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What defines the success of maps and additional information on a multi-hazard platform?

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ABSTRACT

Triggered by technical progress that has allowed for the combining of information about natural, anthropogenic and socionatural hazards, numerous multi-hazard platforms have been established over the last years. Despite their increasing use, surprisingly, little research has been conducted evaluating how the public perceives of the hazard information provided by these multi-hazard platforms. Because most of them use maps on the start page, we were especially interested in the different approaches towards presenting multiple hazards and towards compiling the contents of the hazard announcements attached to the maps. With an online conjoint choice experiment (N = 768, fully randomised design), we tested different start page designs and hazard announcements representing the diversity of elements used in multi-hazard platforms. The alternatives were randomly displayed as pairs to the participants (between-subjects design), asking them to first rate the alternatives separately and then to choose which of the two they preferred. Our main results are that the participants prefer a start page consisting of a single map with textual information about the current hazards below the map. In addition, they prefer hazard classifications with four or five hazard categories. Moreover, the participants appreciate the embedding of a sharing function in the hazard announcements. Finally, the participants prefer a combination of textual and pictured behavioural recommendations. To conclude, the results indicate that the design of information provided on multi-hazard platforms indeed affects the public's preferences. Therefore, in parallel to the continuous improvement of scientific-technical products, the communication and perception of these products should be systematically examined too.

1. Introduction

Earthquakes pose a major threat to many countries. Of all the natural hazards, worldwide, earthquakes cause the most fatalities and financial losses [1]. Additionally, despite various efforts, the actual preparedness levels of societies remain universally low [2,3]. Several studies have concluded that the information for preventing and limiting damage from hazards is available but has limited use if not correctly applied and broadly shared. As a result, the threats of many disasters are made worse by a lack of coordination between authorities and an ineffective communication among authorities and the public [4,5].

In Switzerland, catastrophic earthquakes are characterised by a low probability and a high impact and are not predictable. This is one of the reasons why most of the Swiss population is not prepared for earthquakes and why the population underestimates the potential damage of them. For the responsible authorities, it is a key challenge to make sure that the information provided about low-probability and high-consequence hazards has an impact [6], namely, that people know how to react in the case of a (impending) hazard. Additionally, the right choice of an effective communication channel is vital: the responsible authorities must aim to inform and warn as many people affected by a hazard as possible.

A relatively new approach is communicating information about earthquakes or other low-probability hazards in a multi-hazard context [7]. Because of the synergies among different hazards, communicating earthquake information in a multi-hazard context could be more effective. For example, compatible and consistent maps and announcements among the different hazards might facilitate non-experts' ability to handle the information presented them. People are already familiar with the weather announcements they frequently receive and, thus, should be

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able to better handle announcements of rare hazards. Furthermore, in many situations, the first hazard triggers other hazards, and via a multi-hazard platform, all relevant information can simultaneously be spread [8]. A further advantage is that people only have to visit one website or download one app to stay informed about the situation of the hazards included in the app.

Besides the advantages of a multi-hazard approach, there are also some technocratic challenges: (i) the absence of common methodologies and classifications for different hazard types (ii) a limited comparability of hazardous events (e.g., return periods, predictability); and, thus, limited harmonised representation; and (iii) the lack of cooperation among the institutions involved [9–11].

Moreover, the usefulness of multi-hazard platforms for the public is influenced by various demographic, cognitive, normative and social factors. For example, a low risk perception and missing sense of self-efficacy can prevent people from taking action when receiving warnings [12]. Furthermore, people's numeracy skills determine whether they understand probabilities or not [13]. In addition, the public's trust in authorities affects whether they respond to warnings or simply ignore them [14,15]; not to mention, people who have already experienced a disaster are better prepared and able to react immediately to warnings [3,14,16].

Previous studies have mainly focused on the technical capabilities regarding the implementation of multi-hazard platforms [11,17]. However, questions regarding the end users' perspectives of multi-hazard platforms also arise. Is the information presented correctly understood by the receivers? Which information content do the users prefer? Are people overwhelmed with all the information about the different hazards combined on one platform? Even if information about earthquakes and other hazards is embedded in weather apps frequently used, do the users even look at this information? Which individual characteristics influence their preferences for and ability to handle information provided on multi-hazard platforms? Surprisingly, little research has been conducted evaluating these questions [18,19].

Therefore, we conducted a case study in Switzerland to fill this research gap by assessing the public's preferences and needs for information and warnings presented in a multi-hazard environment. To this end, we applied an online conjoint choice experiment, which is also known as a stated preference choice experiment [20,21]. In our experiment, consecutive pairs of specially designed start pages and hazard announcements were randomly displayed to each participant. First, the participants rated them separately before having to choose which of the two they preferred. This method allowed us to simultaneously assess the influence of multiple attributes on the public's preferences for information provided on multi-hazard platforms.

2. Multi-hazard platforms

Worldwide, there are different approaches towards the design of multi-hazard platforms. All these approaches try to communicate (scientific) information that is comprehensible, timely, feasible and consistent to everyone in society, to encourage them to stay informed and to take (precautionary) action, if needed [22]. However, they contain different information and functionalities, ranging from hazard descriptions to behavioural recommendations through disaster toolkits, hazard maps, quizzes, emergency plans, chat forums, blogs and so forth (Table S1 in the Supplement). In addition, the platforms variously attempt to communicate among the phases of a hazard, ranging from long-term to real-time information. We identified that on the start page of most platforms the current hazards are displayed on maps, with additional hazard information attached to the areas affected by a hazard [23]. Therefore, we focused on the start page designs and the announcements attached to the maps. A further reason why we focused on the start page was that users often do not go beyond that page and that the most important information is displayed on the first page. Additionally, the long-term hazard map for Switzerland was already tested [13], and thus we focused on how to best design maps for short-term and real-time hazard information.

2.1. Start page designs

Maps are a prominent element of most multi-hazard platforms (see a selection in Fig. S1 in the Supplement). The use of maps to illustrate hazards has several advantages. First, maps allow for the hazard to be visualised across an entire region [9]. Second, if well designed, graphics can lead to greater risk avoidance than numerical risk representations [6,24]. Third, maps can be understandable for those who do not speak the language in which the textual message is issued [14]. Fourth, maps visualise who should and should not take protective action [25]. However, hazard maps are mainly designed for experts but are often also used to communicate with non-experts who may be unable to intuitively understand the information provided [26,27]. This can cause barriers in hazard and risk communication by leading to inappropriate decisions and actions by people.

There are two main formats for presenting hazard information on the maps of multi-hazard platforms: single and multiple maps. Most only use one map to depict the different hazards. In comparison, some platforms – especially those including only weather-related hazards – offer both a single map displaying all hazards and separate maps for each hazard. What is true for all platforms is that in the case of an (impending) hazard, the hazardous regions are coloured according to a corresponding hazard category. In addition, an icon for the hazard is displayed in the coloured area. This allows people to recognise at first glance which area is affected and which hazard is affecting the area.

The hazard classifications and icons differ among the platforms. The classifications differ in terms of the number of categories, colour schemes and category names. The hazard categories are mainly either defined as 'alert, warning or information', 'no or low hazard, moderate hazard, considerable hazard, severe hazard, very severe hazard' or 'considerable hazard, severe hazard, very severe hazard'. So, the number of categories ranges from three to five. Additionally, the colour schemes used are quite similar ranging either from green to red or from yellow to red. However, within most platforms, the categories are harmonised for the different hazards. In comparison, the icons for the hazards look quite similar and only slightly differ among the platforms.

In addition, some of the platforms provide – either below or beside the start page map – further textual information. This information is mainly about ongoing or impending hazards, the area affected and the time (e.g., earthquake occurred) or duration (heatwave period), respectively. The other platforms only show pictograms of ongoing hazards or do not contain any directly visible, textual information related to the map content. Some of them provide further information when users click on the icons presented on the map. This issue will be discussed in Section 2.2.

2.2. The content of hazard announcements

On most multi-hazard maps, users can click on the hazard icons displayed on the map. After clicking on the icon, a subpage or information box with a hazard announcement pops up. In general, those hazard announcements contain the following information: hazard, location, guidance, time and source [25]. In addition, some of them also include information about the possible impacts [28], emergency numbers or triggered hazards. However, we know little about which of those elements people prefer. In our study, we focused on the two elements: 'format of behavioural recommendations' and 'sharing function', which are increasingly embedded in announcements but have not been evaluated yet.

It is commonly agreed that hazard announcements should include instructions about the recommended behaviour for users [7,29]. So far, behavioural recommendations have mainly been included in text format. However, Bossu et al. [30] uses pictured behavioural recommendations on the EMSC app (LastQuake) to inform users what to do during an earthquake. This minimises language barriers and is intended to ensure a rapid understanding of the behavioural recommendations. In addition, graphical displays attract and hold people's attention better than textual information [31], which might increase their motivation to act. However, unclear, unfamiliar and complex graphical displays can lead to misunderstandings [31]. Moreover, graphical displays should not present more information than what is required for the purpose of the display [32].

The number of individuals using social media – especially Facebook and Twitter – via smart phones and tablets is constantly increasing [33, 34]. Social media use by the public to share information about (impending) hazards of all kinds is also more and more recognisable [35, 36]. In addition, Bossu et al. [30], for example, show that the first thing people want to do after having received a hazard announcement is to inform their family members and friends. Therefore, the need to be able to share hazard announcements via social media might already be there or increase in the future.

2.3. Research questions

Triggered by the technical progress that allows for the combination of information about natural, anthropogenic and socionatural hazards, numerous multi-hazard platforms have been established over the last years. Previous studies have mainly focused on the technical capabilities regarding the implementation of multi-hazard platforms. Therefore, we still have to explore whether those platforms are actually used by the public or not and what preferences they have. Moreover, a better understanding of how the public perceives the different hazard information provided on those multi-hazard platforms is lacking. Because most multi-hazard platforms use maps on the start page, we are especially interested in the different approaches towards presenting multiple hazards and towards compiling the contents of the hazard announcements attached to the maps. Hence, with our study, we aim to answer the following three research questions:

(i) Does the public prefer and actually use multi-hazard platforms to get information about the current hazard situation?
(ii) Which elements of the start page design does the public prefer, correctly interpret and perceive as useful?
(iii) What contents of the hazard announcements attached to the maps on start pages does the public prefer?

3. Material and method

3.1. Conjoint choice experiment

To compare and contrast the public's perception and preferences, we applied an online conjoint choice experiment based on a paired-profile design. Choice experiments were first developed in marketing research in the 1970s [37] and are now also applied in other research fields, such as health [38], food consumption [39] and political science [40]. In general, participants are put in a hypothetical choice situation in which they are confronted with bundles of relevant product attributes [41]. The levels of these attributes are varied randomly across participants and tasks, allowing for an estimation of the relative importance of each attribute [42]. By observing the stated preferences regarding the alternatives presented, it is possible to examine the relevance of certain product attributes and their characteristics to individual choices. Compared with single-profile designs, paired-profile designs induce more engagement and less satisficing among participants, maximising the external validity about real-world causal effects [42].

3.2. Start page designs and hazard announcements developed for the conjoint choice experiment

We developed twelve different start page designs (Table S2 in the Supplement) and eight hazard announcements (Table S3 in the Supplement) representing a hypothetical hazard situation in Switzerland. They are representative of the different international approaches of combining multiple hazards on a single platform (see Section 2). In Table 1, the attributes we varied for the different alternatives are listed. When selecting and varying the attributes, we followed both current practice in different fields and best practice from research (see Sections 2.1 and 2.2).

Regarding the twelve start page designs, the same hazards were either presented on separate maps or combined on a single map. Furthermore, we defined three hazard classifications by varying the number of categories, the names of the categories and the colour used. Moreover, half of the start page designs contained textual information below the map (hazard type, hazard category and locations affected). The other half only contained an icon bar with pictograms of the current hazards below the map (single maps) or an icon in the left upper corner of the map (separate maps).

Regarding the eight hazard announcements, four informed users about an earthquake, and four issued a thunderstorm warning. We chose

Table 1
Attributes that were varied for the start page designs and for the hazard announcements, respectively (first column). When selecting and varying the attributes, we followed both current practice in different fields and best practice from research (see Sections 2.1 and 2.2). In the second column, the levels of each attribute is described in detail. In the third column, some examples of the platforms with corresponding attribute levels are listed (see also Table S1 in the Supplement).

Start page designs		
Attribute	**Levels**	**Examples of platforms**
Map format	1. Single map displaying all current hazards 2. Separate maps for each current hazard	1. HungerMap, Disaster Alert 2. Vigilance météorologique, ThinkHazard
Hazard classification	1. Three categories: considerable hazard/severe hazard/very severe hazard (orange/red/dark red) 2. Four categories: information/warning/alert/all clear (blue, orange, red, green) 3. Five categories: low hazard/moderate hazard/considerable hazard/severe hazard/very severe hazard (green, yellow, orange, red, dark red)	1. Global Disaster Alert and Coordination System 2. AlertSwiss, KATWARN 3. Natural Hazards Portal, MeteoSwiss, WIND
Additional information (around the map)	1. List with textual information (hazard type, hazard category and location) below the map 2. Pictograms of the current hazards below the map (single maps) or in the upper left corner (separate maps)	1. Disaster Alert, AlertSwiss 2. WarnWetter, MeteoSwiss
Hazard announcements		
Attribute	**Levels**	
Behavioural recommendations	1. Textual 2. Pictured	1. NINA, AlertSwiss 2. LastQuake, First aid app
Sharing function	1. Available 2. Not available	1. FEMA, LastQuake 2. On most

these two hazards to test unpredictable and predictable hazards and a more versus a less familiar hazard. We further varied whether the behavioural recommendations were textual or pictured. For this, we used the official statements and pictograms of the Swiss National Emergency Operations Centre (NEOC). Furthermore, on half of the announcements, it was possible to share the information with family members and friends via Twitter, WhatsApp or Facebook (sharing function). The announcements were reviewed for plausibility by an expert of the responsible federal institutions, the Swiss Seismological Service at ETH Zurich and MeteoSwiss.

3.3. Structure of the survey

The online survey consisted of five question blocks: (i) use of communication channels; (ii) start page designs; (iii) hazard announcements; (iv) cognitive and normative factors; and (v) sociodemographic data (Fig. 1). The survey can be found in Fig. S2 in the Supplement.

The first question block started with a description of a hypothetical situation in which the readers were exposed to multiple hazards. Based on this, they were asked which communication channels they would consult to get information about the (impending) hazards. Further questions assessed whether the participants knew and used multi-hazard apps or whether they could imagine using one in the future or not. Additionally, participants had to indicate which hazards they would combine on a multi-hazard app (open question). For the analysis, we categorised the hazards mentioned by the participants into natural, anthropogenic and socionatural hazards [43].

The second question block assessed which start page designs people preferred; this was done by conducting a conjoint choice experiment. Therefore, three consecutive pairs of different start page designs were randomly displayed. With 768 study participants, this led to 4608 observations (2*3*768). The participants were first asked to separately rate the two start page designs – presented side by side – on a scale of 1 (would not use it) to 5 (would use it). Afterwards, they had to indicate which of the two they preferred. Also, as part of this question block, we assessed whether the maps were interpreted correctly and whether they were perceived as useful. For this purpose, the participants randomly received one of the twelve start page designs. Their interpretation abilities were measured with three items that asked the participants if, at a specific location on the map, they have to be prepared for an earthquake, thunderstorm or heatwave. The answer possibilities were yes, no and do not know. The usefulness was measured with three items asking the participants if they understand to which hazards they were exposed to at the moment, if they would seek further information and if they would take (precautionary) actions. The scale ranged from 1 (strongly disagree) to 5 (strongly agree), showing good internal consistency regarding the summative scores across all three items (Cronbach's alpha = 0.80, N = 3).

In the third question block, again, a conjoint choice experiment was conducted. The participants randomly received one pair of earthquake announcements and one pair of thunderstorm warnings. With 768 study participants, this led to 3072 observations (2*2*768). Equal to the second question block, the participants first separately rated the announcements – presented side by side – on a scale of 1 (would not use it) to 5 (would use it); afterwards, they chose which of the two they preferred. In addition, they indicated which setting options for receiving such announcements they would like to have.

The fourth question block covered the four cognitive factors 'hazard experience', 'risk perception', 'trust' and 'numeracy skills'. To measure *hazard experience,* the participants were asked whether they had already experienced the following hazards with substantial negative impacts: earthquake, forest fire, storm, heat wave, pandemic, animal epidemic, power failure and chemical or nuclear plant accident [44]. These are the main hazards identified by the Federal Office for Civil Protection (FOCP) as the ones causing most damage in Switzerland [45]. The summative scores across the nine items showed an acceptable internal consistency (Cronbach's alpha = 0.76, N = 9). *Risk perception* was measured with the following question: 'Natural, socionatural and anthropogenic hazards (such as, for example, the ones in the previous question)…' (a) endanger my personal safety; (b) endanger the safety of my family; (c) limit my quality of life; (d) are difficult for me to control; (e) cause financial losses for me; and (f) cause a general fear in me' [46]. We used a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) [47], showing good internal consistency regarding the summative scores across the six items (Cronbach's alpha = 0.86, N = 6). *Trust* was measured with the following question: 'How much confidence do you have in the following authorities'? The list of authorities was compiled based on the main involved actors providing information and issuing warnings via multi-hazard platforms in Switzerland. The scales for this assessment ranged from 'no trust' (1) to 'high trust' (5) [48]. The scale yielded good internal consistency for the summative scores across all items (Cronbach's alpha = 0.81, N = 5). The participants' *numeracy skills* were measured with four items based on Fagerlin et al. [49], where they had to indicate if certain mathematical operations are very easy (1) for them or very difficult (5), showing excellent internal consistency for the summative scores across all items (Cronbach's alpha = 0.94, N = 4).

The last block contained questions about the participants' sociodemographic data: gender, age, educational degree, employment and residential canton. An open item asked for final questions and remarks.

3.4. Sample

In total, 810 participants who were recruited from the German-speaking part of Switzerland completed the online survey from November 18 to November 28, 2019. They were recruited by Respondi, an online access panel provider. We used quota sampling with the quotas based on age and gender, representing the average population of

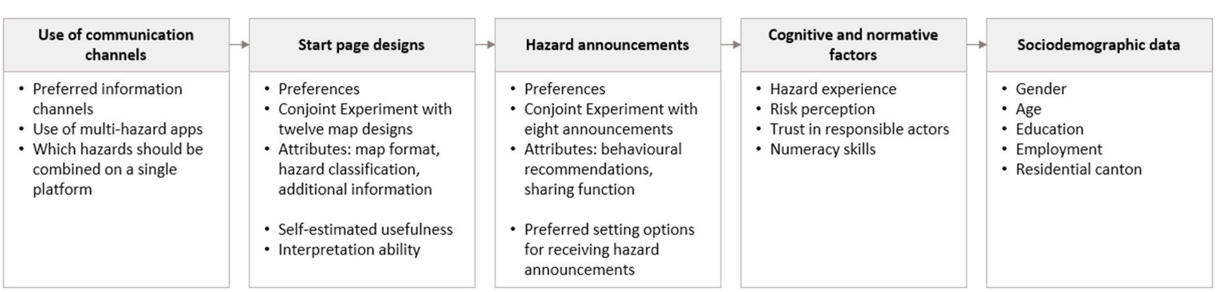

Fig. 1. Structure of the survey. The survey consisted of five question blocks. As part of the second and third question blocks (start page designs and hazard announcements), we applied conjoint choice experiments. Regarding the start page designs, to each participant, three consecutive pairs of different start page designs were randomly displayed. First, they had to rate them separately before having to choose one of them. Regarding the hazard announcements, each participant received a pair of earthquake announcements and a pair of thunderstorm warnings. As before, they first rated them separately before indicating which of the two they preferred.

Switzerland. Because of unrealistic short answering times (below 5 min), 42 participants were excluded from the analysis, leading to 768 participants. The participants ranged in age from 18 to 69 years (M = 44.10, SD = 14.24), and 58% were female. The percentage of females is a bit higher than the Swiss average [50] because the excluded short-answer participants were mainly men. Furthermore, most participants had a federal diploma (18.4%), completed university (14.7%), vocational school (14.7%) or an apprenticeship (14.8%), representing quite well the average distribution of the Swiss populations' educational degrees [51]. Most participants worked full-time (46.7%) or part time (21.5%).

3.5. Analysis

For the statistical analysis of the quantitative data, we used R, especially the package cregg [52]. For the qualitative data, we used NVivo [53]. Three-way analyses of variances (ANOVAs) were conducted to analyse the effects of the three attributes 'map format', 'hazard classification' and 'additional information' on the participants' preferences, interpretation abilities and perceived usefulness of the start page designs. Furthermore, for the analysis of the hazard announcements, two-way ANOVAs were conducted to assess the effects of the two attributes 'behavioural recommendations' and 'sharing function' on the participants' preferences. In a next step, ANOVAs were carried out to include the covariates hazard experience, risk perception, numeracy skills and trust, along with the control variables gender, age, educational degree and living residence.

We were able to apply a fully randomised design because all combinations of attribute levels were possible [41,42]. We identified no carryover effects ($p = 0.19$), so the outcomes across the choice tasks were stable, and the treatment given to a participant in her/his other choice tasks did not affect her/his response in the current task. Additionally, the ordering of the alternatives within a choice task did not affect the responses ($p = 0.10$) [20].

4. Results

4.1. Preferences for communication channels

The participants prefer to stay informed and receive information about the current hazards via a single website or app, respectively. The traditional communication channels radio and television are also highly appreciated. Less preferred are separate websites and separate apps for each hazard and information dissemination via social media (Table S4 in the Supplement).

About 32.3% percent of all participants indicate that they know at least one multi-hazard app. Of those, only 11% often and 60% rarely use multi-hazard apps, which are mainly weather apps such as MeteoSwiss. Most participants not yet using an app could imagine using one in the future.

On a multi-hazard platform, the participants would include information about natural hazards (1277 mentions) followed by socionatural (425 mentions) and anthropogenic hazards (89 mentions). In their answers, they mainly combine natural and socionatural hazards. With respect to the natural hazards, they would prefer information about severe weather events in general, thunderstorms, floods, earthquakes, snow avalanches, snowfall, rockslides and so forth. The socionatural hazards mentioned are mainly traffic issues (e.g., accidents), industrial and chemical accidents, disturbances of public transport, water pollution, power outage, terrorist attacks, stampedes and riots and killing sprees. Lastly, anthropogenic hazards, such as urban fire, air pollution, diseases and siren alarm testing, are mentioned, too.

4.2. Preferences for start page designs

4.2.1. Influence of the attributes map format, hazard classification and information added around the map

The results of the separate rating show that the three attributes 'map format', 'hazard classification' and 'additional information' significantly influence participants' preferences for certain start pages (Fig. 2). A single map is better rated than separate maps for the same hazards. In addition, Tukey *post hoc* testing reveals a significant preference for maps with the hazard classification with the five hazard categories over those with only the four or three categories, respectively. Additionally, maps with the hazard classification with the four hazard categories are significantly better rated than those with only the three categories. Moreover, the designs, including textual information about the current hazards below the map, are preferred over those with only pictograms of the current hazards.

A significant interaction effect between the attributes 'map format' and 'additional information' is present, too ($p = 0.02$). When the hazards are displayed on a single map, the start page designs containing textual information below the map are better rated than those with only an icon bar with the hazard pictograms below the map. This difference in preference regarding the inclusion of textual information below the map is significantly smaller when the hazards are displayed on separate maps.

The forced choice task shows the same results as the separate ratings but with one difference (Table S7 in the Supplement). The preference for the hazard classification with five hazard categories over those with four categories is not statistically significant.

4.2.2. Interpretation and perceived usefulness of the information presented

Most participants (66.8%) answer the question about the earthquake wrong. We asked them whether they should be prepared for an earthquake in Basel (no earthquake was currently mapped at that location). The answer would be 'yes' because Basel is a comparably earthquake risky area in Switzerland, and people should always be prepared for an earthquake there. In comparison, most of them correctly answer the questions for thunderstorms (78.4%) and heatwaves (87.11%) (Table S9 in the Supplement).

The participants indicate that they are more motivated to seek further information (M = 3.80, SD = 0.06 vs. M = 3.55, SD = 0.06; $p = 0.003$) and to take (precautionary) actions (M = 3.75, SD = 0.06 vs. M = 3.48, SD = 0.06; $p = 0.001$) when the hazards are combined on a single map compared with separate maps for each hazard. In comparison, there is no significant difference between a single map and separate maps regarding the participants' self-estimated understanding of the current hazard situation (Table S12 in the Supplement).

4.2.3. Influence of the cognitive factors and the sociodemographic characteristics

The four cognitive factors influence participants' preferences, perceived usefulness and interpretation abilities of the start page designs (Tables S6, S8, S11 and S12 in the Supplement). The participants with high levels of *trust in actors involved in the communication process* rate the start page designs in general more favourably ($p < 0.001$), are more motivated to seek further information ($p < 0.001$) and are more likely to take (precautionary) actions ($p < 0.001$) compared with the participants with low levels of trust. The participants with high levels of *risk perception* rate separate maps (M = 3.67, SD = 0.03 vs. M = 3.36, SD = 0.05, $p < 0.001$) more favourably but perceive single maps as more useful (M = 4.01, SD = 0.06 vs. M = 3.63, SD = 0.11, $p < 0.001$) compared with participants with low levels of risk perception. In addition, those with high levels of risk perception prefer the hazard classification with the four hazard categories 'alert, warning, information and all clear' and the colour scheme blue-orange-red-green (M = 3.82, SD = 0.04 vs. M = 3.50, SD = 0.07, $p < 0.001$). Furthermore, the participants who have not *experienced* any hazard yet tend to more often answer the

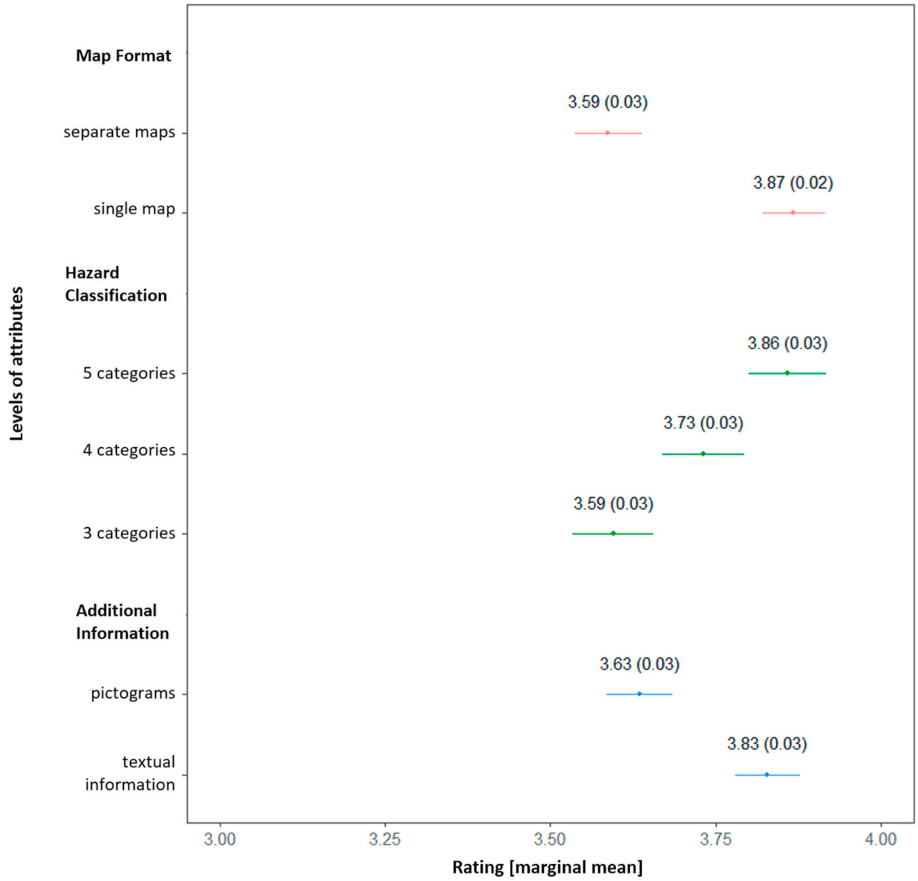

Fig. 2. Separate rating of the start page designs. The numbers above the lines are the marginal means and the standard deviations (in brackets). The horizontal bars represent the 95% confidence intervals. The scale for the rating is from 1 (would not use it) to 5 (would use it). The corresponding statistical test can be found in Table S5 in the Supplement.

interpretation questions – especially the one for earthquakes – wrong ($p = 0.03$). Finally, the participants with high *numeracy skills* answer more interpretation questions correctly ($p = 0.008$).

The participants' sociodemographic characteristics also influence the preferences for certain start page designs (Tables S6, S8, S11 and S12 in the Supplement). Men rate all start page designs in general better compared with women, regardless of the different attribute combinations ($p = 0.04$). Furthermore, housewives and househusbands prefer the designs with a single map over those with separate maps for each hazard ($M = 3.67$, $SD = 0.03$ vs. $M = 3.36$, $SD = 0.05$, $p < 0.001$). The same applies to those in education with remuneration, for example, doctoral students ($M = 3.68$, $SD = 0.15$ vs. $M = 3.24$, $SD = 0.14$, $p < 0.001$). In addition, the participants in education with remuneration significantly prefer the inclusion of additional textual information below the map compared with an icon bar with pictograms ($M = 3.70$, $SD = 0.14$ vs. $M = 3.16$, $SD = 0.15$, $p < 0.001$).

4.3. *Preferences for hazard announcements*

4.3.1. *Embedding of a sharing function*

For both hazards, the announcements with a sharing function are preferred (Fig. 3). Earthquake announcements with a sharing function are significantly better rated and more often chosen than the ones without this function (rating: $M = 3.87$, $SD = 0.04$ vs. $M = 3.73$, $SD = 0.04$; $p = 0.03$/choice: $M = 0.55$, $SD = 0.02$ vs. $M = 0.45$, $SD = 0.02$; $p < 0.001$). Regarding the thunderstorm warnings, only the forced choice shows a significant preference for announcements with a sharing function over the ones without that possibility ($M = 0.55$, $SD = 0.02$ vs. $M = 0.45$, $SD = 0.02$; $p < 0.001$).

4.3.2. *Format of the behavioural recommendations*

The public's preferences for the format of the behavioural recommendations differ between the two hazards (Fig. 3). Thunderstorm warnings with textual behavioural recommendations are more often chosen compared with the ones with pictograms ($M = 0.54$, $SD = 0.02$ vs. $M = 0.46$, $SD = 0.02$; $p = 0.004$). In comparison, there is no significant difference between earthquake announcements with textual versus pictured behavioural recommendations. However, many participants state to prefer a combination of pictograms and textual instructions in their final remarks.

Moreover, for the earthquake announcements, a significant interaction effect is present ($p = 0.005$). When the behavioural recommendations are presented as pictograms, the participants significantly prefer the announcements that also allow them to share it via WhatsApp, Facebook and Twitter. In comparison, this difference is smaller when the behavioural recommendations are in text format.

4.3.3. *Influence of the cognitive factors and the sociodemographic characteristics*

The participants' trust in actors involved in the communication process (earthquake: $p < 0.001$/thunderstorm: $p < 0.001$) and risk perception (earthquake: $p = 0.008$/thunderstorm: $p = 0.002$) positively correlate with the overall rating of the different announcements. Regarding the earthquake announcements, the participants with high levels of trust particularly rate announcements with pictograms more favourably ($M = 3.88$, $SD = 0.04$ vs. $M = 3.20$, $SD = 0.17$) and prefer announcements with a sharing function ($M = 3.92$, $SD = 0.04$ vs. $M = 3.30$, $SD = 0.17$) compared with the participants with low levels of trust. High levels of risk perception tend to lead to a more favourable rating of

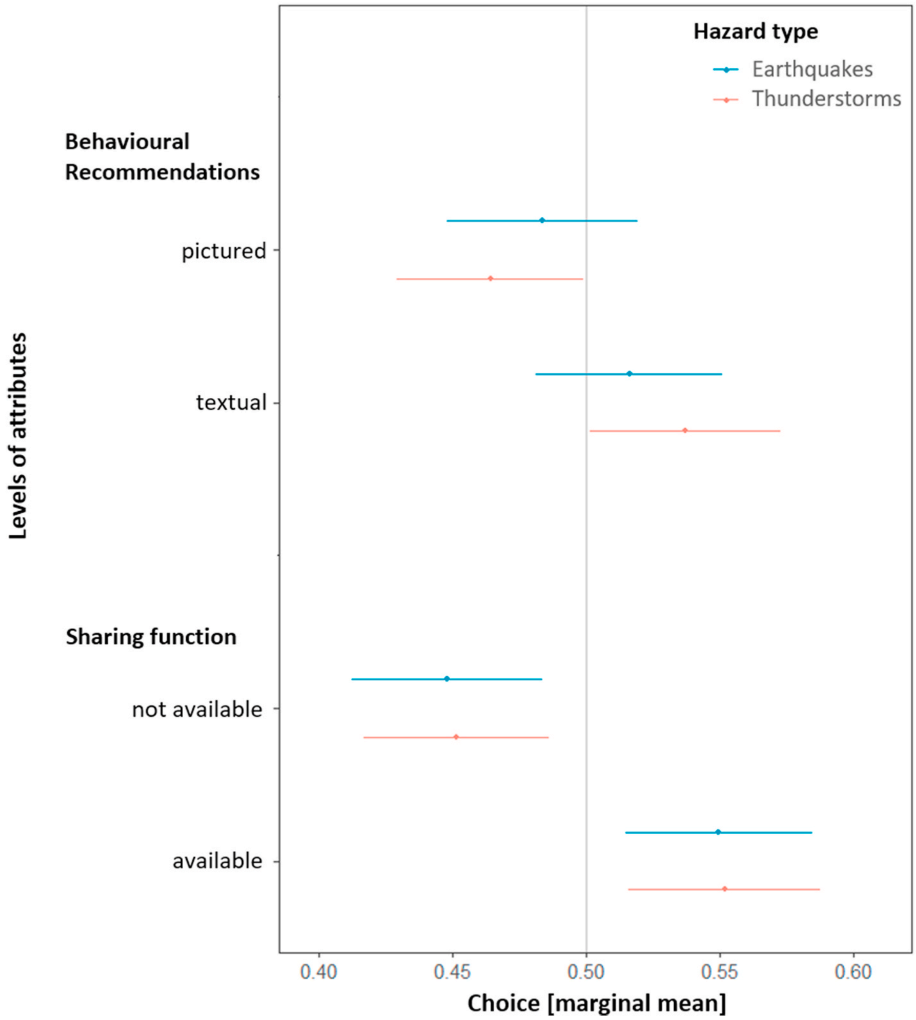

Fig. 3. Results of the forced choice task. Values above 0.5 indicate attribute levels that increase preferences, and values below 0.5 indicate attribute levels that decrease preferences. The horizontal bars represent the 95% confidence intervals. The upper blue lines are the results for the earthquakes and the lower red lines for the thunderstorms. The corresponding statistical tests and tests of the separate rating can be found in Tables S13–S20 in the Supplement. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

announcements with a sharing function compared with low levels of risk perception (M = 3.92, SD = 0.05 vs. M = 3.70, SD = 0.09). Regarding the thunderstorm warnings, the participants with high levels of trust especially rate announcements with pictograms as behavioural recommendations higher compared with participants with low levels of trust (M = 3.78, SD = 0.04 vs. M = 3.07, SD = 0.18). The same applies for the participants' risk perceptions (M = 3.80, SD = 0.05 vs. M = 3.49, SD = 0.09). The other covariates show no significant effects.

5. Discussion

Our study indicates that the public has clear preferences for certain start page elements and contents of hazard announcements. Additionally, some information is better interpreted and motivates people to take (precautionary) actions. Therefore, in parallel to the continuous improvement of scientific-technical aspects, the usefulness of these products for society should be systematically examined, too. The literature lacks empirical evidence of how the public perceives the multi-hazard platforms. Hence, the current study presents an online conjoint choice experiment (N = 768) that empirically tested participant's preferences for start page designs and hazard announcements. The main findings are threefold and are summarised according to preferences for communication channels, for start page designs and for hazard announcements (Fig. 4).

5.1. Preferences for communication channels

The participants prefer a single platform (website or app) combining information about multiple hazards. This preference has also been shown by the studies conducted by Maduz et al. [29] and Helmerichs et al. [54]. In addition to the natural hazards mentioned by most participants, anthropogenic and sociocultural hazards are also appreciated on a multi-hazard platform. Gill and Malamud [8] recommend bundling these hazards on one platform to communicate cascading effects via one platform.

Our results show that besides a single platform, the traditional channels of TV and radio are appreciated as well. In comparison, social media is less preferred, which might be explained by an unfamiliarity with the channel, a limited credibility of the messages or a low accessibility to this medium [55]. However, a multi-channel communication system is recommended because of its ability to inform and warn as many people as possible and to compensate for the failure of other channels [56,57]. Thereby, authoritative information and warnings should be consistent among the multiple communication channels to achieve a desired response by the public [58].

5.2. Preferences for start page designs

The participants prefer a start page that consists of a single map with textual information below the map and that uses four or five hazard categories (Fig. 4). The interaction effect of the attributes also underlines that the combination of all hazards on a single map leads to a

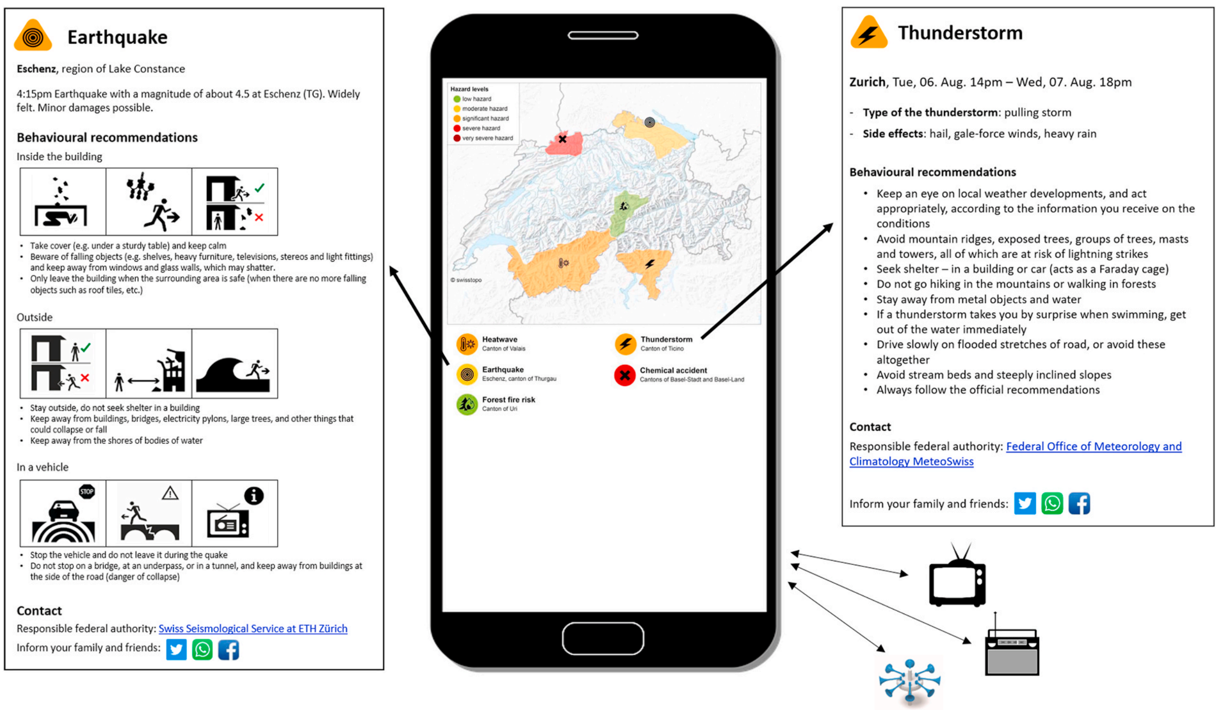

Fig. 4. Participants' preferred start page design and favoured hazard announcements. The earthquake announcement on the left is adjusted (combination of pictograms and textual instructions) based on the participants' remarks. The symbols on the bottom right represent the need for a multi-channel communication strategy to inform as many people as possible.

favourable rating of textual information below the map. A list with some brief information is beneficial, as Savelli and Joslyn [59] have found that forecast messages containing only visualisations are more likely to lead to erroneous interpretation than text alone. Broad et al. [60] come to the same conclusion when evaluating hurricane forecast graphics. Additionally, Bean et al. [25] show that indicating the user's current location on a map leads to more personalisation of risk and improves participants' perceptions of personal risk.

The participants' perceived usefulness of the different start page designs shows the clear advantage of a single map as well. The participants are more motivated to seek further information and to take (precautionary) action when all hazards are presented on a single map. However, it is not only the format of the information presented that plays a crucial role in increasing the public's responses, but also people's individual characteristics. Several studies, for example, have shown that people who have already experienced a disaster are better prepared and able to react immediately to warnings [3,14,16]. In comparison, our results show no influence of participants' hazard experience on their motivation to take (precautionary) actions.

Regarding the participants' interpretation abilities, we wanted to test whether there are differences between the hazard types. Currently, the multi-hazard platforms communicate information about predictable hazards (e.g., thunderstorm warning) and about unpredictable hazards (e.g., earthquake). This may lead to misunderstandings as for example people start thinking that they will also receive warnings for earthquakes as they do it for weather events. Our results show that the two questions about thunderstorms and heatwaves are answered correctly by most participants. In comparison, most are not aware that even if a comparably high-risk area for earthquakes is currently not coloured that they still should be prepared for an earthquake. This difference might be explained by the fact that the participants indicate that they already experienced thunderstorms and heatwaves and were negatively affected by them. Hence, they are familiar with the possible impacts of these two hazards and probably know that they receive warnings. In comparison, only a few participants already experienced an earthquake and were negatively affected by its impacts (Table S10 in the Supplement). Also, other studies have shown that the risk of hazards that occur only rarely (e.g., earthquakes) is underestimated or wrongly perceived by the public [61–63]. Furthermore, such platforms only display current hazards, and people are not informed about the long-term risks. However, especially for unpredictable and high-consequence hazards, the awareness of long-term risk is needed to increase society's preparedness. Therefore, it is needed to link the information about real-time and long-term hazards and to design the platforms accordingly.

Our results of the covariates' effects go along with the findings of other studies [15,64]. The participants with high levels of risk perception and high levels of trust rate all start pages we designed better. In addition, they are more motivated to seek further information and to take (precautionary) actions. Solberg et al. [16] also identify a weak correlation between risk perception and seismic adjustment, particularly regarding response- and recovery-related actions. Furthermore, the participants with high numeracy skills are better at interpreting maps correctly, which is also shown by Marti et al. [13] and Peters [65].

5.3. Preferences for hazard announcements

There is no doubt that the public's need for behavioural actions in the event of an incident are generally high. Therefore, the behavioural recommendations should include clear and locally relevant instructions about measures to be taken [63,66]. Regarding earthquakes, our participants prefer announcements consisting of textual behavioural recommendations and pictograms (Fig. 4); they mention that they are not familiar with the pictograms and that at first glance, some pictograms are not understandable. Therefore, the inclusion of verbal explanations might help people understand the pictograms correctly [67]. A further benefit of a combination is that people not speaking the language in which the message is issued could still look at the pictograms [30]. Regarding thunderstorms, warnings with textual behavioural recommendations are favoured (Fig. 4).

Our results show that a sharing function should be integrated in hazard announcements, regardless of the hazard type. This indicates that people's needs to inform family and friends are present. Sung [17] also sees great potential for 'information sharing' via app or social media, especially during and after an emergency, because people can also provide information about a current hazard to emergency managers, who have to estimate, for example, the damage of an event.

5.4. Limitations and future research

Despite all the new insights, our findings are restricted to the attributes we varied for the different alternatives and the cognitive factors we included.

Regarding the maps, we only displayed five hazards at once. However, in a situation with more simultaneous hazards, the preference for separate maps instead of a single map might increase. Thus, the complexity of the information presented should be analysed. Future research could look at questions such as the following: What is the upper threshold for information presented on a single map? How many different hazards on one map make sense? Could it be an option to have a single map for all natural hazards, one for all socionatural ones and one for all anthropogenic hazards? Furthermore, as the map is a main element of the current multi-hazard platforms, we have not tested a start page with only textual information. Moreover, for the hazard categories we used colour schemes that are frequently used by the current platforms but further thoughts about the perception of these by colour blind users are needed [24]. And lastly, even though we described a hypothetical situation indicating that they receive real-time information at the beginning of the survey it might be that some participants interpreted the maps as long-term hazard maps.

Regarding the hazard announcements, we only varied the format of the behavioural recommendations and the possibility to share the information with others. In addition, only two hazards – earthquakes and thunderstorms – were included. However, other factors, such as the length of the announcements, is crucial as well. Longer hazard warnings, for example, reduce people's intention to seek further information and to confirm the message, leading to fast response times [68]. In addition, high-consequence language used for warnings increases people's intention to evacuate [69]. Also, the communication of actionable risk has been found to increase people's motivation to take preparedness actions [70].

Besides the four cognitive factors we tested, further factors, such as familiarity with reading maps, self-efficacy, social interaction and environment, knowledge, perceived property at risk, milling, responsibility within and outside the family and so forth, influence the public's preferences for information platforms, motivation to seek further information and willingness to take action [25,68,70–74]. For a holistic overview, research assessing further individual, social and contextual factors is recommended [12].

In addition, the analysis concentrates on the design of the start pages and the hazard announcements. Thus, future research is needed to also assess the public's preferences for all the other functionalities and information contents on multi-hazard platforms. For example, a newly implemented functionality is that users can receive an exemplary hazard announcement. This allows them to become familiar with the structure of warnings and alerts and to be prepared in the event of a real incident [75,76]. Also push notifications are widely used but the public's preference for and efficacy of such notifications still need to be explored in the future. Moreover, different measures to increase people's preparedness are used, namely emergency plans, disaster toolkits, preparedness quizzes and so forth. However, their actual effect on people's behaviour is still unexplored.

6. Conclusion

Research on the communication of information about unpredictable, low-probability and high-impact hazards, together with predictable and frequently occurring hazards, on a multi-hazard platform is still in its infancy. We tested the public's preferences for certain start page elements and contents of hazard announcements in a multiple hazard environment. Our main results are that people prefer a single map with textual information added below the map and a four- or five-scale hazard classification. Moreover, a single map motivates people to seek further information and to take (precautionary) actions. Furthermore, textual instructions are preferred for thunderstorm warnings; for earthquakes, a combination of pictograms and textual recommendations is perceived as being the most useful. Finally, people want to be able to share announcements with family members and friends. Those insights are crucial because information and warning platforms aim at increasing the public's preparedness and ability to act in the event of an incident. Indeed, people will only use these platforms if they see a benefit in doing so. Thus, we encourage researchers to consciously include end users in the development processes to increase the platforms' effectiveness and usefulness.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2020.101761.

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