will be outlined. These include proposals for specific and understandable action-oriented warning signals channelled through a trusted source; avoiding false alarms where possible; building individual self-efficacy for disaster preparedness; and educating communities on the actions associated with each level of warning.

Early Warning Systems: Towards People-Centred and Multi-Hazard Systems

Early warning systems (EWS) disseminate timely information to a population about an impending hazard (e.g., natural, biological, socio-political, or industrial/chemical). They are preventative in nature by prompting advanced action and anticipatory adaptation to reduce hazard-associated risks and costs (i.e., loss of human life, economic costs). Such cost-effective risk mitigation systems are critical in protecting disaster-affected populations from harm.

Over recent years there has been a move towards people-centred and multi-hazard EWS, as outlined in the Hyogo Framework for Action (2005-2015).[2] These EWS are shifting to focus on social, community and psychological factors in addition to technological aspects; many now accommodate various types of weather hazards via shared observation systems and multi-agency coordination.[3]

Although the significant progress made with Hyogo has saved thousands of lives through early warnings,[4] evidence suggests that many people continue to ignore warnings and refuse evacuation orders.[5,6] The danger associated with the failure to act early in disasters suggests that more work is needed to understand how to communicate information in a way that enhances protective action and how to foster strategic decision-making in times of crisis. Accordingly, a focus on integrating knowledge about human decision-making and protective behaviour into the effective design of early warnings has become a focus for the revised priorities outlined in the recently established Sendai Framework.[4,7]

Hazard Risk Context: Current Early Warning Systems in Hong Kong

With its sub-tropical climate and low lying coastal geography, Hong Kong is frequently exposed to severe weather phenomena including gales, tropical cyclones, monsoons, and thunderstorms.[8] While deaths from tropical cyclones have been significantly reduced in the past century,[9] there is growing concern about the potential socioeconomic impact of severe weather phenomena in Hong Kong's future. The Hong Kong Climate Change Report[10] outlines the projected changes in Hong Kong's weather due to climate change, which include:

- increases in the number of very hot days and hot nights,
- increases in the average rainfall intensity and frequency of extreme rainfall,
- sea-level rise and coastal changes, and
- increased threat of storm surges associated with tropical cyclones.

The Hong Kong government has strengthened physical infrastructure and established a sophisticated early warning system for weather-related phenomena.[10] The first numbered warning signals were originally created for the use and benefit of mariners but have since been adopted for public use. The warning system is a comprehensive and effective system managed by the Hong Kong Observatory (HKO), and warns the public of the threat of winds associated with a tropical cyclone (see Table 1). Given population growth, there is currently a requirement for a 2-hour advance alert if a Number 8 warning is issued.[11] Systems similar to that of the cyclone warning system exist for rainstorms, floods, landslides, and extreme temperatures. For example, there is a colour-coded rainstorm warning system (amber, red, and black), which is accompanied by action guidelines for the public, schools, and workplaces (see HKO website).

Action-Oriented Warnings

Warnings must present accurate and succinct information about the hazard, what is expected, and in what way it will threaten people's safety.[12] Details on location and timing of the hazard are important, so that people can make effective decisions about shelter or evacuation, and engage contingency plans if necessary. Emerging technologies may augment traditional media and signage, to ensure that actionable risk is communicated quickly. Guidance should be easily accessible, clearly stated, and describe protective action recommendations.[13] Action-oriented warning systems have been implemented to some degree in the United States,[14] the Caribbean,[15] the Philippines (Asia Disaster Preparedness Centre) and Australia,[16] but evidence of their success is limited.[17] Further research is

needed to determine whether action-oriented messages improve decision making, increase rates of protective action, and save lives.

Table 1: Current Warning Levels and Corresponding Actions for Weather-Related Events in Hong Kong

WARNING	MEANING	ACTION
	1: A tropical cyclone is centred within about 800 kilometres (km) of Hong Kong and may affect the territory.	If you are planning an outing, remember that there is a tropical cyclone near Hong Kong which may affect your plans. Beware that strong winds may occur over offshore waters. Listen to radio and TV broadcasts or browse the Observatory website on the progress of the tropical cyclone.
	3: Strong wind is expected or blowing generally in Hong Kong near sea level, with a sustained speed of 41-62 kilometres per hour (km/h), and gusts which may exceed 110 km/h, and the wind condition is expected to persist.	Secure all loose objects, particularly those on balconies and rooftops. Flower pots and other objects likely to be blown away should be taken indoors. Secure hoardings, scaffoldings and temporary structures. Drains should be cleared to avoid blockage and overflows. Stay away from the shoreline and not to engage in water sports. Fishing vessels should seek shelter without delay. Listen to radio and TV announcements and browse the Observatory website for further information about the tropical cyclone.
	8: Gale or storm force wind is expected or blowing generally in Hong Kong near sea level, with a sustained wind speed of 63-117 km/h from the quarter indicated and gusts which may exceed 180 km/h, and the wind condition is expected to persist.	Complete all precautions now before gales commence. Lock all windows and doors. Fit bars into positions and insert reinforced shutters and gates if available. Adhesive tape fixed to large window panes in exposed positions will reduce damage by broken glass. Do not stand near windows on the exposed side of your home. Move all furniture and valuables away from these areas. Make sure you have a safe place to shelter, should windows be broken. Now is the time to decide which rooms you will use to shelter if the windows on the exposed side of your home become broken. Owners of neon signs should arrange for the electricity supply to their signs to be switched off. Park your car where it is least likely to be damaged. Avoid staying in the street. Return home as soon as possible if conditions so permit.
	9: Gale or storm force wind is increasing or expected to increase significantly in strength.	Stay indoors. Stay away from exposed windows and doors to avoid flying debris. Close all interior doors and make sure children are confined to the least exposed part of your home. Do not touch electrical cables that have been blown loose. You should fix broken windows and doors only when there is no danger in doing so. If you are away from home, find a safe place and remain there until the danger is over.
	10: Hurricane force wind is expected or blowing with sustained speed reaching upwards from 118 km/h and gusts that may exceed 220 km/h.	The same precautions as above apply. Remember that if the eye of the typhoon passes directly over Hong Kong, there may be a temporary lull lasting a few minutes to several hours. Do not relax your guard, as there will be a sudden resumption of violent winds from a different direction. Remain where you are if protected and be prepared for destructive winds.

Based on information from Hong Kong Observatory, "Precautionary Measures when Tropical Cyclone Warning Signals are in force" webpage, http://www.hko.gov.hk/informtc/precaution.htm, accessed April 26, 2017, and "Hong Kong's Tropical Warning Systems" pamphlet, Hong Kong: Hong Kong Special Administrative Region, June 2012.

Changing Environments: Emerging Technologies for Warning

The growing pace of the technological revolution creates a rapidly changing environment for dissemination of warning information. People no longer rely on their physical neighbours and traditional media to source risk advice, but participate in the dialogue through social media networks.[18] With change comes significant opportunity. The diffusion of social media has resulted in new avenues for

interacting with the public, as people move from passive to active engagement – uploading, sharing, analysing and organizing information as it emerges.[19] People expect information in real time, and will actively seek communication online.[20] Particularly among young and middle-aged adults, the internet provides the primary source of weather-related information and is likely to be the mode through which disaster-related warnings will be sought.[21] The Hong Kong Observatory currently has 9,660 Twitter followers, and the personalised weather service smartphone app 'My Observatory' received more than 35,000 views in the last quarter of 2016.

The preference for online sources of disaster-related information, rather than direct communication with physical neighbours, friends and family builds on the concept of 'networked individualism'.[22] As linkages become increasingly individual-focused, rather than embedded in groups, information will be sought that focuses on the person. Individuals are able to seek tailored information, with unparalleled speed and accessibility. The use of social media for information dissemination (e.g., retweeting on Twitter) is powerful for outreach and results in exponential proliferation of hazard-related information.[23] For example, at the peak of Hurricane Sandy, twenty million tweets were posted within six days.[24]

Yet information abundance can be problematic. The high volume of messages that arise before and during disasters can be difficult to sort through, and the lack of regulatory processes creates a potential distance between ease of access and accuracy. Nor is there any requirement for people uploading information to be on site, which has proved useful for shaping the conversation in some disaster-related scenarios (such as media outlets collating information offsite for the Boston bombing), but less so in others (for example, the growing visibility of celebrities' and private citizens' opinions on high-profile disasters).[19] **Valuable information can be drowned out in the data stream.**[25] In the lead up to Hurricane Sandy, there was little information detailing specific behavioural recommendations available, and as the storm worsened, it became more difficult to sort through the affect-driven Tweets to find action-specific information.[26] Similar evidence suggests that citizens of Taiwan struggled to determine valuable directions in the abundance of risk information during the 2009 Typhoon Morakot.[27]

Online tools have been developed to address this issue. For example, crowdsourcing platforms Twitter, Ushahidi, CrisisTracker, and Google Person Finder enable sharing of disaster-related information, such as hazard impact, location of loved ones, and resource availability.[19] Twitter hashtags are frequently used to organise and filter information, and support the creation of self-organised online communities,[28] which enables traditional media outlets and government bodies to strategically direct information. However, beyond the use of hashtags as a simple search filter, Twitter has no regulatory mechanism for relevance, content substantiation, or accuracy of data. Although in previous disasters, citizens contributed most to the use of specific hashtags,[29] people are more likely to seek information during crises from traditional media outlets and trusted sources (including government agencies) that had large, well-established audiences prior to the event.[19,30]

Despite the changing social dynamics that accompany technological advancement, people's engagement in protective actions continues to rely on cognitive processes. While the content, source, and timing of messages play an important role in how people react, there is a wealth of other human-related variables

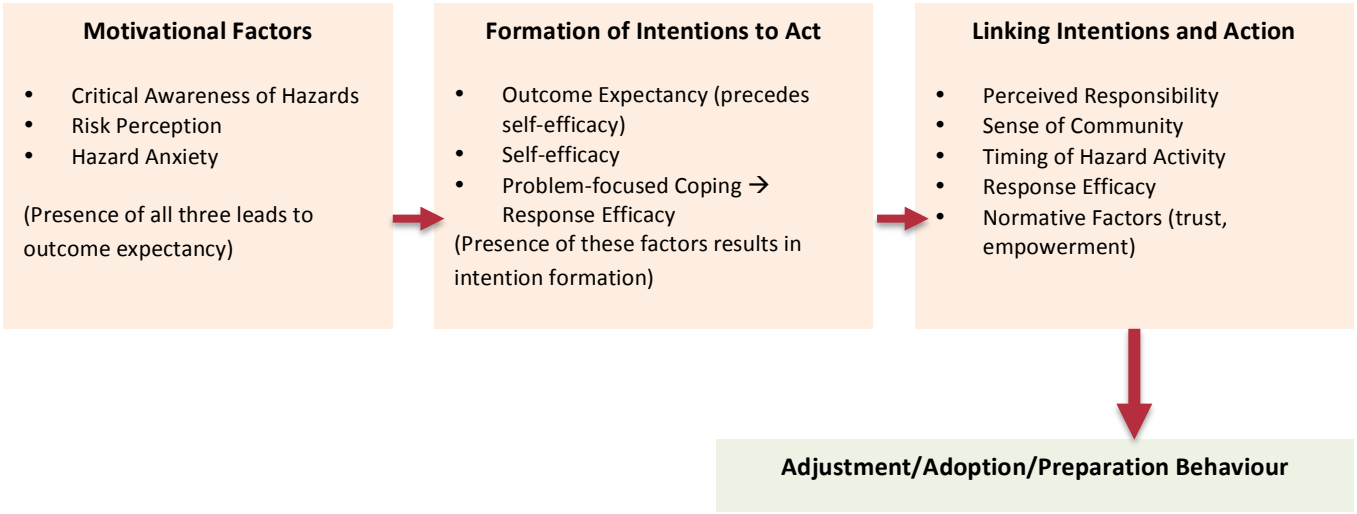
that influence decision making. Accordingly, it is important that policy account for the cognitive factors that mould future behaviour.

Moving Forward: Understanding the Link between Risk Perception, Decision Making, and Human Behaviour

Risk perception is a crucial motivating factor in threat response, influenced by human cognitive attribution and decision making.[31,32] While risk is often communicated in an objective way (e.g., prediction of a natural hazard's occurrence or consequences), humans interpret this information in the context of their own circumstances and past experience with natural hazards, making perception of the risk relative rather than absolute.[33] People must first recognize and interpret risk, then develop strategies to reduce the possibility of harm.[19] Paton's social-cognitive model of disaster preparedness and response[34,35] and Lindell and Perry's protective action model[36] are informed by evidence concerning strategic decision-making and health protective behaviours. In brief, the models propose that the relationship between motivation and engaging in risk reduction behaviour is mediated by intentions, with each of these three stages influenced by numerous factors (see diagram below).

The motivational stage in Paton's model[34,35] includes factors relating to the saliency of a hazard, a person's awareness of the risk, and associated anxiety. The presence of these factors is associated with the degree to which a person believes that they can affect the outcome of a hazard event (outcome expectancy), which contributes to the formation of intentions. Other variables influencing the formation of intentions include the degree to which they believe they have the ability to act effectively (self-efficacy) and the presence of problem-focused coping. Once intentions to act are formed, protective behaviour manifests based on the perception of responsibility, sense of community, timing of the hazard activity, and trust in the warning sources. The socio-cognitive factors involved in risk perception are outlined in Table 2 (please see Online Supplement).

Figure 1. A Socio-Cognitive Model of Disaster Response



Adapted from D. Paton, "Disaster preparedness: A social cognitive perspective, *Disaster Prevention and Management: An International Journa*l, 2003;12(3):210-216; and "When good intentions turn bad: promoting natural hazard preparedness," *The Australian Journal of Emergency Managemen*t,2005;20(1):25-30.

The Importance of Community and Education

The importance of delivering action-oriented EWS is clear. Additional consideration needs to be given to education about relevant EWS in communities, especially if a new EWS is developed or changes are made to a current system. Ongoing education about current systems can increase individuals' awareness of personal responsibility and appropriate action to take during an emergency. It may also manage expectations about the extent of assistance likely to be received during hazards.[37] Indeed, it has been found that people tend to take greater control over their behaviour and safety in disaster contexts when there are community-managed initiatives.[37] An effective EWS ideally links community-managed initiatives to a broader centralised national warning system.

The Hong Kong Jockey Club Disaster Preparedness and Response Institute (HKJCDPRI) is poised to play a vital role in this process. The annual Community Campaign on Disaster Resilience is an excellent avenue for raising awareness among Hong Kong's residents and providing education in the meaning of early warning signals, where to find information, and how to decide on the best course of action. Similarly, HKJCDPRI's Disaster Preparedness Training for Secondary Schools could incorporate early warning information and contingency planning protocols for children and adolescents. Children and youth often act as catalysts for sharing preparedness information within their families and communities,[38] and as adolescents become increasingly engaged with social media, complementing educational programs with online platforms will reinforce opportunities for learning.

Gaps in Practice and Recommendations

Strategic decision-making is the core component of effective action. Providing accurate, action-oriented warnings with sufficient time for action will support individuals' capacity to assess risk and determine a decisive plan of action. Emerging technologies have created new avenues for frequent dissemination of tailored risk warnings. As such, we propose the following recommendations for Hong Kong:

1. **Warning messages need to be easily understood.** Hong Kong's current warning system focuses on wind strength and uses this to communicate the level of risk. Reliance on maritime terminology is not necessarily understood by members of the public and has potential to cause confusion or ambivalence about the level of risk. There needs to be a shift in focus to the development of categories of actionable risk (describing risk in terms that lead to clear action) so that individuals are aware of the consequences of not taking action.

2. **More specific and logical warnings may increase protective behaviour.** The current numbering system used for the cyclone warning system should be revised to ensure logical progression in levels of risk. The large gaps between numbers in the current system may create confusion (i.e., 1, 3, 8, 9, 10). These gaps will increase the possibility that people will not respond to warnings appropriately. Any changes to the EWS require public education.

3. **Risk information needs to be specific and action-oriented**. Existing information on the current warning system suggests that people consider their own circumstances and level of acceptable

risk when responding to warnings and decide on the actions to take in response to the signal issued. Given the evidence presented on human risk perception and decision making, such statements need to be altered to explicitly tell people what the risk is, how it may affect them, and the actions they need to take. This specificity ensures that the appropriate information is provided and guidance is action-oriented, which avoids people making inferences about whether or when they might need to act. Indicating that a person must take action based on the warning rather than informing a person about intensification of risk is much more likely to result in appropriate individual responses.

4. **Avoid false alarms where possible.** It is still unclear how effectively Hong Kong's population engages with the current warning messages issued by the HKO. There may exist a degree of "habituation" to lower-level warnings (e.g., level 1 and 3) if they are issued for a significant period of time and the cyclone does not come to full-force fruition.

5. **Build an online community.** People rely on information from trusted sources and will use their established networks to seek information during crises. It is important that government agencies and traditional media stations promote their social media accounts and online platforms to build an audience during periods of calm, so that an extensive outreach can be achieved during disasters. The Hong Kong Observatory has begun establishing robust avenues for communicating warnings online through their website, the 'My Observatory' app, and HKO Twitter account.

6. **Consider the role of active and passive communication.** New technologies that include "push notifications" and mass SMS texting allow authorities to reach the public without waiting for them to access information, similar to the "amber alert" currently used for disaster warning in the United States. While useful for alerting large populations to potential risks, these warning systems need to be used judiciously, to reduce the likelihood of causing signal-fatigue in the population. Notifications can be customised by geo-tracing but must be used responsibly to ensure they provide a mechanism of support without eroding trust.

7. **Consider social and psychological factors.** Socio-cognitive factors need to be considered to enhance the effectiveness of early warning systems by building a sense of community and individual self-efficacy via education, promoting protective behaviours, and accurately communicating risk. Community engagement programs run through agencies such as the HKJCDPRI have potential to foster preparedness and warning literacy.

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Supplementary Information to Policy Brief, The Changing Landscape of Early Warning Systems

Table 2. Socio-Cognitive Factors Relating to Hazard Risk Perception and Behaviour

Age and Sex	Findings on the relationships between age, sex and risk perception are inconsistent,[1] but evidence suggests that older adults differ in their response to disaster warnings and preparedness compared to younger age groups.[2-4]
Socioeconomic Status	Socioeconomic status can be associated with warning compliance due to accessibility to resources (e.g., having basement in one's home) and the perceived costs of compliance (e.g., money, time, needing transport).[5] This relates to a person's response efficacy, or a person's perception of the availability of resources to make appropriate risk-related adjustments.[6]
Ethnicity and Culture	Research on ethnicity and its effect on warning compliance is unclear.[2] There is some evidence to suggest that cultural worldview can be an important determinant of environmental risk perception,[7] and that warnings need to be culturally sensitive and appropriate.[2]
Prior Experience	Direct experience of a hazard plays a primary role in shaping an individual's perception of risk,[1] but there exists a paradox in the relationship between these two factors. In most cases, personal experience of a previous hazard leads to higher risk perception.[1] However, this can be influenced by the degree of personal consequences resulting from previous hazards.[1,8,9] That is, individuals with previous experience of a hazard who did not suffer any personal damages or negative consequences from the event are more likely to believe that a future event will not pose a risk to them.[8] This issue is highlighted by Chan et al.'s[10] findings that nearly 80% of the 1002 respondents they surveyed in Hong Kong reported having nil experience of disasters. Indirect experience (e.g., via hazard witnesses, media, or education) has also been suggested as important, such that it is critical to help people recall the consequences of previous hazards in order to motivate protective behaviour for an emerging hazard.[11] However, there remains a fine line between making the warning salient whilst minimising re-traumatisation from previous experience. This highlights the need for sensitive delivery of information about a hazard, and the need for appropriate psychological support systems in the community so the saliency of the threat can be maintained without causing unnecessary distress.
Pre-Existing Beliefs and Cognitive Biases	When faced with complex situations or problems (e.g., receiving a hazard warning), people tend to rely on their pre-existing beliefs about the hazard and how likely it is to occur. However, human decision-making is often influenced by cognitive biases. Tversky and Kahneman's[12] work on the presence of heuristics and biases in human decision-making and probabilistic thinking has been deemed important in understanding people's responses to perceived risk posed by natural and technological hazards.[13] Heuristics, a type of cognitive bias, are "rules of thumb" which are used while making judgments in conditions of uncertainty. They are used to reduce the cognitive complexity of assessing probabilities and predicting unknown outcomes.[14] While these cognitive shortcuts aid in "fast thinking" to make sense of situations in a complex world, they can lead to predictable errors.[14] Heuristics and other cognitive biases proposed to play a role in risk perception include: ○ **Representativeness Heuristic:** The tendency to judge the likelihood of an event by the degree to which it resembles the "typical" case.[15] This may play a role in "false alarms', such that if it is quite typical for a dangerous hazard to not come to fruition after a warning, this may lead to assuming that such warnings carry little weight the next time it is issued. ○ **Availability Heuristic:** When an event that is more easily recalled is judged as more probable (increased likelihood) than events that are difficult to remember. This can be influenced by mass media such that frequent coverage of an event can lead to overestimating the probability of the

	event occurring. In a disaster context, the recent experience of a disaster may influence perceptions regarding the likelihood of such an event reoccurring in the future. ○ **Anchoring and Adjustment Heuristic:** Tendency to place value on the first piece of information received and use this as an anchor (or relative estimate), and adjust one's estimate around this anchor until a satisfactory solution or answer is reached. Adjustments are typically inadequate and remain close to the anchor. This may have implications for people receiving warning information that is subsequently changed. ○ **Affect Heuristic:** When affect (emotion) is used as a cue to make judgments (e.g., probability, risk). It is believed that basing judgements on affect is much quicker and less effortful than trying to retrieve relevant information from memory and weighing up all the possible pros and cons (i.e., more logical, rational thinking). This is especially the case when the decision is complex and/or mental resources are quite limited. Typically, if someone has positive feelings about an object or event they tend to judge the risk as low and benefits as high, whereas if they have negative feelings the benefits are low and risk is high.[16,17] Thus, prior negative experiences with a natural hazard is more likely to result in and intentions to engage in protective behaviour.
Outcome Expectancy and Self-Efficacy	Outcome expectancy refers to a person's judgement about whether actions they take will effectively mitigate or reduce the effects of a hazard.[6,18] Natural hazards tend to be infrequent and highly destructive, and the highly destructive nature of such events is typically reinforced via the media. Without previous experience of responding to a hazard, such factors can potentially reduce an individual's belief that their actions will reduce the effect of a hazard. Linked to this is self-efficacy, which is a person's belief that they have the *personal capacity* to act.[6,19] Self-efficacy significantly influences a person's behaviour when events are perceived as less controllable and is related to the degree of effort investigated in risk reduction behaviours (e.g., the more someone believes their own actions will have little influence, the less preparedness behaviour they may have).[20] As per Paton's socio-cognitive model,[6,18] outcome expectancy is thought to precede efficacy judgments, and both are predictors of the formation of intentions to act. Such factors will also be influenced be previous experience with a hazard (i.e., may have less self-efficacy if implementation of protective behaviour in past was not successful) and one's physical capacity.
Perceived Responsibility	The degree to which people believe that it is their personal responsibility to act and keep themselves safe is related to implementing protective behaviour.[6] Intentions to act are less likely to turn into protective behaviour when individuals perceive other people (e.g., emergency management agencies, local councils, neighbours) as responsible for their safety.[6,18]
Sense of Community	The degree to which people feel attached to people and places can also influence decision to implement protective behaviour, with stronger positive feelings associated with an increased likelihood of intentions turning into preparedness behaviours.[6] This relates to hazard saliency and discourse about hazards in a community, as motivation to act may be reduced if natural hazards are not a salient issue.[6] Community engagement and involvement of local stakeholders is critical in addressing the mistrust issue related to responding to hazard warnings.[21]
Habituation	"False alarms" (i.e., continuous warnings of a hazard and it potential impact result, but the event does not come to fruition) can result in habituation, which is a psychological phenomenon in which a stimulus that remains unchanged becomes progressively less effective at attracting a person's attention.[22] This has been known as the "cry wolf phenomenon", in which there is eventual desensitisation to warning messages and the validity of future warnings diminishes.[23] Thus, people may become immune to repeated warnings and feel no need to implement safety behaviours, have weaker fear reactions, and may be less willing to attend to warnings with protective behaviour. In Hong Kong, a highly dense urban setting, the business sector has previously asked for shorter and more confined warnings to reduce false alarms.[24] Recent research suggests that merely lowering the false alarm

	rate however does not necessarily result in increased warning compliance; rather, information about the probability of negative consequences must also be included in the warning message to increase protective behaviour.[23]

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