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# The influence of impact-based severe weather warnings on risk perceptions and intended protective actions

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ABSTRACT

This paper presents the results of an online survey of the New Zealand public (n = 1364), conducted in 2015, that tested the influence of impact-based severe weather warnings on risk perceptions and intended protective actions. We used a hypothetical severe weather event involving strong winds, with 50% of participants receiving an impact-based warning, and 50% receiving a more traditional phenomenon-based warning (which in this case is when the wind speed is expected to be higher than a given number).

Our results indicate that impact-based warnings may be more effective than phenomenon-based warnings in influencing the recipient's perception of the hazardous event (their sense of threat, concern, and understanding of the potential impacts), but this does not translate to a higher level of action. Characteristics of gender, age, and location of residence were also influences on risk perceptions and intended actions. However, experience with having been affected by strong winds in the past was not a strong influence on intending to respond. Our findings support the inclusion of information about hazards, impacts, and 'what to do' information in a warning message.

## 1. Introduction

Globally, significant damage and casualties result from hydro-meteorological events every year, despite many of these events being well forecast, and warnings being issued. The World Meteorological Organization [46] describes this to be the result of a perceived gap between the forecasts and an understanding of the potential impacts by responding agencies and the public. Traditionally, National Meteorological Services have issued phenomenon-based weather warnings based on fixed criteria (for example, when the wind speed is expected to be higher than a given number) regardless of the expected effects of the event. WMO advocates for a more comprehensive warning system, which links weather modelling and forecasts to hazards and impacts. Impact-based warnings use flexible thresholds to trigger the issuance of a warning. The thresholds vary in space and time to reflect changing exposure and vulnerabilities [46]. For example, an impact-based severe weather warning for strong wind might be issued in one city, but not another for an identical event, if the second city was known to be more resilient to such events. This system requires an integrated, multi-disciplinary and multi-hazard approach [46]. Such an impact-based forecast and warning system is supported by the Implementation Plan for the WMO Strategy for Service Delivery, adopted in 2013 (cited in [46]). However, very little research has been conducted on the efficacy of impact-based warnings.

The Meteorological Service of New Zealand Ltd. (MetService) issues severe weather warnings for New Zealand. Prior to the development and implementation of an impact-based weather warning system for New Zealand, MetService expressed a desire for research to be conducted to investigate the effectiveness of such a system in a New Zealand context. The research was conducted in collaboration with GNS Science and Massey University with input by social scientists, meteorologists, and end-users, including from the Wellington Regional Emergency Management Office (WREMO). A data report of the results of this survey has been published by Potter et al. [31]. This paper describes and discusses those results.

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### 1.1. Literature review and research hypotheses

A warning system should "empower individuals, communities, and businesses to respond to hazards in a timely and appropriate manner that will reduce the risk of death, injury, property loss, and damage" ([35], p. 74). Prompting actions in response to a warning is fundamental to the design of an effective warning system. Perceived challenges of warning systems include that the local, regional and national governmental organisations, as well as the public, often do not understand what the impacts of severe weather and storm surge will be. This was noted following both Hurricane Ike [20] and Hurricane Sandy [35] in the US, prompting a call for more studies on people's interpretation and use of severe weather warnings. Risk perceptions of the public have been found to relate to taking protective actions (e.g., [26,1,6,13,23]). As described by Peacock et al. [24], it should be recognised that public and scientific risk perceptions may differ due to social and cultural contexts; and research on risk perceptions differ in terms of what is measured. Research has shown that people are more likely to believe and respond to a warning if they understand the warning [19], and are knowledgeable about the hazard (e.g., [33]) and potential impacts (discussed further by [26,20]). In a review of research about 12 hurricanes in the US, Baker [1] found that residents' knowledge about the hazard is only weakly related to evacuating, but knowledge about potential impacts at a personal level is a strong influence on evacuating. In 2008, Morss and Hayden [20] interviewed residents in Galveston, US, who had recently been affected by Hurricane Ike. They found that evacuation planning and preparations began prior to the official call for evacuations, highlighting the importance for warnings to include information on the storm forecast, potential impacts, and recommended actions. They also found that residents prepared for strong winds, but not flooding associated with storm surge, due to lack of risk perception and knowledge about that peril. Our first research hypothesis (RH) investigates the role of the impact-based warning in helping receivers to understand the consequences of a hypothetical strong wind event.

**RH1.** *The participants find it easier to understand the effects of the hazard if they receive an impact-based warning in comparison to receiving a phenomenon-based warning.*

People make decisions about protective actions according to the level of threat that they perceive from the hazard, provided they believe that protective actions will be effective at mitigating the hazard ('response efficacy'), and they are capable of undertaking the protective action ('self-efficacy'; e.g., [36,2,17,26,28]). For example, hurricane-effected residents in the US were found to be more likely to evacuate if they believed that the winds would be strong enough to cause damage, or would cause flooding to their property; i.e. were seen as being threatening [1]. The downgrading of Hurricane Irene in the US, 2011, was perceived by members of the public to indicate that the level of risk had decreased [21]. These authors suggested emphasising impacts in messaging to maintain higher risk perceptions, and prompt an appropriate response. Ripberger et al. [33] found that US participants receiving hypothetical tornado warnings were more likely to take some sort of protective action as tornado impact descriptions increased in severity. We tested which type of warning influences the level of threat perceived by the New Zealand participants:

**RH2.** *The participants believe the hazard to be more threatening when they receive an impact-based warning than a phenomenon-based warning.*

Credibility of official warnings has been found by some [11,32], but not all [25,38] researchers to be an influencing factor in prompting response actions. In perhaps the only previous study that tested impact-based warnings and credibility, Perreault et al. [25] found that regular warning messages (without impact information) were seen as more credible than the new 'scary' messages (with impact information) for tornadoes in the US. We tested to see whether this finding was valid with New Zealand participants. In support of the findings by Perreault et al. [25], we predict that:

**RH3.** *The participants believe the message to be more credible when they receive a phenomenon-based warning than an impact-based warning.*

Fear appeals can cause receivers of the message to be concerned about a hazard by describing the impacts on them should they not follow recommended courses of action [44]. They are persuasive messages that intend to "scare people" and prompt actions, to reduce the impacts of the hazard ([44], p. 329). In fear appeal messages, the recommended action must be perceived as being effective in reducing the risk, and the receiver must believe that they are capable of performing the action [44]. Increased fear can lead to an intended behavioural response (e.g., [42]). Based on these prior findings, we suspected that warnings that describe impacts will arouse more concern, and therefore may lead to more actions. We investigate whether impact-based warnings are more likely to promote a level of concern in a New Zealand context:

**RH4.** *The participants are more concerned about the hazard when they receive an impact-based warning than a phenomenon-based warning.*

The overall purpose of warnings is to achieve an appropriate and timely response to mitigate the risk. Appropriate responses to a hypothetical strong wind event (described further in the methods section) would include securing loose items on one's property, driving carefully, and considering alternative transport options (because, for example, driving a motorbike or high-sided vehicle may be more vulnerable to wind-related impacts). Searching for additional information is also a common response to receiving warning information. In this research, we wish to understand the benefits of impact-based warnings in comparison to phenomenon-based warnings. We undertake this research in an experimental, hypothetical environment to allow for a clear distinction between the two types of messages and the outcomes, which are intended responses. The intention to respond to information has been found to correlate to actual responses (e.g., as reviewed by [43]). Given the previously-discussed findings from research that increased perceptions of threat, concern, credibility, and an understanding of impacts can increase the likelihood of a behavioural response, we hypothesise that:

**RH5.** *Impact-based warnings are more effective at prompting the public to intend to take protective actions than phenomenon-based warnings.*

In addition to the influence of warning characteristics, factors including receiver characteristics and prior experience influence the decision to respond (e.g., [16]). Previous direct experience as an influence on how people react to warnings with similar events has had mixed results in past studies, with some researchers finding that a higher level of experience is related to increased protective behaviours [20,22,26,39] and others finding little to no influence [1,11,14]. Demuth et al. [8] found in a study of the influence of people's past experiences with hurricanes on evacuations during future events that some processes, including past experience with evacuation and financial loss, can increase evacuation intentions, while others (such as past emotional impacts from hurricanes) can cause decreased evacuation intentions. The influence of experience on the intention to respond is not a primary focus of this research, so we keep our hypothesis at a fairly broad level:

**RH6.** *Participants who have previously been affected by strong wind events are more likely to intend to respond.*

Demographic factors such as socioeconomic status, age, and gender have also been found to influence the processing of information and responding [16]. Females are more likely to respond to warnings than

males, due to reasons such as their more dominate roles as caregivers, their heightened perceived risk, and their higher exposure to risk [3,33]. People in younger age groups also tend to be more likely to evacuate (e.g., [5,10,29]). We are not aware of existing research looking at the influence of warnings on behavioural response according to participants' locations in New Zealand. However, on average, Wellington experiences around 200 days a year with gusts greater than gale force (33 knots, approximately 60 km/h). In contrast, the number of days per year with gusts of this strength in Auckland and Christchurch are 55 and 58 respectively [41]. Because Wellington residents are more exposed to strong winds, they are likely to have a higher tolerance of strong wind events, and a lower threat perception. Therefore, we hypothesise that:

**RH7.** *Females, participants under the age of 35, and participants living in Auckland, are more likely to intend to respond to the warnings.*

## 2. Methods

We used an online questionnaire ([7]; which we will refer to as a survey) to collect data from as many self-selected members of the public as possible, to gather opinions from a wide range of populations within New Zealand. As this research involves human participants, appropriate ethical procedures were followed. The potential risks of conducting the survey were carefully considered (e.g., [34]), and a low risk notification was submitted to the Massey University Human Ethics Committee prior to the collection of data. Participants voluntarily participated once they had been informed about the research project. Data are anonymous (names of participants were not collected) and securely stored at GNS Science and Massey University in New Zealand.

### 2.1. Survey design

Introductory text outlined a scenario, and participants were randomly assigned one of two warnings; fifty per cent received a phenomenon-based warning, and fifty per cent received an impact-based warning (Table 1). Our survey design allowed us to test the value of including impact information into a warning message, in comparison to a message with no impact information.

### 2.2. Measures

Survey questions (see [31] for a copy of the survey form) were designed to investigate the research hypotheses, following the principles described by Dillman et al. [9]. Following the introduction and scenario, we asked questions to investigate the participants' perceptions of factors that have been found in previous research (described in the introduction) to influence their protective action decision-making – how easy they find it to understand the possible effects of the weather event, how threatening they believe the hazard will be, how credible they perceive the message to be, and how concerned they would be about the hazard. These were asked using positively framed statements and a five-point Likert scale, ranging from 'strongly disagree' to 'strongly agree'. The four questions were presented in random order for each participant.

In the second section of questions, we asked each participant "how likely is it that you would take the following actions?". The ten actions included protective measures such as driving more carefully, deciding whether to do outdoor work or activities, deciding what clothes to wear, ensuring loose items on their property are secure, and changing plans for getting to work. They also included information-seeking questions such as checking with others to see what they were going to do, checking other information sources for confirmation or advice, and looking out the window to see how strong the wind appears. Additionally, we asked how likely it is that they would use the information simply to know what the weather will be like, for situational awareness. Again, a five-point Likert scale was used, ranging from 'extremely unlikely' to 'virtually certain', and the order of the statements was randomised. An 'other' open comment box was included to capture additional actions. We then asked the participants whether there is any other information that they would have liked to receive, using an open comment box.

The third section collected experience and demographic data. The participants were queried about their experience with a "storm with very strong winds", including whether they had been affected in some way. No further definition of 'very strong winds' was included in the survey. As pointed out by Demuth et al. [8], people can feel severely impacted by an event even if they have not needed to evacuate, or have not suffered financial loss or property damage. Our broad survey question did not ask whether they had directly suffered a tangible loss, and allowed the participants to determine themselves whether they had been 'affected' or not in the past, in order to include possible emotional impacts.

Information was also gathered on the participants' gender, age, ethnicity, level of education, occupation, location that they usually live, and whether they live in a rural or urban area. Several of these demographic questions were designed using New Zealand census data categories (e.g., for ethnicity and occupation). Participants stated where they lived by selecting a Local Government region from a drop-down list. All demographic questions used drop-down lists or tick boxes, with only the ethnicity question including an open 'other' comment box. Results relating to the level of education, and non-significant results, are presented by Potter et al. [31].

### 2.3. Survey analysis

A series of Analyses of Covariance (ANCOVA) tests was conducted using IBM SPSS 22 to investigate the difference in perceptions and intended actions between recipients of phenomenon-based and impact-based weather warnings, controlling for the differences due to relevant demographic variables (e.g., gender, age, ethnicity, education, whether participants had previously been affected by strong winds, and whether participants lived in a rural or an urban area). A series of ANCOVAs was also conducted to investigate demographic differences in the perceptions and intended actions between recipients of the two types of warnings, controlling for all other demographic differences as well as the type of weather warning received. A series of ANCOVAs was conducted to investigate differences across five grouped regions of New Zealand (1 = Auckland; 2 = Wellington; 3 = Canterbury; 4 = Other North Island; 5 = Other South Island), controlling for all relevant

**Table 1**
Introductory text and warnings provided to participants.

| | |
|---|---|
| *Introductory text given to all participants* | It is 7 p.m. on a Monday. You see the following Severe Weather Warning issued by New Zealand's MetService for the next day (Tuesday) for your area: |
| *A) Phenomenon-based warning:* | Severe Weather Warning: Westerly winds are expected to rise to severe gale, with gusts of 140 km/h, around 6 a.m. on Tuesday morning. Winds easing after 6 p.m. Tuesday. |
| | *Or* |
| *B) Impact-based warning:* | Severe Weather Warning: From 6 a.m. Tuesday to 6 p.m. Tuesday, westerly winds strong enough to bring down trees and power lines, and make driving hazardous for high-sided vehicles and motorcycles, are expected. Some possible impacts of this are travel delays, power outages, and damage to buildings. |

demographics (as above) as well as the type of weather warning received.

As is commonly done in previous research (e.g., [18]), we made the assumption that our Likert scales are linear, and so report the means throughout. We consider p-values of 0.05 and less to be statistically significant in this research.

The open-ended questions and comments were coded using thematic analysis. Thematic analysis is commonly used in qualitative research [4], and involves coding (or labelling) sections of text so that they can be grouped under common themes, and the themes can then be described.

### 2.4. Participants

We used the online data collection tool SurveyMonkey for the survey, which was run from 14 September 2015 until 7 October 2015. The survey was promoted as an advertisement on the MetService website (www.metservice.com), and through social media (Facebook and Twitter) by agencies including MetService, WREMO, Auckland Civil Defence and Emergency Management (CDEM) Group, and Waikato CDEM Group, as well as by the researchers. In an attempt to increase Maori participation, a ten-minute interview on topics including the survey was given on Radio Ngati Porou, which is based in the East Coast region of the North Island and has a largely Maori audience. The survey was only accessible online, and it took most participants between three and six minutes to complete.

A total of 1364 responses were collected from members of the New Zealand public in the locations in Fig. 1. Seventy-one per cent of participants stated that they lived in urban areas. Females were over-represented in the survey (58% compared to 51% in the 2013 New Zealand census [40]), as were New Zealand European ethnicities (84% of survey participants compared to 70% in the census). The survey participants were reasonably well represented in terms of age, with most groups within 5% of the census data. However, there was over-representation of the 35–44- and 45–54-year-old age groups by 10–12%. During the analysis stage, participant age was categorised as 34 years old and younger, and 35 years and older. This threshold was chosen because it may coincide with generational differences in information seeking, such as the use of the internet as a primary source. Approximately 20% of participants were 34 years or younger, and 79% were 35 years or older.

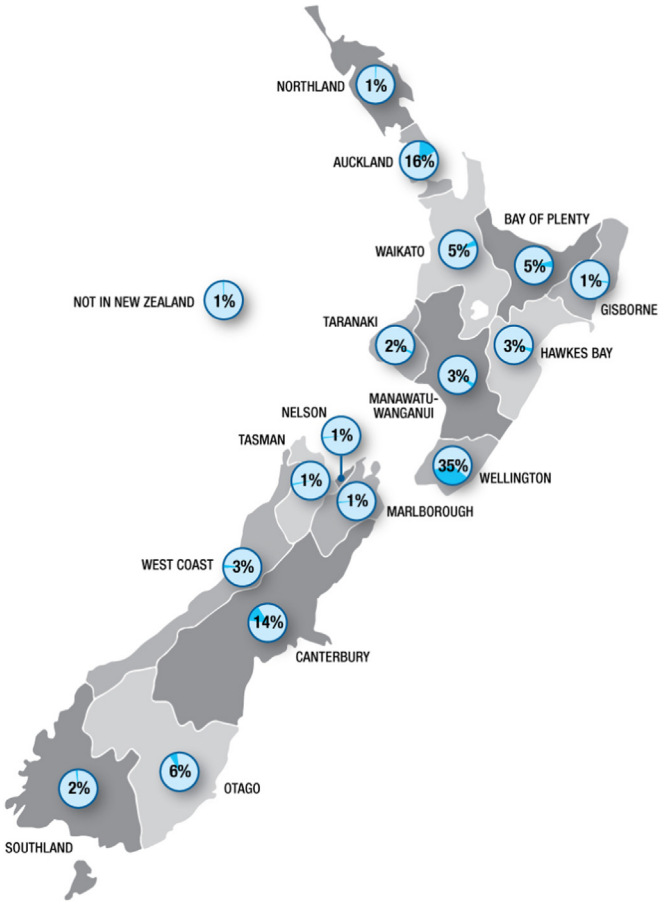


**Fig. 1.** Map of regions where survey participants usually live. The percentage of survey participants in each region are indicated (n = 1344).

Participants living in Auckland, New Zealand's largest city, were under-represented in the survey (16% compared to 33% of New Zealand's population according to census data), and participants from Wellington were over-represented (35% compared to 11% of New Zealand's population). Further details of participant demographic characteristics and representativeness are described in Section 2.4 of Potter et al. [31].

As the participants self-selected and the survey was administered online, the results of this research should not be taken as being representative of the opinions of New Zealand's general population. However, the findings may be indicative of the opinions of users of online weather warnings.

## 3. Results

### 3.1. RH1: The influence of warning type on understanding the effects of the hazard

RH1 predicted that participants who received impact-based warnings would find it easier to understand the effects of the hazard than those who received phenomenon-based warnings. A significant (but weak) effect of weather warning type was observed (Table 2), indicating that those participants who received the impact-based weather warning did indeed report finding it easier to understand the possible effects of the weather event compared with those who received the phenomenon-based warning, supporting RH1.

### 3.2. RH2: The influence of warning type on threat perceptions

RH2 predicted that the participants believe the hazard to be more threatening when they receive an impact-based warning than a phenomenon-based warning. A significant (weak) effect of weather warning type was observed (Table 2), indicating that participants who received an impact-based warning reported believing that the wind would be more threatening than those who received a phenomenon-based warning. Thus, RH2 is also supported.

### 3.3. RH3: The influence of warning type on credibility perceptions

RH3 predicted that the participants believe the message to be more credible when they receive a phenomenon-based warning than an impact-based warning. However, there was no significant difference in the

**Table 2**
Summary statistics for supported Research Hypotheses one to four (n = 1364).

| | Impact-based Warnings (N = 679) | | Phenomena-based Warnings (N = 685) | | | | |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | F-statistic | p-value | Cohen's d |
| RH1 | 4.62 | .810 | 4.29 | 1.037 | 38.399 | < .001 | .035 |
| RH2 | 4.39 | .888 | 4.23 | .963 | 9.722 | .002 | .18 |
| RH4 | 4.19 | .987 | 4.04 | 1.062 | 5.947 | .015 | .14 |

**Table 3**
Summary statistics for statistically significant variables for Research Hypothesis five.

| | Impact-based warnings (N = 679) | | Phenomenon-based warnings (N = 685) | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **SD** | **Mean** | **SD** | **F-statistic** | **p-value** | **Cohen's d** | **N** |
| Do nothing differently | 2.33 | 1.147 | 2.47 | 1.225 | 5.169 | .023 | .12 | 1354 |
| Check information sources | 3.69 | 1.250 | 3.44 | 1.350 | 11.197 | .001 | .19 | 1363 |

perception of the credibility of the warning message between the participants who received impact-based warnings and those who received phenomenon-based warnings ($F(1, 1225) = .061$, $p = .801$). RH3 was not supported, and as such, the statistics are not reported in Table 2.

### 3.4. RH4: The influence of warning type on level of concern

RH4 predicted that the participants are more concerned about the hazard when they receive an impact-based warning than a phenomenon-based warning. There was indeed a significant (weak) effect of the type of weather warning (Table 2), indicating that the participants who received the impact-based warning reported having a higher level of concern about the wind event than those who received the phenomenon-based warning, supporting RH4.

### 3.5. RH5: The influence of warning type on intended behavioural response

RH5 predicted that impact-based warnings are more effective at prompting the public to intend to take protective actions than phenomenon-based warnings. This was tested using the ten individual variables for intending to take actions and seek information, with results as follows. Results for statistically significant variables tested for this hypothesis are described in Table 3.

There was a significant (but weak) effect of the type of weather warning, indicating that those participants who received a phenomenon-based warning reported being more likely to do nothing differently than those who received the impact-based warning. Interestingly, there was a significant (weak) effect of the type of weather warning, with participants who received the phenomenon-based warning reporting being less likely to check other information sources for confirmation or advice than those who received the impact-based warning. There were no significant differences for intending to take any of the remaining eight actions provided in the survey as an influence of the type of weather warning received. Full results are described in Potter et al. [31].

Thus, participants who received impact-based warnings were reportedly slightly more likely than those who received phenomenon-based warnings to state that they would check other information sources and take action of some sort, but not any of the specific actions provided. This indicates that RH5 was largely unsupported.

### 3.6. RH6: The influence of experience on perceptions and intended actions

RH6 predicted that participants who have previously been affected by strong wind events are more likely to intend to respond. Of the 94% of participants (n = 1261) who said that they had experienced a storm with very strong winds, 70% said that they have been affected in some way by the wind. Experiences included tree damage (36% of those stating they had been affected); damage to property (e.g., to houses; 21%) and their section (e.g., to fences and crops; 14%); service outages (power, phone and water; 17%); travel disruptions (13%); and loose items blown around their property (13%).

We observed a weak effect on the participants' perceptions of the level of threat of being previously affected by strong winds, regardless of the type of warning received (described in Table 4); those previously affected by strong winds reported finding the forecasted hypothetical event as being more threatening than those who had not previously been affected. Additionally, having experience in being affected by strong winds in the past influenced the level of concern, with those who had previously been affected being more concerned about the wind event than those who had not previously been affected. The credibility of the message, and understanding the possible effects of the event, were not significantly influenced by participants having been affected by strong wind in the past.

Participants who had previously been affected by strong winds were slightly less likely to 'do nothing differently' than those who had not previously been affected by strong winds. In other words, those previously affected were more likely to do something (unspecified) differently as a result of receiving the weather warning, than those who had not previously been affected. There was also a significant (but weak) relationship between having been previously affected by strong winds and using the information to decide whether to do outdoor activities, indicating that those previously affected were more likely to use the information for this decision than those who had not previously been affected. There was no significant influence of previously being affected on the other eight protective actions. Thus, there is only weak support for RH6.

### 3.7. RH7: The influence of demographic characteristics on perceptions and intended actions

RH7 predicted that females, participants under the age of 35, and participants living in Auckland, are more likely to intend to respond to the warning. Demographic characteristics were tested against each perception and intended action, regardless of the type of warning received. Significant results are described here; full results are in Potter et al. [31]. There were no significant differences in perceptions or intended actions due to ethnicity or occupation.

With regard to the effect of age on beliefs, participants 35 years or older found it easier to understand the possible effects of the weather event, compared with those younger than 35 (Table 5). They also thought that the warning was more credible; and they reported being more concerned by the event in comparison to those younger than 35. Those younger than 35 saw the event as being less threatening than those older than 35. In terms of the effect of age on intending to take actions, those older than 35 reported being more likely to intend to drive more carefully than those younger than 35; they were more likely to change their travel plans; they were slightly more likely to check with others to see what they were going to do; and they reported being more likely to check other information sources than was reported by those younger than 35. In a similar theme, those younger than 35 reported being slightly more likely to do nothing differently than those older than 35; they were less likely to use the information for deciding whether to do outdoor work or activities in comparison to that reported by participants older than 35; and they were less likely to intend to secure loose items than those older than 35.

Significant differences between responses by male and female participants were found in one type of perception and four intended actions (Table 6). Women thought that the warning they received was more credible than was reported by men. Men reported that if driving, they would be less likely to intend to drive more carefully in the wind event than was reported by women; they were slightly less likely to

**Table 4**
Results for statistically significant variables tested for Research Hypothesis six.

| | Previously affected (N = 879) | | Not previously affected (N = 385) | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **SD** | **Mean** | **SD** | **F-statistic** | **p-value** | **Cohen's d** | **N** |
| Threat | 4.36 | .900 | 4.20 | .986 | 5.795 | .016 | .17 | 1264 |
| Concern | 4.19 | .964 | 3.93 | 1.138 | 12.038 | .001 | .25 | 1264 |
| Doing nothing differently | 2.34 | 1.168 | 2.54 | 1.223 | 5.028 | .025 | .17 | 1254 |
| Outdoor activities | 4.24 | .998 | 4.05 | 1.088 | 5.314 | .021 | .18 | 1263 |

intend to secure loose items than women; they were slightly less likely to check with others to see what they were going to do than women; and they were slightly less likely than women to look out the window to see how strong the wind appears.

Participants from Wellington generally saw the hypothetical event as being significantly less threatening, and had lower levels of concern than those from Canterbury and Auckland regions. They were also significantly less likely to drive more carefully and to use the information to decide whether to do outdoor work or activities than Aucklanders; and to secure loose items than both Aucklanders and Cantabrians. They were significantly less likely than Aucklanders to check with others to see what they were going to do; and less likely than both Aucklanders and Cantabrians to check other information sources. Detailed (statistical) results for differences between regions are in Appendix A. Please see Section 4.0 for a discussion of these results.

We also explored whether there was an influence on response according to if the participants resided in a rural or urban environment. We found that urban dwellers are more likely to use the weather information to decide what clothes to wear, and rural dwellers are more likely to secure loose items on their property. Full results are in Appendix B.

RH7 is largely supported, as women and participants from Auckland are more likely to intend to respond to the warning. However, it is older participants who were more likely to intend to respond than younger participants, in our research.

### 3.8. Other actions, and other information needed

Participants were given the option to describe any other actions they would intend to do on receipt of this weather warning. Qualitative analysis of the comments reported by 185 participants for both warning types indicate that the most frequent 'other' intended actions include move or check on farm animals (n = 17); complete tasks relating to responsibilities at work (such as informing staff and cancelling outdoor activities; n = 16); pass on information to others (n = 14); and do preparedness activities such as check emergency supplies or prepare for a power outage (n = 11).

Participants were asked to comment on any other information they would have liked to receive. Those who received the phenomenon-based warning were just as likely to state that they wanted other information as those who received the impact-based warning (280 respondents vs. 279, respectively). This is despite the finding that participants who received the phenomenon-based warning were less likely to check other information sources for confirmation or advice than those who received the impact-based warning. Qualitative analysis of this data indicates that some participants would have liked to receive further information on factors such as:

- more details about the wind (of the 109 respondents who requested this, 83 had received impact-based warnings), for example maximum gust speed and average wind speed and direction;
- potential impacts (of the 83 respondents who requested this, 72 had received the phenomenon-based warning), including on transportation, trees, property and power outages;
- more detailed information about locations likely to be affected (n = 67) (e.g., differences between suburbs and cities, inland areas, coastal, hill tops);
- level of confidence in the forecast, such as by using likelihood or a scale, and information showing how often these warnings are correct (n = 36); and
- suggested mitigation actions or safety precautions (of n = 29, 21 received the phenomenon-based warning), such as 'be careful while driving/cycling, or avoid if it's too dangerous', 'secure loose items such as trampolines and recycle bins' and as stated by one participant "have torches at ready in case power goes out. Charge cell phones". This 'call to action' information goes further than simply including impact information in a warning, and requires prepared mitigation advice in coordination with responding agencies.

Much of this information would normally be included in full weather warnings by MetService, but was not included in the example given in this survey due to a desire to keep the survey focussed and as short and quick to fill in as possible.

**Table 5**
Results for statistically significant influences of age on perceptions and actions, for Research Hypothesis seven.

| | Age: Younger than 35 (N = 273) | | Age: 35 and older (N = 1056) | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **SD** | **Mean** | **SD** | **F-statistic** | **p-value** | **Cohen's d** | **N** |
| Easier to understand | 4.28 | .965 | 4.50 | .934 | 8.067 | .005 | .23 | 1329 |
| Credibility | 4.30 | .810 | 4.53 | .851 | 18.141 | < .001 | .28 | 1329 |
| Concern | 3.70 | 1.114 | 4.21 | .980 | 39.790 | < .001 | .49 | 1329 |
| Threat | 4.01 | .968 | 4.38 | .906 | 25.265 | < .001 | .40 | 1329 |
| Drive more carefully | 3.86 | 1.099 | 4.16 | .981 | 16.232 | < .001 | .28 | 1324 |
| Change travel plans | 2.31 | 1.239 | 2.57 | 1.236 | 7.465 | .006 | .21 | 1325 |
| Check with others | 2.49 | 1.200 | 2.68 | 1.238 | 4.948 | .026 | .16 | 1328 |
| Check other information sources | 3.22 | 1.370 | 3.65 | 1.277 | 16.891 | < .001 | .32 | 1328 |
| Do nothing differently | 2.60 | 1.201 | 2.35 | 1.181 | 7.252 | .007 | .16 | 1319 |
| Outdoor activities | 3.94 | 1.204 | 4.24 | .975 | 14.885 | < .001 | .27 | 1327 |
| Secure outdoor items | 3.57 | 1.150 | 4.22 | 1.015 | 62.433 | < .001 | .60 | 1326 |

**Table 6**
Statistically significant results for the influence of gender on perceptions and actions, for Research Hypothesis seven.

| | Women (N = 779) | | Men (N = 547) | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **SD** | **Mean** | **SD** | **F-statistic** | **p-value** | **Cohen's d** | **N** |
| Credibility | 4.57 | .756 | 4.38 | .952 | 15.958 | < .001 | .23 | 1326 |
| Drive more carefully | 4.23 | .950 | 3.92 | 1.066 | 34.438 | < 001 | .31 | 1321 |
| Check with others | 2.72 | 1.268 | 2.54 | 1.175 | 8.238 | .004 | .14 | 1325 |
| Look out the window | 4.28 | .967 | 4.17 | 1.034 | 4.134 | .041 | .11 | 1319 |
| Secure outdoor items | 4.15 | 1.071 | 4.02 | 1.073 | 9.858 | .002 | .12 | 1323 |

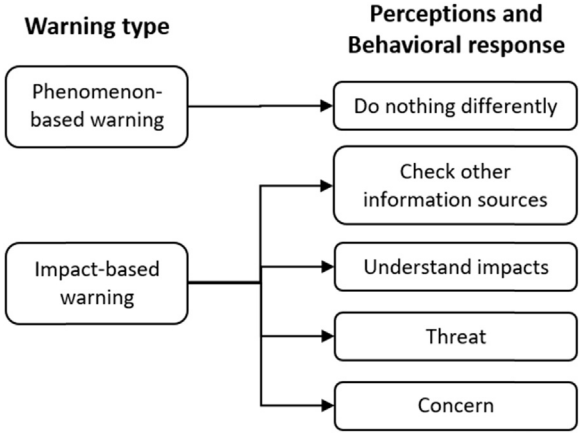


**Fig. 2.** Illustration of the influences of warning type on perceptions and responses. All influences are statistically significant, and positive in the direction of the arrow (for example, participants who received a phenomenon-based warning were more likely to do nothing differently).

## 4. Discussion and conclusions

### 4.1. The influence of warning type on perceptions and actions

Our statistically significant results on the influence of warning type on perceptions and responses are graphically displayed in Fig. 2. Our results indicate that participants who received impact-based warnings found it significantly easier to understand the possible effects of the weather event, believed that the wind would be more threatening, and were more concerned about the wind event, in comparison to those who received the phenomenon-based warning. This is in support of previous research such as Baker [1], that communicating the likely impacts of an event will improve understanding of the effects of the event and heighten risk perceptions, and therefore achieve an appropriate and timely response. Unlike the findings of Perreault et al. [25], there was no difference in the perceived credibility of the message between the two types of warnings. These findings support the use of impact-based warnings, as some (but not all, e.g., as discussed by [16]) previous research has found that increasing these perceptions can help prompt actions to warnings, especially if the credibility of the message is not jeopardised.

Despite our risk perception findings (and those in the aforementioned literature), there was no significant difference in participants' stated likelihood for intending to take most individual protective actions, on account of the type of warning received. The purpose of impact-based warnings is to increase recipients' understandings of the impacts, with the desire for this to lead to taking protective actions [46]. However, while receivers of impact-based warnings in our research had higher levels of understanding about the impacts, they were not more likely to intend to take most protective actions. This may suggest that impact information in warnings needs to be more specific and personally relevant to receivers, in support of the findings by Baker [1]; a difficult task with large audiences. Further detailed analysis needs to be conducted to unpack the reasons why an increase in understanding did not relate to an increase in taking action. Impact-based warning recipients were significantly less likely to 'do nothing differently' than those who received phenomenon-based warnings – i.e., they were more likely to do something differently, but what exactly that is did not seem to be included in our list of tested actions. Further possible actions should be included in future surveys, or more in-depth qualitative research could investigate this in future.

Interestingly, participants who received the impact-based warning were significantly more likely to state that they would check other information sources for confirmation or advice, than those who received the phenomenon-based warning. Information seeking takes place when an individual experiences uncertainty in the protective action decision-making process, and is an important step in reducing that uncertainty so the individual can continue to the next phase of taking protective actions [16]. Our results indicate that impact-based warnings may not fulfil all the information requirements of the recipients, or perhaps the heightened risk perceptions of impact-based warning recipients encouraged further information seeking.

### 4.2. The influence of experience and demographic characteristics to perceptions and response

Our findings that participants with prior experience in being affected by strong winds had slightly higher perceptions about threat and concern than those without that experience, support findings by Demuth et al. [8], and are illustrated in Fig. 3. Demuth et al. found that past experience affected their participants' perceptions of fear, worry, dread, and anxiety. Our findings that eight out of ten response variables are not significantly influenced by past experience, and the two that are significantly significant have a reasonably weak effect, do not support the findings of previous researchers (e.g., [26,22,20,39]). However, they may be explained by Demuth et al.'s (2016) research. They found that emotional impacts as a result of past experience can result in both lower evacuation intentions in the future, due to lower self-efficacy (i.e. a belief that evacuating does not reduce the risk of harm), and higher evacuation intentions, due to a heightened negative affect (i.e. higher perceptions of fear, worry, dread, and anxiety). These two factors conflict, and have a net result of experience not influencing the intention to respond.

Our findings that the older age group were more likely to intend to

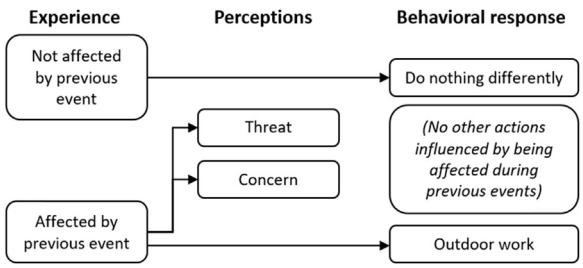


**Fig. 3.** Influence of being affected by a weather event involving strong winds in the past on perceptions and behavioural responses. Only relationships that were statistically significant are displayed; all are positive influences in the direction of the arrow.

respond to the warning for most of the response variables in comparison to the younger age group supports the findings of Perry and Lindell [27], who found that citizens in older age groups (which they classify as over 65 years old) are no less likely to comply with warnings. It also supports the findings by Lazo et al. [15], who found that evacuation intentions increased with age for participants who saw a hurricane forecast.

We found that women were a little more likely than men to intend to respond to four of the ten response variables. This is unsurprising given the frequency of this finding by previous researchers (e.g., [3,33]). To illustrate the engagement of this demographic in seeking information, the majority of Facebook followers of the Wellington Region Emergency Management Office are female, and the most populated age group is 35–44 years old.

It was interesting to confirm that there were regional differences, with participants from Auckland (and in some cases Canterbury) stating that they had higher risk perceptions, and were more likely to intend to respond, than participants from Wellington. This is likely to be due to the higher exposure of participants from Wellington to strong winds annually than the other two regions. Further research should be conducted on the influence of living in a location frequently exposed to a hazard in responding to warnings (including warning fatigue), the role of experience in influencing risk perceptions and responding to warnings, and how impact-based warnings could contribute to these factors.

Additionally, developing a detailed impact database would assist in implementing location-specific impact-based warnings. Recording impacts following events would require an interagency, collaborative effort, using standardised measures to enable sharing of data, and collection of information about the hazard event that caused the impacts. Such a database would help responding agencies to understand past and likely future impacts to events to assist with their mitigation decisions. It would help inform impact and risk models to calculate likely consequences of future events for scenario-based planning. A spatial database of impacts would also assist in issuing impact-based warnings through helping to identify vulnerable and exposed locations, assets and people, which would inform thresholds for triggering a warning, and impact messaging. Reducing the number of warnings for strong wind in highly exposed areas, such as Wellington, by taking an impact-based approach may result in an increase in risk perceptions, if not intended responses.

The population least likely to take protective actions for a severe wind event in a New Zealand context appear to be those younger than 35 years old, men, from Wellington, who have lower perceptions of concern, threat, and credibility of the message. This is consistent with what has been termed by some as the 'young, white male effect', reflecting this demographic as having lower risk perceptions (e.g., [12]). This population could be specifically targeted in future communications.

The breadth of additional information requested by participants indicates that warnings should include information on the hazard (phenomenon, e.g., wind speed and direction), impacts, and 'what to do' (or 'call to action') information. More research could be done to understand the relative importance of each of these types of information in a warning message, particularly if there are constraints on the length of the message (e.g., [45,30]).

### 4.3. Limitations and future research

While this research provides insights into the potential effectiveness of impact-based severe weather warnings in a New Zealand context, it has several limitations:

- The warning messages used in the survey were for a hypothetical event and participants stated their intended actions; their reactions might differ during a real event when warning messages would form part of a larger forecast picture broadcast widely through various media.
- The warning messages used were brief and would usually be accompanied by more information from MetService. The impact-based warning message was general, with no specific location names or detailed information. In alignment with the WMO guidelines on multi-hazard impact-based forecast and warning services document [46], it would therefore be an "impact-based warning", and not an "impact warning", which requires more local details and acknowledgement of exposure. The results are thus constrained to the former type of warning.
- The phenomenon-based warning message used in this experiment was shorter than the impact-based warning message. It is possible that participant's responses varied due to the difference in length, rather than the content of the message. For example, Sutton et al. [42] found that longer messages are more likely to be understood and an intended action decided on, and there was more fear amongst those recipients.
- Many participants accessed the survey through the MetService website or saw the link through social media messages by MetService. This indicates that the participants may be familiar with the usual warning structure and content of MetService warnings, and were therefore considering the difference between the hypothetical warning and the 'usual' warnings as they answered the survey questions, rather than basing their answers solely on whether it was an impact-based warning or a phenomenon-based warning.
- The survey was conducted online only, and therefore did not reach populations that do not have internet access.
- As stated earlier, the demographics of the survey participants were not representative of the New Zealand population, and the sample was not random. Further, a small proportion of the participants (0.7%, or 9 participants) stated that they were not in New Zealand when filling in the survey. As such, the results are not generalisable to the New Zealand population.

Further research is needed to address some of these limitations, such as to investigate reactions to real severe weather warnings and events. While it is outside the scope of our research to test a theoretical model of protective action decision making (e.g., PADM by [16]), our results can contribute to future studies which seek to do this.

A review of health studies relating to fear appeal messages was conducted by Ruiter et al. [37]. These authors describe how information on a threat (such as a graphic picture of a diseased lung) can cause those most at risk of the associated health issues (such as smokers) to be defensive and reject the information. They found that people are more likely to take protective action as a result of being given coping information, rather than information on the threat, which is designed to raise risk perceptions. Ruiter et al. [37] also describe how researchers in health have found that it is effective to raise self-awareness in receivers of information about the risk, prior to presenting them with information about the threat, what action they can take to mitigate it (to support response efficacy), and reassuring them of the ease to undertake the action (self-efficacy). It would be interesting to conduct research in a natural hazard context to test whether raising self-awareness in the population prior to issuing an impact-based warning would increase the response, and whether including information that supports response efficacy and self-efficacy on taking protective actions in an impact-based warning would increase the response.

### 4.4. Conclusions

In summary, our survey results indicate that impact-based warnings may be more effective than phenomenon-based warnings in influencing the recipients' perception of the hazardous event, but this doesn't necessarily translate into a higher likelihood of intending to take protective actions. We acknowledge that our research involved a non-random sample of New Zealanders and our findings are therefore not representative of the general public. Nonetheless, our findings support

those of Morss and Hayden [20] and Baker [1] in the respect that severe weather warnings should contain information on the storm characteristics, specific and personally relevant potential impact information, and response actions that are effective and easy to do, to have the highest chance of promoting an appropriate behavioural response.

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## Appendix A

A series of ANCOVAs were conducted to investigate differences in perceptions and intended actions across five grouped regions of New Zealand (1 = Auckland; 2 = Wellington; 3 = Canterbury; 4 = Other North Island; 5 = Other South Island), controlling for all relevant demographics as well as the type of weather warning received. Only statistically significant results are reported here.

There was a significant overall difference across regions for believing the wind to be a threat ($F(4, 1214) = 11.181$, $p < .001$). Specifically, those from the Auckland region ($M = 4.37$, $SD = .869$) had higher scores than those from Wellington region ($M = 4.06$, $SD = .999$, Cohen's $d = .33$), and lower scores than those from the Canterbury region ($M = 4.60$, $SD = .750$, Cohen's $d = .29$). Those from the Canterbury region also had higher scores than those from the Wellington region (Cohen's $d = .62$).

There was a significant overall difference across regions for being concerned about the wind ($F(4, 1214) = 10.291$, $p < .001$). Those in the Auckland region ($M = 4.23$, $SD = .935$) had higher scores than those in the Wellington region ($M = 3.83$, $SD = 1.087$, Cohen's $d = .39$). Also, those in the Wellington region had lower scores than those in the Canterbury region ($M = 4.38$, $SD = .909$, Cohen's $d = .55$).

There was a significant overall difference across regions for 'doing nothing differently' ($F(4, 1204) = 5.334$, $p < .001$). Specifically, those in the Auckland region ($M = 2.28$, $SD = 1.157$) had lower scores than those in the Wellington region ($M = 2.58$, $SD = 1.197$, Cohen's $d = .26$).

In terms of intending to drive more carefully, there was a significant and strong overall difference across regions ($F(4, 1209) = 4.509$, $p < .001$). Those in the Auckland region ($M = 4.23$, $SD = 1.005$) had higher scores than those in the Wellington region ($M = 3.94$, $SD = 1.039$, Cohen's $d = .81$).

There was a significant overall difference across regions for intending to u**se** the information to decide whether do outdoor work or activities ($F(4, 1213) = 3.260$, $p = .011$). Participants in the Auckland region ($M = 4.25$, $SD = 1.027$) had slightly higher scores than those in the Wellington region ($M = 4.07$, $SD = 1.108$, Cohen's $d = .17$).

In terms of checking with others to see what they are going to do**,** there was a significant overall difference across regions ($F(4, 1213) = 6.446$, $p < .001$). Aucklanders ($M = 2.86$, $SD = 1.246$) had higher scores than those in the Wellington region ($M = 2.45$, $SD = 1.206$, Cohen's $d = .33$).

There was also a significant overall difference across regions for checking other information sources for confirmation or advice ($F(4, 1213) = 11.030$, $p < .001$). Specifically, those in the Auckland region ($M = 3.81$, $SD = 1.176$) were more likely to check other information sources than those in the Wellington region ($M = 3.18$, $SD = 1.319$, Cohen's $d = .50$). Those from the Wellington region also had lower scores than those from the Canterbury region ($M = 3.88$, $SD = 1.262$, Cohen's $d = .54$).

There was a significant overall difference across regions for intending to ensure loose items on participants' properties were secure ($F(4, 1211) = 9.284$, $p < .001$). Specifically, those in the Auckland region ($M = 4.22$, $SD = 1.025$) were more likely than those in the Wellington region to secure loose items ($M = 3.80$, $SD = 1.165$, Cohen's $d = .39$). Those from the Wellington region also had lower scores than those from the Canterbury region ($M = 4.38$, $SD = .885$, Cohen's $d = .56$).

## Appendix B

A significant (weak) effect of living in a rural vs. urban area was observed, with those living in an urban area reporting thinking that the message was more credible compared with those living in a rural area (Table B1). There was also a significant effect found with those living in an urban area reporting that they were more likely to use the information to decide what clothes to wear in comparison to those living in a rural area. Those living in a rural area were reportedly more likely to secure loose items on their properties than those living in urban areas. The results for the remaining three perception variables and eight actions were not statistically significant.

**Table B1**
Statistically significant results for the influence of living in a rural vs. urban area on perceptions and actions.

| | Rural (N = 389) | | Urban (N = 955) | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variable** | **Mean** | **SD** | **Mean** | **SD** | **F-statistic** | **p-value** | **Cohen's d** | **N** |
| Credibility | 4.39 | .914 | 4.53 | .817 | 8.46 | .004 | .16 | 1344 |
| What clothes to wear | 3.67 | 1.210 | 3.96 | 1.075 | 14.645 | < .001 | .26 | 1342 |
| Secure outdoor items | 4.30 | 1.014 | 4.01 | 1.086 | 8.474 | .004 | .28 | 1341 |

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