A comparison between GeoNet's 'Felt RAPID' and 'Felt Detailed' online questionnaires

T. Goded, N. Horspool, M. Gerstenberger, M.A. Coomer, J.S. Becker, S. McBride, S. Canessa & A. Lewis

Institute of Geological Sciences Ltd, Avalon, Lower Hutt.

2017 NZSEE Conference

ABSTRACT: GeoNet's internet-based questionnaire 'Felt Detailed' (pre-September 2016 called 'Felt Classic') has been operative since 2004. Its aim is to provide an automatic intensity assignment using New Zealand's Modified Mercalli (MM) intensity scale based on answers to a set of standardized questions. More than 914,000 felt reports from 27,688 earthquakes have been received (by August 2016), demonstrating the immense public contribution to earthquake research. Results from the questionnaire have been analysed for research purposes, including estimation of community MM intensities to obtain the spatial damage distribution, and social science research. In November 2015, GeoNet launched 'Felt RAPID', an online tool (and mobile app, released in May 2016), where the public chooses from a set of cartoons depicting their experience of an earthquake. Its purpose is to obtain quick responses to be used for early damage estimations. While 'Felt RAPID' might provide a high number of responses in a short timeframe, the reliability of the results may be compromised by the lack of detailed questions. By comparing the responses between 'Felt Detailed' and 'Felt RAPID' we can identify whether public interpretation accurately reflects the MM intensities intended by each of the cartoons. A comparison of both datasets has been carried out and is presented in this paper, together with a list of limitations and future work. A better understanding of how these two types of reports compare will inform future use and development of tools for calculating MMI, and will further contribute to earthquake research in New Zealand.

1 INTRODUCTION

Internet-based macroseismic surveys have been implemented in the last fifteen years by several international seismological institutions, and are becoming a very popular way of the public contributing to science through sharing their experience during an earthquake.

GeoNet is New Zealand's national geological hazards monitoring service (http://www.geonet.org.nz/). In 2004, GeoNet implemented an internet-based questionnaire ('Felt Classic') for members of the public to voluntarily complete following an earthquake. GeoNet also implemented an algorithm (Coppola *et al.*, 2010) to automatically assign intensity values to each felt report in New Zealand's MMI (Modified Mercalli Intensity, called MMI scale throughout this paper for simplification) scale (Dowrick, 1996; Dowrick *et al.*, 2008), based on felt information captured from the questionnaire. Three years after the implementation, the success of the online questionnaire project was seen following earthquakes such as the magnitude 6.8 Gisborne event in December 2007, when more than 3,400 felt reports were received (Coppola *et al.*, 2010). The Canterbury earthquake sequence (2010-present) challenged the facility, which needed to deal with more than 15,000 felt reports for the four major events (Darfield main shock, 4/9/2010, M_w 7.1; Christchurch 22/2/2011, M_w 6.2; Christchurch 13/6/2011, M_w 6.0; Christchurch, 23/12/2011, M_w 5.9).

GeoNet's automatic algorithm assigns an intensity to each felt report. However, intensity values applied to single locations are not consistent with the way traditional MMI values were estimated, by estimating the seismic impact at a regional scale. Thus GeoNet's MMI values do not provide information on the geographical damage distribution, essential in seismic hazard and emergency planning. This is being carried out with the use of "community intensities", which estimate the intensity using multiple responses over a region (Goded *et al.*, 2017a,b). These are essential to create

intensity maps that could be included in GeoNet's website minutes after an earthquake occurs and be used to inform local authorities, emergency planning agencies and the general public. In addition, the implementation of community intensities could be used to generate intensity maps for the recently developed ShakeMapNZ (Horspool *et al*., 2015).

'Felt Classic' questionnaires were operative between October 2004 and August 2016. During this period, GeoNet received more than 914,000 felt reports from 27,688 different earthquakes. After that, they have been divided into two: 1) 'Felt Detailed' (FD) are GeoNet's new questionnaires, very similar to 'Felt Classic' with similar questions and answers plus some additional questions related to tsunami evacuation and attitudes towards GeoNet communication; and 2) 'Felt RAPID' (FR), a questionnaire available on internet and mobile devices where the public chooses from a set of cartoons (each corresponding to a different MMI level) depicting their experience of the earthquake. 'Felt Classic' and 'Felt Detailed' take about ten minutes to fulfil. The use of the data for research purposes has been approved as a Low Risk project by the Massey University Human Ethics Committee.

The purpose for 'Felt RAPID' is to obtain quick and numerous responses from the public using a simplified questionnaire. FR is mainly used by the media and GeoNet as a public communication tool. 'Felt RAPID' has great potential to be used for emergency planning and early damage estimations through tools such as ShakeMapNZ. However, its simplicity makes it very difficult to capture all the aspects of the earthquake, as the respondent only chooses from a set of cartoons. Thus, we are questioning its value as a tool to provide accurate intensity values to be used by emergency planners, local authorities and scientists. The 'Felt Detailed' and 'Felt Classic' questionnaires have the necessary level of detail to provide more detailed information on the damage distribution caused by an earthquake. They are currently being used for research purposes such as for estimation of MM intensities (Goded *et al*., 2017a,b). FD and FR are currently operating at the same time to provide us with an opportunity to compare the quality of the results from both datasets for each earthquake. However, 'Felt RAPID' is the only questionnaire linked to the GeoNet webpage for each event, whereas the link to the 'Felt Detailed' questionnaire is accessed from the main GeoNet website and is not linked to specific earthquakes (https://www.surveymonkey.com/r/Feltdetailedmaster). In the future, two links will be provided for each earthquake, one for 'Felt RAPID' and one for 'Felt Detailed'. This arrangement will greatly benefit researchers, as the two datasets will be simultaneously available. It should be noted that currently 'Felt RAPID', although linked to an event on the GeoNet website, simply stores the data up to one hour after the earthquake, and does not keep the information on the event ID. Even if respondents keep providing data, it will not be stored if more than an hour has passed since that particular earthquake. Thus, if there are two or more events in a one-hour period, the data will be mixed. On the contrary, 'Felt Detailed' surveys are permanently available, and the respondent is asked to provide some earthquake information (at least the earthquake ID) to identify the event they have felt. This survey can be filled in at any time after the event. Thus, the different intentions and configuration of both surveys makes a comparison between them a difficult task.

The major Kaikoura M7.8 earthquake occurred on 14 November 2016 and happened when 'Felt Detailed' was almost ready to be released. A specific online questionnaire for the Kaikoura main event was released on the day of the earthquake. This voluntary survey for the public contained both 'Felt Detailed' and 'Felt RAPID' questions. It was intended as an opportunity to compare the two surveys by asking the same respondent to fill in both surveys. The Kaikoura combined survey takes about ten minutes to fill in and is under the same ethical approval as 'Felt Detailed'.

This paper describes the comparison between 'Felt Detailed' and 'Felt RAPID' online questionnaires carried out for the Kaikoura earthquake, from two different perspectives: a) seismology, by comparing the MM intensity results derived from both datasets; and b) social science, by comparing the main focus of the respondents when choosing a cartoon from FR, and how well these are describing the MMI descriptions in the New Zealand macroseismic scale. The manuscript will show the main results and conclusions, together with the limitations and the areas where future work is needed.

2 COMMUNITY MODIFIED MERCALLI INTENSITIES FROM 'FELT RAPID' AND 'FELT DETAILED' DATA DURING THE KAIKOURA 14/11/2016 M7.8 EARTHQUAKE

2.1 Community MM intensities for the Kaikoura earthquake

Although GeoNet used to automatically calculate MMI values for each report in 'Felt Classic' surveys, until recently there was no method to convert this data into a reliable spatial damage distribution at a community scale. This limits our ability to understand past disasters and help future evacuation and emergency planning. Our team has recently developed a method to obtain spatial damage distribution maps from MMI values derived from 'Felt Classic', 'Felt Detailed' and 'Felt RAPID' questionnaires (Goded *et al*. 2017a,b). The method to obtain community intensities is based on the one developed at the *Instituto Nazionale de Geofisica e Vulcanologia* (INGV, Sbarra *et al*. 2010; Tosi *et al*. 2015) for Italian felt reports and has been adapted to GeoNet's online questionnaires and to the MMI scale (Dowrick 1996). It is an expert-based approach that follows the indications of a macroseismic scale and assigns a set of matrix scores using inputs from an expert panel. The scores are assigned to the answers to certain questions in the survey. In the end, a community MMI (or "CMMI") value is assigned to a community (being towns in rural areas and suburbs in urban regions), thus being able to provide a geographical damage distribution for each earthquake. With this method, all the responses for the same community are weighted and considered, avoiding taking maximum MMI values that might not accurately indicate the intensity generally felt in that community. CMMI values have only been assigned for communities with 5 or more felt reports, as this is considered the minimum number to obtain reliable results. This criterion has been followed by previous studies (Wald *et al*. 1999, Tosi *et al*. 2015). The method has been tested for nine recent New Zealand earthquakes and has been applied for the whole set of 'Felt Classic' surveys, adding to a total of 27,688 earthquakes that now have CMMI values assigned.

The CMMI method was applied to the Kaikoura 14/11/16 M7.8 earthquake for the 'Felt Detailed' + 'Felt RAPID' online questionnaire. Figure 1 shows the community MMI values for both datasets. As it can be seen, there are very few suburbs with MMI assigned. The reason for this is that, even though more than 3500 reports were received, as the event occurred in a rural area, the reports were widely distributed across the country. As a consequence of this, only 42% of the reports were able to be used to calculate CMMI. The rest of the reports correspond to suburbs with less than 5 reports, for which CMMI values have not been assigned, following a criterion in agreement with other similar studies. For the few suburbs with CMMI assigned in both datasets, there seems to be a slight tendency of FR values to be one MMI unit above FD CMM intensities.

2.2 MM intensities from individual 'Felt Detailed' and 'Felt RAPID' reports corresponding to the Kaikoura earthquake

To be able to make a better comparison of 'Felt Detailed' and 'Felt RAPID' datasets, the individual MMI values derived from each report have also been compared. These correspond to the MMI with the maximum score (modal) for the CMMI method for each report in 'Felt Detailed', and the MMI from the cartoon chosen by the respondent in FR. This means that in FD the MMI chosen is the one with higher probabilities of being the MMI felt, as it is the one with a higher score pointing towards that intensity level. A total of 2997 reports had both 'Felt Detailed' and 'Felt RAPID' responses, corresponding to 85% of the total amount of reports received. The results are shown in Figures 2 and 3. As it can be seen, 27% of the reports had the same MMI value using both datasets. However, 40% of the reports had an MMI value one level higher when using FR vs FD, with a total of 66% of the reports with MMI from 'Felt RAPID' higher than 'Felt Detailed' (Figure 2a). When analysing these differences by MMI levels (Figure 2b) it seems that there is a tendency for FR data to overestimate the MMI with respect to FD for intensities 5 or below, and to underestimate it for MMI 7 or 8. At MMI 4 and 5, 'Felt RAPID' overestimates with respect to 'Felt Detailed' by mostly one intensity level, and in some cases more than one. At MMI 2, all the reports from 'Felt RAPID' overestimated the MMI compared to 'Felt Detailed' by more than one intensity unit (500 reports). This can partly by because FR starts at MMI 3 (see next section), thus very weakly felt events will be assessed as MMI 3 in that survey, as there is no cartoon for MMI 2. It should be noted that the most affected areas (Kaikoura,

Ward, Waiau) did not have power shortly after the earthquake, and thus were not able to fill in FR, only FD when the power was back. This issue can partly explain some of the differences observed.

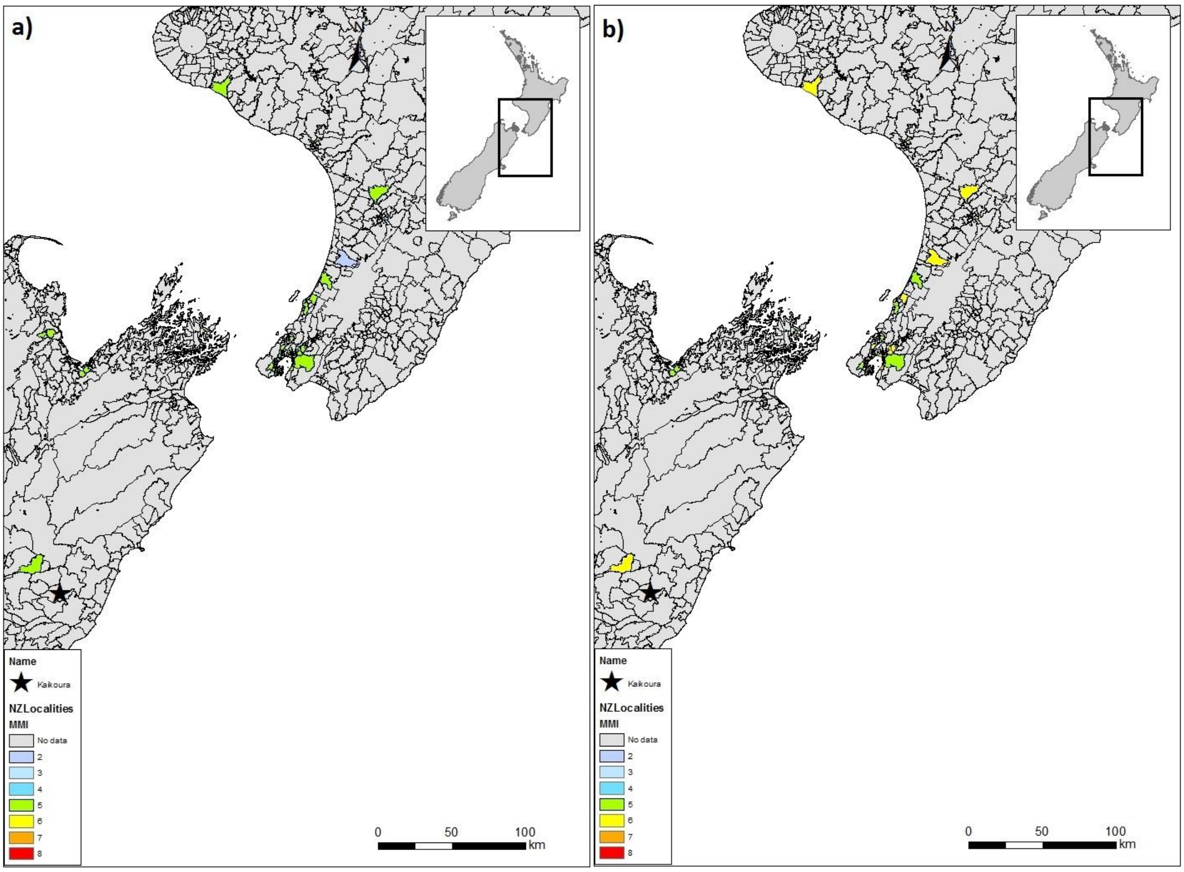

Figure 1. Community MM intensity distribution corresponding to the 14 November 2016 M_w 7.8 Kaikoura earthquake, using 'Felt Detailed' (a), and 'Felt RAPID' (b), GeoNet online questionnaires. The epicentre is indicated with a black star ("Kaikoura" in the legend). The inset shows the marked area represented in each map.

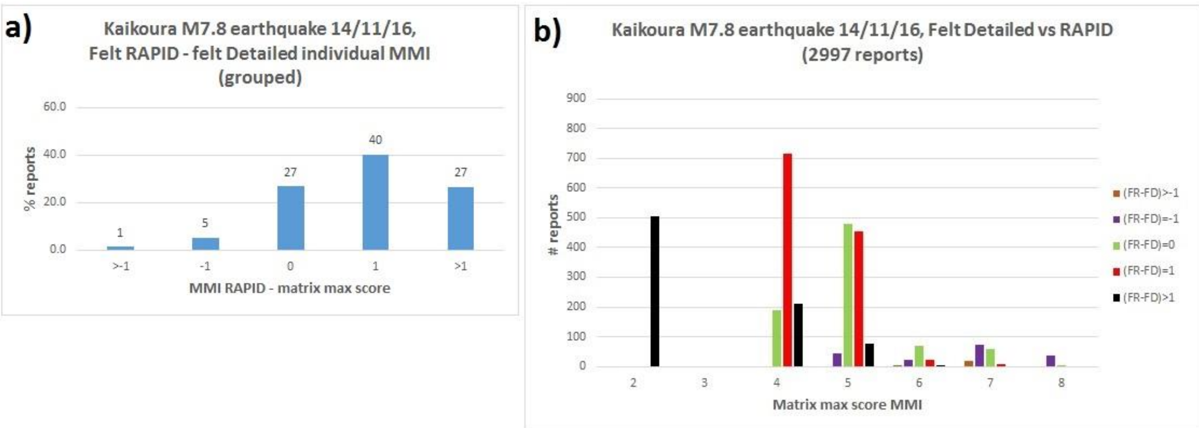

Figure 2. Comparison of MM intensities from 'Felt Detailed' and 'Felt RAPID' datasets from individual reports corresponding to the 14/11/2016 M_w 7.8 Kaikoura earthquake. FD MM intensities correspond to the maximum MMI value (modal) for each report. FR MMI values correspond to the MMI for the cartoon chosen by the respondent. The comparison is shown in terms of: percentage of reports with each MMI level difference between FR and FD (a); and reports distribution by MMI level, for individual MMI 'Felt RAPID' – 'Felt Detailed' (b).

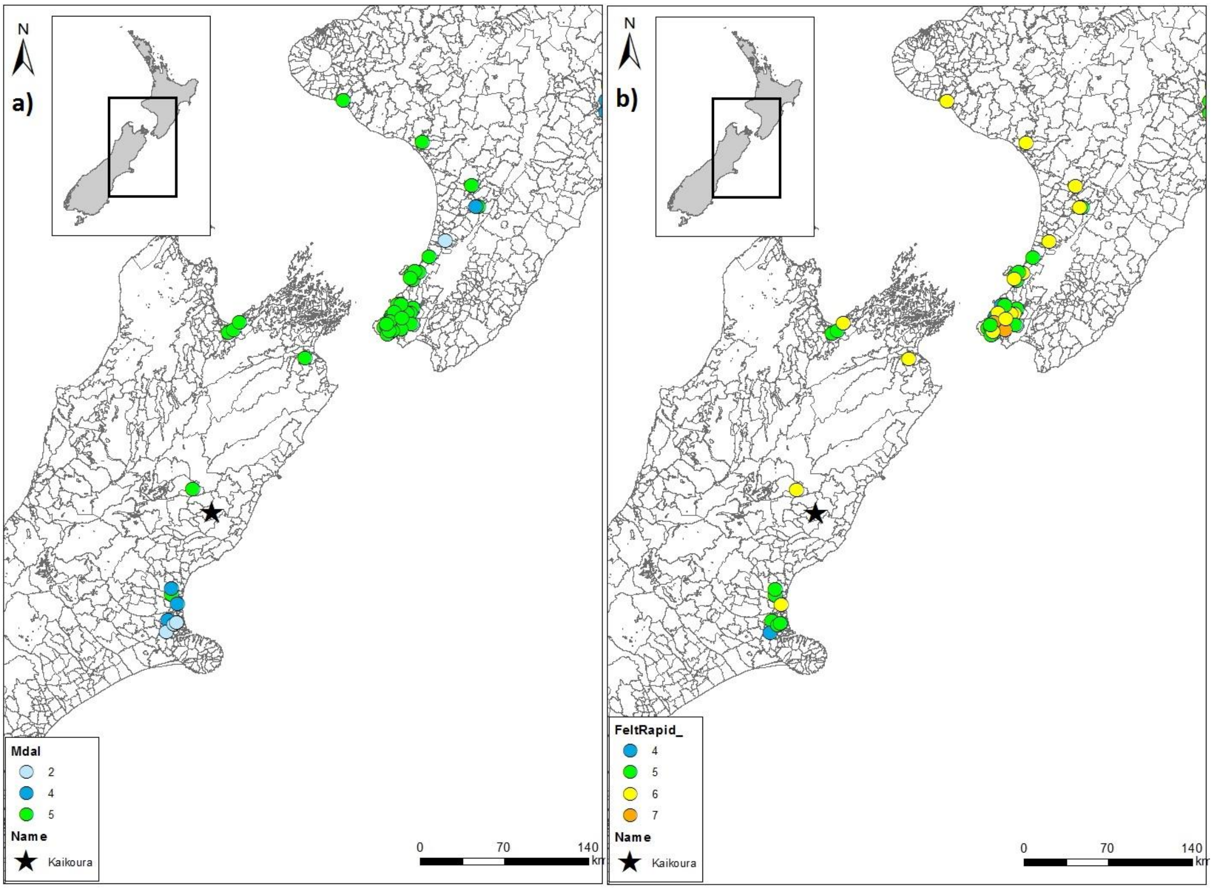

Figure 3. Individual MM intensity distribution corresponding to the 14 November 2016 M_w 7.8 Kaikoura earthquake, using 'Felt Detailed' (maximum score MMI values or modal) (a), and 'Felt RAPID' (MMI values corresponding to the chosen cartoons) (b), from the GeoNet online questionnaires. The epicentre is indicated with a black star ("Kaikoura" in legend). The inset shows the marked area represented in each map.

3 SOCIAL SCIENCE DIFFERENCES BETWEEN FELT RAPID AND FELT DETAILED

3.1 Shaking intensities

'Felt RAPID' was designed as a set of six cartoons, each of them representing a single MM intensity level, between MMI3, and MMI8 or above. The cartoons are accompanied by a summary of the damage descriptor from New Zealand Modified Mercalli scale (Dowrick *et al.*, 2008). The correspondence between the MMI level and the FR shaking description is shown in Table 1.

Table 1. Correspondence between 'Felt RAPID' and MMI.

Felt RAPID description	MMI
Weak shaking	3
Light shaking	4
Moderate shaking	5
Strong shaking	6
Severe shaking	7
Extreme shaking	8

As a first step to compare 'Felt RAPID' and 'Felt Detailed' surveys, the cartoon chosen in FR (and thus the MMI it corresponds to) has been compared to the question "How would you best describe the shaking?" in FD. Results are shown in Figure 4. As it can be seen, there is a correspondence between

the responses to FD and FR for the low shaking levels, where low intensity levels in FD (gentle and jolt shaking) match well with MMI3 and MMI4 answered in FR. Similarly, at very high intensity levels, FD and FR responses have good agreement (FD "violent/severe" vs FR MMI8). This indicates that respondents are able to provide consistent responses when the shaking intensity level is described. However, these results differ from the ones obtained in the previous section (overestimation of FR at MMI below 5, and underestimation for MMI 7-8). A further analysis of the questions that might have lead the respondents to choose a specific cartoon in FR is needed. As a first step, questions related to rattling objects and to effects on furniture have been analysed and are described in section 3.3.

For moderate and strong shaking, FR seems to be underestimating the shaking with respect to FD: 56% of responses to FR MMI5 (moderate shaking) have chosen "strong/powerful" in FD, and only 26% have selected "moderate" in FD. Reasons for this discrepancy could be that in FR respondents reply in accordance to what draws their attention in the cartoon in FR. This result is in agreement with the ones from the previous section, indicating that the moderate-strong level of shaking needs to be reviewed in both surveys.

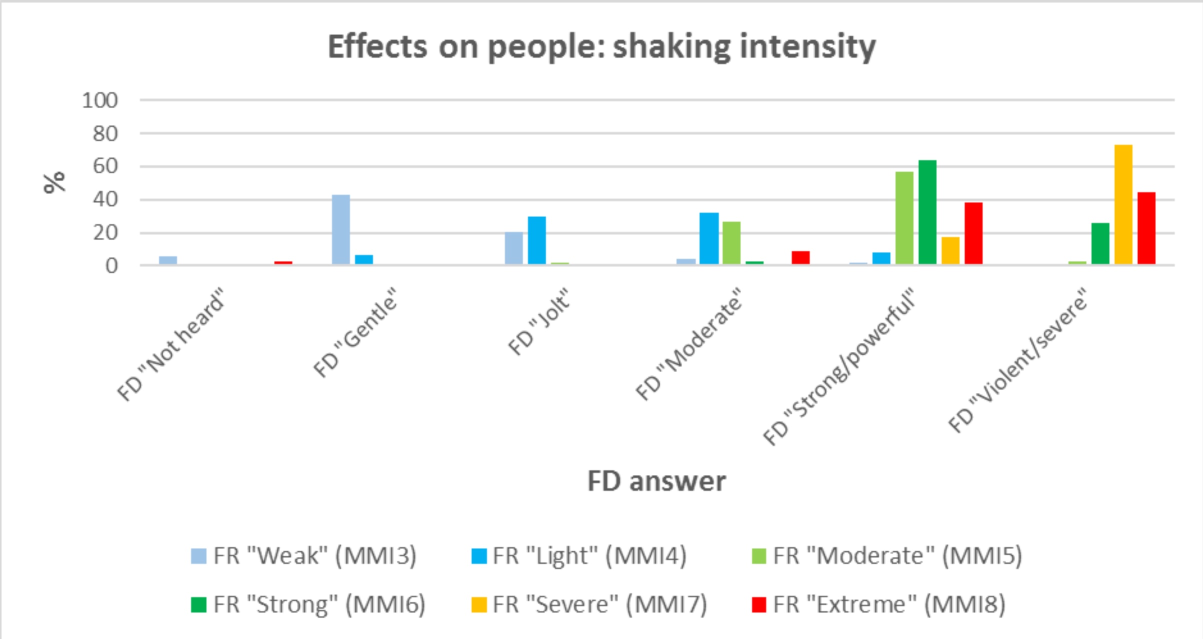

Figure 4. Comparison between GeoNet's 'Felt RAPID' and 'Felt Detailed' surveys in terms of shaking intensities

3.2 Respondents situation

As the Kaikoura earthquake occurred at night and the effect of awakening people is described in the MMI scale, a comparison between the MMI level chosen in FR and the respondents situation was carried out. At MMI4 level, the MMI scale (Dowrick *et al*., 2008) says that "Light sleepers may be awakened", versus "Most sleepers awakened" at MMI5 level. For the Kaikoura earthquake, about 50% of people who chose MMI4 in FR ("Light shaking") were awoken (according to the data in FD), and about 60% for MMI5 ("Moderate shaking"). Reasons for the other 40% not being awoken at MMI5 were that they seemed to have been awake at the time of the earthquake, with 3% standing, 35% sitting/lying, and 0.2% walking/running.

3.3 Effects on fittings and furniture

Effects on fittings have also been contrasted with responses to the FR survey. At MMI4 level, "glassware and crockery rattle". Responses to the question "Did objects such as glasses, dishes, ornaments or other small shelf items rattle, topple over or fall off shelves?" in FD have been analysed in figure 5. As it can be seen, there is a good correspondence between the FR MMI chosen and the effects on glass and ornaments: 30% of people who answered MMI4 in FR said they were rattling

(slightly or loudly), and 55% for FR MMI5. Objects toppling correspond to respondents who answered MMI5 or MMI6 in FR, also in agreement with the MMI scale, where "small unstable objects are displaced or upset", and "some glassware and crockery may be broken" at MMI5 (26% answered MMI5 in FR), and at MMI6 "objects fall from shelves" (49% MMI6 replies in FR). Thus, from these results it can be seen that the objects starting to rattle at MMI4 and to topple at MMI5 (and mostly MMI6) are in agreement with the responses in 'Felt Detailed'.

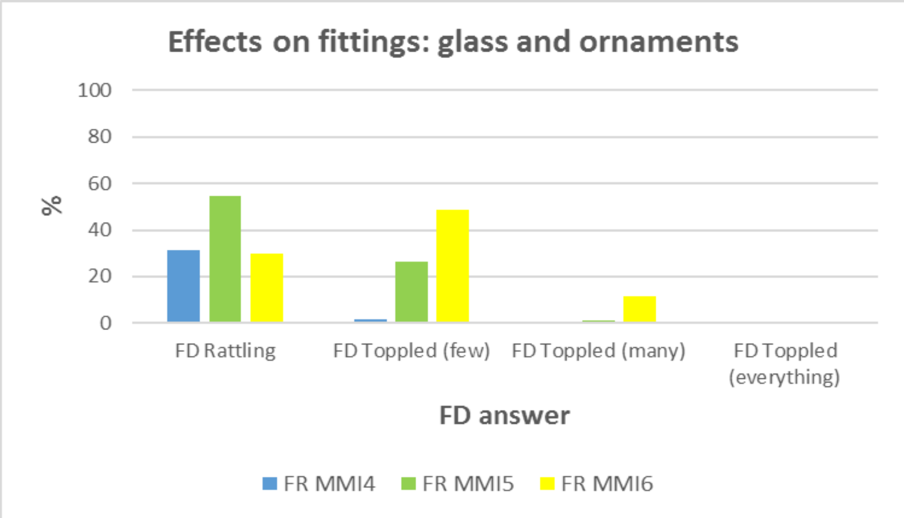

Figure 5. Comparison between GeoNet's 'Felt RAPID' and 'Felt Detailed' online surveys in terms of effects on glass and ornaments

Similarly, effects on small and large furniture have been analysed: according to New Zealand MMI scale (Dowrick *et al*, 2008), furniture starts moving at MMI6 level ("Some furniture moved on smooth floors") with most of them moving at MMI7 ("Furniture moves on smooth floors, may move on carpeted floors"). An analysis of FD answers to the question 'Did any items of furniture – TV, Computer, Microwave, Fridge, filing cabinet or machinery slide (not just sway) or topple over?' has been carried out. Results show that around 96% respondents to that question had small objects sliding at MMI6 and 90% had big pieces of furniture at MMI7. As a conclusion, it can be said that FR answers are consistent with the damage observed in FD in terms of effects on furniture.

The questions analysed in this section (related to shaking intensities, situation and effects on fitting and furniture) are the most clearly described in the MMI scale. Overall, it can be said that the responses to the damage descriptions in 'Felt Detailed' seem to correspond well with the level of intensity chosen in 'Felt RAPID' and the corresponding damage description in the NZ MMI scale. However, the differences between FD and FR in terms of shaking intensities for moderate to strong events (FR overestimating) together with the ones obtained in section 2 show that further analysis of other relevant questions is required to understand the discrepancies observed.

4 LIMITATIONS

Limitations in the comparison between the two questionnaires can be summarised as follows:

- There is a difference in the aims of the questionnaires.
- There was an inability for some people to enter 'Felt RAPID' data following the Kaikoura earthquake due to power failure.
- During normal circumstances, there is an inability to link the FR and FD datasets to a particular person filling out both, making it impossible to compare their answers. As a result from this, no straightforward statistically significant comparison between the two datasets is possible.
- The Community MMI method has recently been developed and has been tested and calibrated with other methods (Goded *et al*., 2017a,b) for the Valentine's Day earthquake (M5.7,

14/2/16). However, the method still requires to be further tested and refined.

It should be noted that the comparison between the two datasets using the combined FR+FD questionnaire has overcome the last two middle limitations. However, only similar combined surveys in future events will provide an opportunity to compare the two surveys in an efficient way.

5 CONCLUSIONS AND FUTURE WORK

Comparisons have been made between the two current GeoNet online questionnaires, 'Felt Detailed' and 'Felt RAPID', in order to check if both datasets lead to similar results in terms of Modified Mercalli intensities. These comparisons have been checked from a seismological and social science perspective. Even though the intentions for both questionnaires are slightly different, we have carried out a preliminary analysis of both based on the reports reviewed for the recent M7.8 Kaikoura earthquake to see whether 'Felt RAPID' could be used as a tool to calculate general and community MMIs and thus be included in the future in tools such as ShakeMapNZ. We found similarities in the middle MM intensity levels of both but some differences in calculations at either end. Currently the 'Felt Detailed' reports are still most accurate for calculating MMI due to the detailed information provided, and remain a useful research tool, but opportunity exists for exploring how 'Felt RAPID' could also provide this function, especially as the publics preference is for contributing via the platform of 'Felt RAPID'. Further research is required to understand how the cartoons are interpreted by the public, and whether 'Felt Detailed'-like data can be captured through this style of reporting.

6 ACKNOWLEDGMENTS

This work has been funded by the RiskScape (www.riskscape.org.nz) and "Understanding Earthquakes and Tsunamis" projects. The authors wish to thank the GeoNet team, GNS Science and the Earthquake Commission (EQC) for the implementation and monitoring of the online earthquake questionnaire. This paper has been reviewed by Sally Potter and Mostafa Nayyerloo from GNS Science. This work would not have been possible without the efforts of so many people in New Zealand who have generously filled in felt reports after each of the earthquakes, providing us with an immensely valuable amount of information.

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