



The public response and educational outreach through social media after the Zagreb earthquake of 22 March 2020

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Received 1 July 2021, in final form 29 October 2021

Following the 22 March 2020 M_L 5.5 earthquake near Zagreb, Croatia, the citizens became increasingly interested in earthquakes and the multitude of simultaneous visitors caused the webpage with Croatian Seismological Survey reports on earthquakes to crash. To remedy the situation, seismologists used social network accounts to provide information, using the opportunity to educate the citizens on basic concepts of seismology, earthquake preparedness and the occurring seismic sequence. Citizens' feedback was useful to improve the communication, but required extensive moderation. In July 2020, three seismologists from the Department of Geophysics, Faculty of Science, University of Zagreb, one from the Slovenian Environment Agency, and a psychologist from the Croatian Catholic University conducted a poll to find out which sources of information citizens mostly use, their knowledge about earthquakes, and the level of fear they were experiencing due to the earthquakes. Most respondents relied on institutional sources of information and their knowledge on different aspects of earthquake preparedness increased relatively compared to the time before the earthquake. The majority of respondents was extremely worried on the day of the mainshock, predominantly because they were concerned of a possible stronger event, their safety and the safety of their close ones.

Keywords: Zagreb earthquake 2020, social networks, educational outreach, earthquake-related worry, earthquake preparedness

1. Introduction

After the 22 March 2020 M_L 5.5 earthquake that happened at 05:24 UTC 7 km NNE of the Zagreb city centre, Croatia, power outages affected offices of the Croatian Seismological Survey (in further text CSS) at the Department of Geophysics, a part of the Faculty of Science at the University of Zagreb, situated in the northern part of the city. At the time, CSS employed ten people, eight of them being seismologists, and further four seismologists worked in academic positions

at the Andrija Mohorovičić Geophysical Institute (AMGI) at the Department of Geophysics. The fact that the earthquake occurred at the beginning of the first wave of COVID-19 pandemic, when the number of affected people in Croatia had started to rise and the government had introduced lockdown measures, additionally aggravated the situation. Citizens were not allowed to leave the place of residency and move outside without special permits, which affected seismologists' duties such as collecting macroseismic data and installing additional seismic stations to monitor the aftershocks. Members of the CSS obtained such permits on 24 March.

The Department of Geophysics building was affected by power outages, but it was accessible, despite slight damage. The CSS Operational centre was the only part of the building equipped with power generators and therefore operational immediately after the earthquake. However, to provide information to the authorities and the public as required by law (Narodne novine, No. 44/85), it was necessary that seismologists access the building in person. Furthermore, it was not feasible to work remotely until later in the day when the power supply was restored. In the first days after the mainshock, CSS with the support of the AMGI installed three additional seismographs in the epicentral area, and remained in constant cooperation with the Civil Protection Directorate from the Republic of Croatia Ministry of the Interior and the Emergency Management Office of the City of Zagreb.

Due to the exceptionally large number of people accessing the CSS webpage with the official reports on earthquake occurrence on the day of the mainshock, the webpage was out of service for an hour or more multiple times a day (webpage activity was not monitored in detail at the time as it was not a priority). In such a situation, relevant information was also transmitted through the existing CSS Twitter account @seizmo_hr (https://twitter.com/seizmo_hr; from now on written as SHR) and the Department of Geophysics' Facebook page Geofizika uživo (<https://www.facebook.com/geofizika.uzivo/>; GU). SHR was opened in December 2019, mainly to share information about earthquakes felt in Croatia, which are routinely published on the CSS website; in September 2021 it had approximately 12,400 followers. GU was created in March 2014 to popularize the Department of Geophysics Open Day, and publishes post on different topics in geophysics for science popularization and educational purposes. In September 2021, it had approximately 16,100 followers.

Social networks have a significant role in today's society, and are widely used in crisis situations such as after strong earthquakes. Numerous seismological organizations continuously provide information about occurring earthquakes on Facebook and/or Twitter, and diverse functionalities of social media have been documented after damaging earthquakes. Jung and Moro (2014) found five functionalities after the 2011 Great East Japan earthquake: citizen interpersonal communication; group-level communication for organizations, local communities, and local media; distribution channels for the mass media; information dissemination and gathering; and direct communication between citizens, the media,

and the government. Social networks have been used by non-profit organizations and the media, for example after the 2010 Haiti earthquake (Muralidharan et al. 2011), as well as to assess citizen mental health after the 2009 L'Aquila earthquake (Masedu et al., 2014), to disseminate information to deaf people after the 2016 Amatrice earthquake (Rotondi et al, 2018) or to continuously discuss earthquake hazard in Alaska (Lambert, 2020).

We present a case study of social media usage by the Department of Geophysics, Faculty of Science, University of Zagreb after the 2020 Zagreb earthquake, predominantly in informing the public and gathering macroseismic data. A motivation for this work was a sudden increase in the number of followers for both SHR and GU, which is explained in detail in Section 2.

1.1. Early stage important messages

The aforementioned social network accounts were used to share information on the location and magnitude of the mainshock and the largest aftershock. The mainshock occurred at 5:24 UTC (6:24 local time) and had a local magnitude of 5.5. The largest aftershock followed at 6:01 UTC with a preliminary local magnitude of 5.0 (which was later updated to 4.9). The official report on these two events was released on the CSS webpage at 6:35 UTC and a shorter message was released on SHR at 6:44 UTC. The CSS webpage was soon overloaded by a very large increase in traffic that crashed it. To continue providing information to the public, the official report was also released on GU at 7:49 UTC. Citizens in Zagreb and suburban places in the epicentral area mostly stayed outdoors after the mainshock, mainly out of fear and to avoid injuries in case of aftershocks and additional damage to buildings. However, the COVID-19 lockdown complicated the situation, as it was difficult to maintain social distancing required in order to slow down the spread of the virus. Moreover, a cold front caused a drop in air temperature and occurrence of snow (DHMZ, 2000).

Soon after the mainshock, a rumour that an even stronger earthquake was going to occur at a specific time started to spread in citizen-to-citizen communication, mostly via private messages on their mobile phones. We were informed of the message, and of the fact that it was causing fear for many citizens. Approximately two hours after the mainshock, posts on both SHR and GU denied these rumours, telling the public that such earthquake prediction is not feasible, informing them that aftershocks of smaller magnitude are definitely to be expected, and that the probability for the occurrence of a stronger earthquake is very low but it does exist (Fig. 1). Available materials on earthquake preparedness, what to do before, during and after an earthquake were shared, as well as simplified advice on the most important actions (*e.g.* to assess the building situation and check the electrical and gas installations). This was particularly important because, according to the International Federation of Red Cross and Red Crescent Societies, in the wake of dangerous events “people need information as much as water, food, medicine or shelter” (IFRC, 2005).

In the following days and weeks, both SHR and GU were used by seismologists to share other relevant information, materials published on the Department of Geophysics website and links to the interviews with Croatian seismologists in different media.



Figure 1. Messages defying rumours about a stronger earthquake occurring in the next hour released on (a) GU and (b) SHR (both are screenshots taken on 28 May 2020). English translations: (a) Dear followers, someone is spreading panic and fake news! No one can say that there will be a stronger earthquake in an hour! Certainly no one from the Seismological survey said that! I ask the media not to share this fake news! Prepare yourself for weak but numerous earthquakes, not only today but also in the coming weeks! (b) We cannot predict earthquakes, any notices about a stronger earthquake coming are incorrect! There is a probability for a stronger earthquake occurring, but it is very low. We can expect further weaker aftershocks. We do not have electricity and we are doing everything we can to give timely and accurate information.

1.2. A Facebook group dedicated to the events

As the 22 March 2020 earthquake occurred in the most populated part of Croatia with approximately 1.2 million inhabitants, videos and photographs of various earthquake effects emerged in the media, on social networks, etc. Following a suggestion of Ina Cecić from the Slovenian Environment Agency (Agencija Republike Slovenije za okolje – ARSO potresi), on 23 March, a Facebook group Zagrebački potres 2020 – vaše info za seizmologe (<https://www.facebook.com/groups/210791050014517/>; english translation: Zagreb earthquake 2020 – your info for seismologists; abbreviation: ZP2020) was opened. The purpose of the group was to collect macroseismic data, and amend the data otherwise collected by CSS using an online questionnaire and, after stronger earthquakes, in field surveys and telephone interviews. We decided to use a Facebook group

because it can be used to exchange textual descriptions, photographs and videos in a fast and simple way. Furthermore, with 2.16 million users (Statista Research Department, 2021), Facebook was the most popular social network in Croatia in 2020. For reference, in 2020 2.85 million people in Croatia used social networks (Degenhard, 2021a), 0.41 million were on Twitter (Degenhard, 2021b) and 1.18 million used Instagram (Degenhard, 2021c), although the numbers are approximate and slightly vary between information providers. The Facebook group was managed and moderated by three seismologists: two (Marija Mustać and Helena Latečki) from the CSS with the help of one (Iva Dasović) from AMGI – none had previous experience in moderating a Facebook group. Eleven months later (after the Petrinja M_L 6.2 29 December 2020 earthquake) the name of the group was changed to Seizmološka služba (HR) – vaše info za seizmologe; english translation: Seismological survey (HR) – your info for seismologists. More information is presented in Section 2.3.

In this paper, we analyse the activity on three social media accounts used for providing earthquake-related information and for educational outreach (SHR, GU and ZP2020), with an emphasis on the newly opened Facebook group ZP2020 in Section 2.2. The comments citizens left on these accounts were an indicator of fear present in the population, mostly in areas strongly affected by the earthquake. They motivated us to share psychological materials relevant for coping with earthquakes as well, and to conduct a questionnaire in cooperation with a psychologist. The goal of the questionnaire was to see which sources of information about earthquakes citizens predominantly use, is the emotional distress expressed in their comments widespread, and to check if their knowledge about earthquake preparedness increased in the few months after the mainshock. Results of this survey are presented in Section 3.

2. Social media metrics

2.1. Twitter profile @seizmo_hr (SHR) and Facebook page Geofizika uživo (GU)

Daily impressions (the number of times a post appears on someone's screen) on Twitter increased from a few hundreds to an astonishing 1.47 million on the day of the mainshock (Fig. 2). Nine CSS tweets were seen 160,471 times on 22 March, which gives an average engagement rate (the number of engagements divided by the number of impressions) of 11%. For reference, the maximum engagement (the total number of times users interacted with a tweet) in March 2020 before the Zagreb earthquake (from 1 to 21 March) was 14. At the time of data collection for this article (May 2020), it was not possible to obtain the number of Twitter followers before 9 April 2020 (Fig. 3). However, we believe that a good estimate of the number of followers before the earthquake was approx. 50; it grew to approx. 6000 in the first week after the mainshock and continued to increase in the following weeks and months.

A similar major jump in daily total impressions (as with SHR) occurred for the Facebook page GU, jumping from a few hundreds to almost 855 thousand on 22 March. GU also had an engagement rate of approx. 11% and the posts had 91,931 engaged users on the day of the mainshock, in contrast to the maximum of 81 daily engaged users in March before that day. On 22 March the total number of people who liked the GU Facebook page increased from 1,037 to 11,418 and continued to grow (Fig. 3).

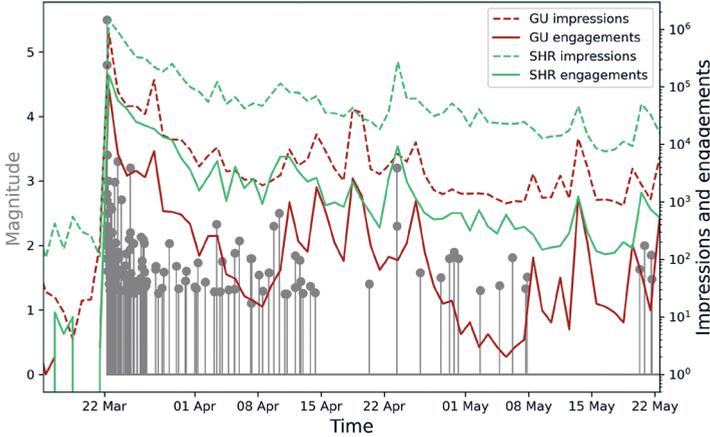


Figure 2. (left y-axis) Aftershock sequence with magnitudes equal to or greater than 1.3 (grey circles) and (right y-axis) GU (red lines) and SHR (green lines) daily impressions and engagements from 15 March to 22 May, downloaded on 29 May 2020.

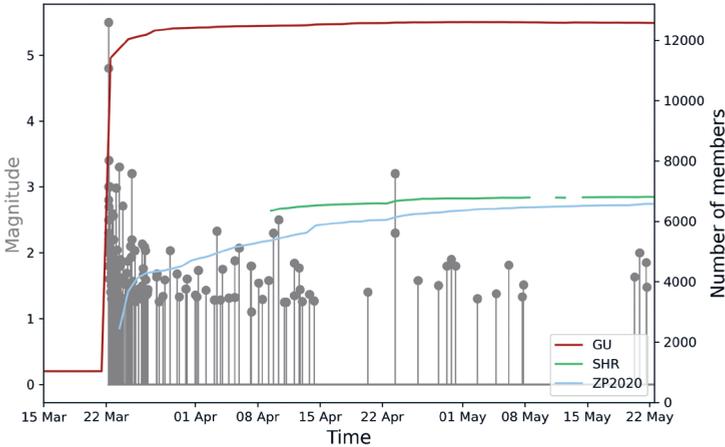


Figure 3. (left y-axis) Aftershock sequence with magnitudes equal to or greater than 1.3 shown in grey and overlain by (right y-axis) the number of GU page (red line) and SHR (green line) followers, and ZP2020 group members (light blue line). Available data is shown from 15 March to 22 May.

The impressions on both social media accounts compared to the pre-event values (Fig. 2) remained high (in tens of thousands) for several days, and so did the engagements (in thousands). Twitter impression and engagement data has peaks on days with larger aftershocks, while the GU impact declined more rapidly, and re-emerged on days when media (a map of historical earthquakes in Croatia and a video showing the aftershock sequence), or news appearances by seismologists were shared. Other published posts, such as information for geophysics students and posts from other branches of geophysics, received less attention. Both social media accounts have a prominent peak on 13 May 2020, when a magnitude 3.9 earthquake occurred near Crikvenica (120 km SW from Zagreb); this event has no relation to the Zagreb aftershock sequence.

2.2. Facebook group Zagrebački potres 2020 – vaše info za seizmologe (ZP2020)

Along with the existing social networks, the ZP2020 Facebook group was opened on 23 March 2020 at 10 AM, with the purpose of collecting macroseismic data. The group was promoted through the existing social network accounts (SHR and GU), personal contacts, and a link to ZP2020 was placed on the CSS webpage. As with SHR and GU, we did not pay for visibility nor include any advertisements. On the first day, 2,458 users joined the group. In the first week after the earthquake the number of members grew to 4,500, and continued to grow to more than 6,500 in the first two months after the mainshock (Fig. 3). For reference, the group reached approximately 7,400 members just before the second strong earthquake in Croatia on 29 December 2020, and was closed on 18 February 2021 because of lack of time to properly maintain it. It had about 9,650 members at the time of closure.

Approximately 40 posts were received with users' input, most often including dozens of photographs of earthquake damage and an approximate or detailed location (the street or neighbourhood). Certain posts contained videos and some only a textual description of the earthquake effects. Most contributions were received in the first three days after the group was created, a few were received on a daily basis in the first week and they continued sporadically until the end of April 2020.

However, it was immediately clear by the members' comments that they wanted and needed rapid information on the occurrence of weak aftershocks, information on how to behave during an earthquake and various details about the geological setting and faults in the Zagreb area. Such indication of worry and fear is commonly seen after natural hazards (*e.g.* Appleby–Arnold et al., 2019; Bossu et al., 2011; Winerman, 2009). Various information was shared in the group, such as the CSS reports on significant aftershocks, regular updates on aftershock occurrence, flyers with earthquake preparedness materials, interviews with Croatian seismologists in the media, information from seismological surveys in neighbouring countries, information given by the Civil Protection,

information on damage assessments (undertaken by civil engineers), available materials from psychologists on coping with fear of earthquakes, and different popular science materials on seismology.

The ZP2020 group members often provided real-time earthquake information, in a way similar to European-Mediterranean Seismological Centre (EMSC) Felt earthquakes (Bossu et al., 2008) or U.S. Geological Survey (USGS) Did You Feel It? (Wald et al., 2011). To organize these observations and clear out the “phantom earthquakes” (a sensation that the ground is moving when no earthquake is taking place) to avoid further spread of fear, all member posts needed to be approved by a group admin, starting from 23 March 2020 at 5 PM. Beside the initial instructions on the type of information seismologists are seeking, additional group rules were posted on 25 March to emphasize the general instructions, and warn about hate speech. A week after the mainshock, the group mostly transformed into educational outreach, while the macroseismic data was collected for some aftershocks. It became similar to numerous Facebook groups opened by seismological organizations and centres in rapidly sharing information about the occurring earthquakes, and similar to some educational groups (*e.g.* Incorporated Research Institutions for Seismology Facebook group) in sharing educational resources, with the emphasis on providing information in Croatian language.

Conversations in the ZP2020 group were mostly top-down and bottom-up, with some transversal conversations (between seismologists and citizens), as much as could be managed considering the large number of citizens and their comments. Examples of top-down conversations were cases when seismologists provided information about earthquakes with local magnitudes larger than or equal to 2,0 and citizens gave their observations. Bottom-up conversations can be separated into two kinds: 1) citizens leaving reports for weak events, which were then approved and confirmed by a seismologist, and 2) asking various questions. The latter prompted us to collect the frequently asked questions, answer them on the Department of Geophysics website and share the answers in the group, to share interviews with seismologists in the media, information and findings about earthquakes from other experts (civil engineers, geologists, etc.), and different popular science material. Citizens occasionally sent screenshots of the Zagreb seismic station live seismogram asking questions about certain features on the seismogram, which were then explained by seismologists. These conversations can be characterized as transversal. Apart from that, citizens tried to share or asked about common misinformation such as relation of earthquakes to a fictitious volcano beneath the Medvednica mountain, strong earthquakes in Turkey and Greece days before the mainshock, a geothermal powerplant, construction of Sljeme cable car, rumours of fracking, unusual animal behaviour, as well as earthquake predictions, possible ground rupture openings in Zagreb, etc. We have included most of these to the newly opened Frequently Asked Questions page on the Department of Geophysics webpage in the form of questions and

answers. Similar questions kept appearing in the group, and we would occasionally respond to them, but would eventually close the commenting option on every post to avoid the spread of misinformation and hate speech when the group admins were not able to actively monitor the group.

Citizens showed initiative in collecting various scientific and non-scientific information. Their efforts in reporting aftershock occurrences and asking for further explanations is similar to what was observed in a citizen Facebook group during the Mayotte seismic sequence (Fallou et al., 2020). The main difference is that ZP2020 was heavily moderated by seismologists. Another Facebook group was opened and moderated by citizens (<https://www.facebook.com/groups/138788690907697>), where they supported each other, organized help for the people most affected by the earthquake (donated clothes, furniture, construction material, offered their help in repairs, etc.), shared information about building inspections and occasionally about aftershocks. In September 2021, this citizen Facebook group had approximately 41,000 members. We do not analyse it in this paper as we do not have access to the data.

3. An online survey

In July 2020, a poll on sources of information about earthquakes, citizens' knowledge of earthquake preparedness, and earthquake-related discomfort was conducted. The authors of the poll were authors of this paper in collaboration with a psychologist Ivan Flis, PhD, from the Croatian Catholic University. It was made available online using LimeSurvey software (LimeSurvey GmbH) and transmitted through social network accounts, the Faculty of Science and the Department of Geophysics websites, and through personal communication. The questionnaire was aimed at the entire population of the affected area, while a part of the questions specifically targeted members of the ZP2020 Facebook group and GU Facebook page.

The survey was completed by 1,330 people (75% female, 24% male, and 1% gender-unspecified), mostly between the ages of 20 and 50. Approximately two thirds of respondents completed a Bachelor's degree or higher, 32.6% had a secondary education and the rest (0.5%) finished elementary school or less. This significantly deviates from the average values in Croatia (16.5%, 52.6% and 30.9%, respectively, according to the Croatian Bureau of Statistics 2011 Census) and indicates that people with a higher education level, women in particular, are more likely to complete an online survey of professional or research kind. Most of the respondents were employed (73%) and considered to earn an average (42%) or above average (36%) salary. This bias in respondents' demographics is consistent with previous findings for online (*e.g.* Smith, 2008) and telephone (*e.g.* Curtin et al., 2000; Singer et al., 2000) survey respondents, which show that women are more likely to participate in surveys than men, more educated and more affluent people are more likely to participate than less educated and less

affluent people, and younger people are more likely to participate than older people. The vast majority of respondents was located in Zagreb (93%) or its near surroundings (6%) on the day of the mainshock.

According to the data, on the day of the earthquake most of the respondents (65%) were extremely worried (5 on a scale 1 to 5, going from not worried to extremely worried; shown in Fig. 4 a), and only 6% of them were worried below-average or not worried at all (2 and 1, respectively, on a scale from 1 to 5). Median of the responses was 5 – Extremely worried. Answers differ between male (Fig. S1 a of the electronic supplement) and female (Fig. S2 a) respondents, with the median of male responses being in group 4. Interviewees mostly expressed extreme worry about the probability of a stronger earthquake (69%), safety of people they live with (65%) and safety of other close ones (51%), while the least number of people felt extremely worried for damage of their homes (30%), the need to leave buildings during the COVID-19 lockdown (21%) and property damage of other assets (19%); shown in Fig. 4 b to j. Median of male respondents' responses was one group lower for most answers, while it was the same for pro-

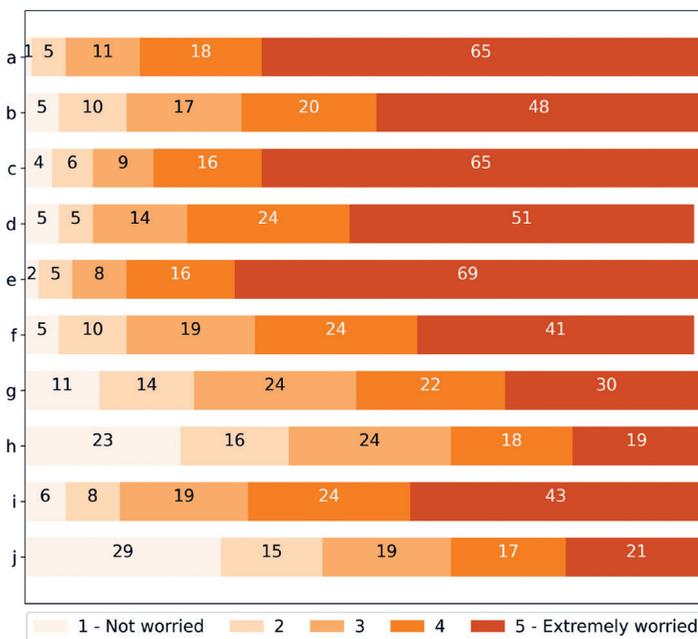


Figure 4. (a) Survey respondents' overall level of worry on a scale from 1 (Not worried) to 5 (Extremely worried) on 22 March and the level of worry for the following reasons: (b) personal safety, (c) safety of people they live with, (d) safety of close ones they do not live with, (e) possibility of stronger future earthquakes, (f) possibility of weaker future earthquakes, (g) damage of their home, (h) property damage of other assets, (i) reactions of people they live with, and (j) the need to go outside during COVID-19 pandemic.

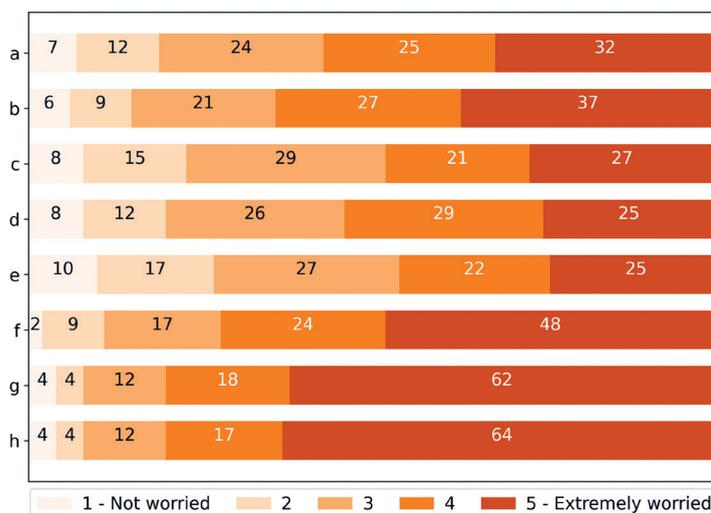


Figure 5. Survey respondents' level of worry on a scale from 1 (Not worried) to 5 (Extremely worried) in the months after the mainshock for the following reasons: (a) personal safety in case of future earthquakes, (b) the fear of earthquakes felt by their close ones, (c) property damage they suffered or property damage their close ones suffered, (d) damage on public buildings in Zagreb, (e) weaker earthquakes that have occurred, (f) possibility of future earthquakes, (g) the way the national institutions are handling the earthquake consequences, and (h) the way the city administration is handling the earthquake consequences.

perty damage of other assets and reactions of people they live with, and two groups lower for personal safety.

In the following months, the feeling of extreme worry was the highest because of the way the city administration (64%) and the national institutions (62%) were handling the crisis (Fig. 5). Personal or close ones' property damage (27%), public property damage (25%), and weaker aftershocks that were occurring (25%) caused extreme worry in a fewer number of people. Once again, male respondents claimed a lower level of worry than female respondents (Fig. S3 and S4 in the supplement), with the median lower for one group (except for the way the city administration is handling the earthquake consequences, where it was the same).

Severe building damage was confirmed, *i.e.* assessed by civil engineers as temporarily unusable (PN1 or PN2 marks) or unusable (N1 or N2 marks), to approximately 8% of the interviewees. A slightly larger fraction of people (12%) left their homes after the earthquake, and only a third of these people had suffered severe property damage. The majority of people who left their homes (62%) returned there by the time of the survey, and the same was true for 42% of people living in buildings with confirmed severe damage. From the respondents who did not suffer severe property damage, 23% did not return to their place of

residence. We did not explore the reasons for this, it is possible that they were temporary residents in Zagreb at the time when the mainshock occurred or that they were staying at a different location during summer, when the survey was conducted.

To estimate the citizens' level of preparedness, the respondents were asked to assess their level of knowledge on five topics covered by the Emergency Management Office of the City of Zagreb flyer that was shared on social network accounts after the mainshock. In addition, they were asked to estimate their general knowledge about earthquakes and the probability of a strong earthquake occurring in the Zagreb area, but what they thought prior to the 22 March 2020 event. Most of the respondents considered they had a fair (39%) or above-average (25%) level of knowledge (Fig. 6a). The question covering the probability was intended as a simple example to critically evaluate citizens' knowledge. The values in answers ranged from 0 to 100% (Fig. 6b); however, the median of their estimate for the probability was 63%, while the lower and upper quartile were 25% and 84%, respectively. Median of male respondents' answers was 70%, but the uncertainty was higher, with a lower and upper quartile of 25% and 90% (Fig. S5). Female respondents were less aware of the possibility of a strong

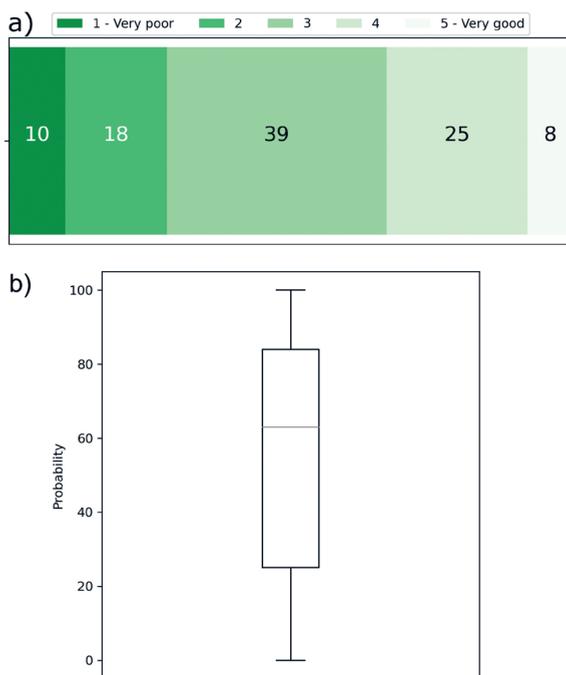


Figure 6. (a) Self-assessed level of knowledge about earthquakes on a scale from 1 (very poor) to 5 (very good) and (b) estimated percent of probability of a strong earthquake occurring in Zagreb before the 22 March 2020 event.

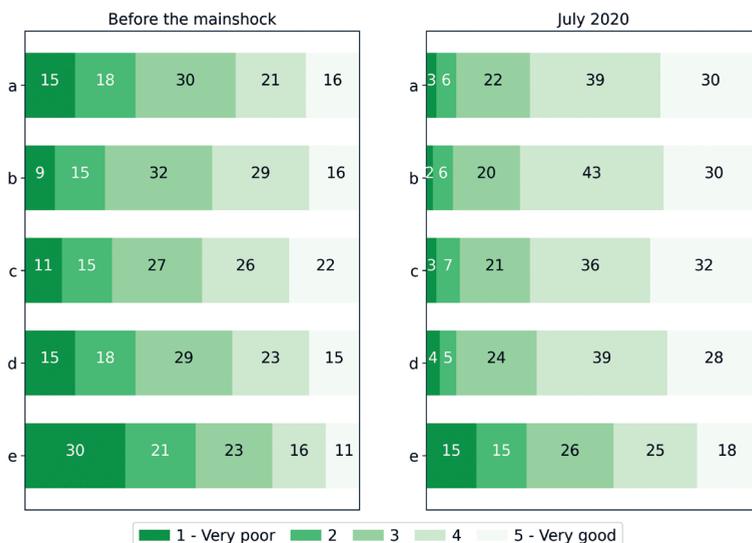


Figure 7. Self-assessed level of knowledge on five aspects of earthquake preparedness (*left column*) before the 22 March 2020 event and (*right column*) in July 2020 on a scale from 1 (very poor) to 5 (very good). The aspects are: (a) Earthquake resistance of your home, (b) Behaviour during an earthquake – indoors, (c) Behaviour during an earthquake – outside, (d) Behaviour after an earthquake and (e) Emergency assembly points.

earthquake with a median of 60%, but their uncertainty was lower as the lower and upper quartile were 27.5% and 81%. We do not correlate results obtained for these two questions with the remaining questions, as we consider the topic too complex for a simple analysis and beyond the scope of this research.

In the five questions related to earthquake preparedness, respondents were asked to grade their knowledge before the event, and at the time of responding to the survey (Fig. 7). As it is difficult to estimate their knowledge, we considered that the comparison of these time periods could aid in critical self-assessment and provide information on whether the knowledge improved after the mainshock. The interviewees assessed their knowledge of earthquake resistance of their homes, on the behaviour during an earthquake (indoors and outdoors), on the behaviour after an earthquake, and on emergency assembly points. For the first four questions, most respondents considered they had fair or above-average knowledge before the event, and approximately one value more (on a scale from 1 to 5) at the time of the response to the questionnaire. Median of their answers increased from 3 (fair) to 4 (above-average), and these values are the same for male (Fig. S6) and female (Fig. S7) respondents. Their knowledge of emergency assembly points was mostly very poor (30%), fair (23%), or below-average (21%), with a median of fair, before the earthquake, and increased to fair (27%), above-average (25%) or very good (18%), with a median of above-average afterwards.

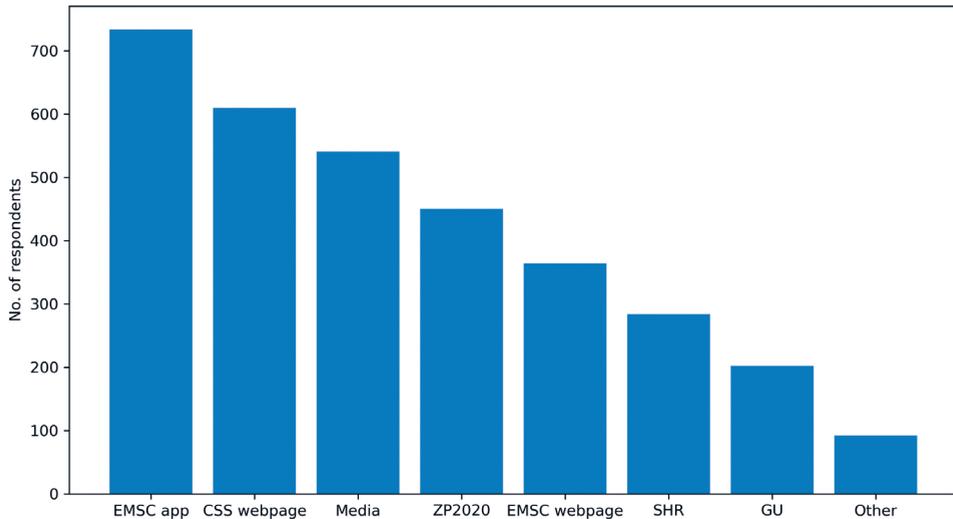


Figure 8. Main sources of information about earthquakes for survey respondents.

The main sources of information about earthquakes for most respondents (Fig. 8) were institutional: EMSC application (22%) and CSS webpage (19%). Approximately 17% of interviewees used media articles as a source of information, while 29% relied on the Department of Geophysics social media (ZP2020, SHR and GU combined). Multiple choice answers were possible in this question so there is some overlap in the answers. Male respondents used the media more than the CSS webpage, placed ZP2020 after the EMSC webpage and SHR, and relied on other sources of information more than on GU (Fig. S8). Expert sources are more predominant in this survey group than for a somewhat smaller group of Italian students interviewed by Musacchio et al. (2016), for whom the television was the main (33%) source of information.

The respondents were asked to rank eight topics by their interest when they are informing themselves about earthquakes. The topics in this question were graded by giving a maximum of eight points to the first answer, seven points to the second one, and one point less for each following answer for each respondent. To get the final ranking for each topic, the number of points was summed up for all respondents. The interviewees were mostly interested in notifications on occurring earthquakes, followed by information on damage and earthquake-resistant structures, and directions for earthquake preparedness (Fig. S9). The next four topics by interest were: interviews with seismologists in the media, information on historical earthquakes, interaction with other people that experienced earthquakes, and popular-science articles about earthquakes. Sharing their own experience and reading advice on mental health were valued the least. A number of previous studies (e.g. IRFC 2005; Veer et al., 2016; Bossu et al., 2018) have

found that people value sharing their experience of an earthquake highly. For our respondents, that answer received about half points of the first one, *i.e.* it was valued less. Possible reasons for this discrepancy are the way the question was formulated, the demographic and education structure of our respondents, and the fact that discussions were mostly deleted in the ZP2020 group to leave only comments with macroseismological data.

When asked to consider where they have learnt the most about earthquakes, the respondents ranked highest 1) the national expert sources of information, 2) web portals, 3) media (TV, radio and newspapers) and 4) foreign expert sources of information, followed by 5) school, 6) friends and family, 7) social networks, and 8) their university or job (Fig. S10).

In a series of questions, respondents were asked to consider if they agree whether certain aspects help to reduce the feeling of earthquake-related discomfort (Fig. 9). The main positive factors for the respondents were the support of their close ones (overall agreement for 81% of the respondents), information given by seismologists in Croatia (69%) and the EMSC app (58%). Information given by seismologists in the neighboring countries largely had a neutral effect (37%), as well as the information given by the national institutions such as the

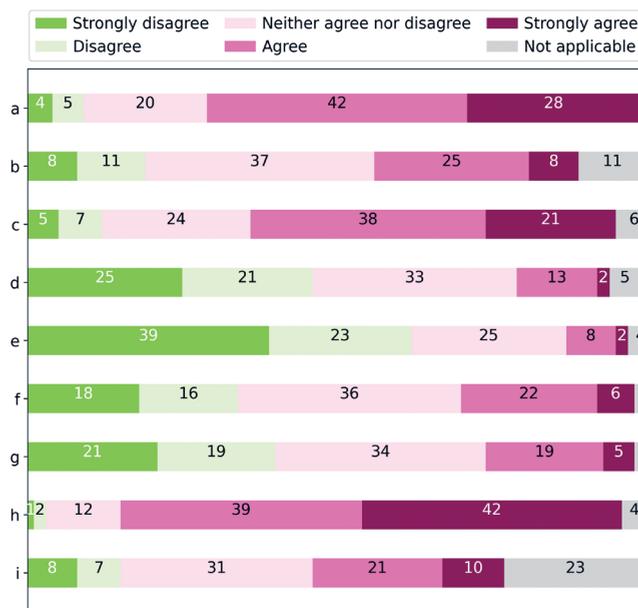


Figure 9. Responses to a series of questions on factors helping to reduce earthquake-related discomfort. The factors are: (a) Information given by seismologists in Croatia, (b) Information given by seismologists in the neighbouring countries, (c) EMSC app, (d) Information given by the city administration, (e) City administration procedures, (f) Information given by the national institutions, (g) National institutions' procedures, (h) Support of close ones, and (i) Professional psychological support.

Civil Protection Directorate and the government (36%). Most of the respondents did not agree that actions taken by the national institutions (40%), information given by the city administration (46%) and actions taken by the city administration (62%) helped to reduce their discomfort. Support of their close ones had a somewhat lower effect on the male respondents, 74% agree that it helped to reduce the discomfort, but only 32% of them strongly agree (Fig. S11), as opposed to 45% female respondents who strongly agree (Fig. S12).

Out of the 1,330 poll respondents, 555 of them (42%) considered the GU Facebook page and/or the ZP2020 Facebook group as a main source of information and were asked a few additional questions. Female to male ratio in this group of respondents was even higher (85% females and 15% males). The majority (79%) thought that the group/page was adequately moderated (Fig. S13). About a third of these respondents did not share their experience in the group/page, 30% of them shared to see if others had a similar experience, 24% shared their experience as a contribution for seismologists, while 13% considered that sharing the negative experience of experiencing an earthquake calmed them (Fig. S14). The Facebook group/page was helpful in informing 78% of these respondents (Fig. S15), helpful to check if the shaking they felt is real for 73% of them (Fig. S16). The majority (59%) of these interviewees thought that it was helpful to deal with feelings of stress and discomfort, and it had a neutral effect for 31% of them (Fig. S17). It was less helpful for male respondents when checking if the shaking they felt is real (62%) and to deal with discomfort (44%). The group/page was even unhelpful for 19% of them in both cases.

4. Lessons learned

The intensified activity of all the Department of Geophysics social network accounts is yet another example of citizens' thirst for information following a stressful situation, such as a damaging earthquake. Similar engagement of the public, with a sudden jump after a natural hazard event and a slow but steady increase afterwards, was previously noticed by EMSC (Bossu et al., 2018; Steed et al., 2019) and USGS (Poland, 2019). Citizens' comments were initially mostly negative, but providing relevant information constantly and consistently turned out to be a key to calm the responses and improve trust towards the information provider. The disadvantages of social media, such as spread of misinformation (Young et al., 2013) and occasional hate speech (Tomisa et al., 2019), were monitored and controlled in the ZP2020 Facebook group with extensive moderation. Facebook group users predominantly considered the amount of moderation to be adequate.

Some citizen feedback was immediately used to improve the way the information is presented (*e.g.* providing images of relevant material on earthquake preparedness, instead of links to existing material in pdf format). Frequently asked questions were collected by group administrators and a journalist,

answered, and made available on the Department of Geophysics website (https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/o_potresima/odgovori_na_pitanja_o_potresima). Citizen activity was a strong motivation to release various reports on the Department of Geophysics website. The website was substantially augmented with information on historical seismicity of the area, a map and a video of the aftershock activity, information given by experts on geology, geodesy and tectonics, interviews with seismologists in the media, and popular science articles published elsewhere (e.g. most information in https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/o_potresima and a new website section https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/o_zagrebackom_potresu_2020). The fact that information given by Croatian seismologists had a positive effect in reducing earthquake-related discomfort for more citizens than information given by any other institution (Fig. 7) shows the importance of providing timely educational materials in the native language.

A large number of people (hundreds in the ZG2020 group and tens of thousands through the EMSC application) reported feeling earthquakes of magnitudes even below 1,0 in the weeks and months after the mainshock. This could be a consequence of the loud rumbling, thunder-like sound that followed a significant number of seismic events, and also of the COVID-19 lockdown. The lockdown caused a reduction in seismic noise throughout the world (e.g. Gibney, 2020), aggravated and delayed repairs in the affected areas, significantly reduced traffic and urban noise, and left the citizens, who stayed largely indoors, more opportunity to notice the aftershocks.

Our approach in monitoring and moderating social networks after a natural hazard required nearly non-stop activity (also in free time), constant monitoring of members' comments, and clear and strict group rules to avoid the spread of misinformation and conflicts between citizens. This was done by three seismologists who participated in a number of popular science events, out of which two had experience with administrating and creating posts on the GU Facebook page, and one of them had very limited experience with the SHR Twitter profile. None had experience in Facebook group moderation. Since we did not have formal training for this kind of a situation, moderating social networks required substantial effort, and a great deal of improvisation. The results were favourable in reducing earthquake-related stress to most of the survey respondents, but considering the high level of education of the respondents compared to the general population, it is questionable how large the effect was on the entire population.

Rapid increase in the number of followers on social networks after a hazard event can be used “to make scientific knowledge an integral part of social knowledge” (Martin and Peppoloni, 2017), especially for an organization with limited resources. However, preparing educational materials, technological solutions and a plan of action for a hazard event in the “peacetime” could significantly reduce the effort and the stress caused by working with a large number of people. Citizen comments and insights gained in moderating the social network accounts

after the 2020 Zagreb earthquake can help to prepare user-friendly and approachable materials.

The survey conducted in July 2020 confirmed the high level of worry amongst citizens on the day of the mainshock, mostly because of concern of a stronger future earthquake and safety of their close ones. The respondents were mostly interested in information about occurring aftershocks, damage and earthquake-resistant structures, and directions for earthquake preparedness. Their knowledge on different aspects of earthquake preparedness had increased. Support of their close ones, information given by seismologists in Croatia and the EMSC application were most beneficial in reducing the earthquake-related discomfort.

Acknowledgements – We would like to thank Ivan Flis from the Department of Psychology at the Catholic University of Croatia, Zagreb for his help in making, uploading and distributing the online survey, members of the ZP2020 Facebook group and other citizens who completed the survey. We also thank two anonymous reviewers who helped to improve the manuscript.

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SAŽETAK

Odziv javnosti i edukacija javnosti pomoću društvenih mreža nakon potresa u Zagrebu 22. ožujka 2020.

Marija Mustać, Iva Dasović, Helena Latečki i Ina Cecić

Nakon potresa 22. ožujka 2020. godine lokalne magnitude M_L 5.5 s epicentrom nedaleko Zagreba, Hrvatska, pojačao se interes građana za potrese i velik broj istovremenih posjetitelja doveo je do pada internetske stranice Seizmološke službe s izvješćima o potresima. Kako bi osigurali nekakav kanal za informiranje javnosti, seizmolozi su se poslužili društvenim mrežama, koristeći pritom priliku da educiraju građane o osnovnim konceptima seizmologije, pripremljenosti za potres i seriji potresa koji se događala. Povratne informacije građana iskorištene su za poboljšanje načina komunikacije. Neki od korištenih računa su zahtijevali strogo moderiranje. U srpnju 2020. godine, tri seizmologinje s Geofizičkog odsjeka Prirodoslovno-matematičkog fakulteta Sveučilišta u Zagrebu, jedna iz Agencije za okoliš Republike Slovenije i psiholog s Hrvatskog katoličkog sveučilišta proveli su anketu kako bi saznali koje izvore informacija o potresima građani najčešće koriste, kakvo im je znanje o potresima i koliko su zbog njih zabrinuti. Anketa je pokazala da se većina ispitanika oslanjala na institucionalne izvore informacija, a njihovo znanje o različitim aspektima pripremljenosti za potres poraslo je u odnosu na vrijeme prije potresa. Većina ispitanika bila je izrazito zabrinuta na dan glavnog potresa, ponajviše zbog mogućnosti jačeg potresa, svoje sigurnosti i sigurnosti svojih bližnjih.

Ključne riječi: Zagrebački potres 2020., društvene mreže, informiranje javnosti, zabrinutost zbog potresa, pripremljenost za potres

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