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Criteria-based visualization design for hazard maps

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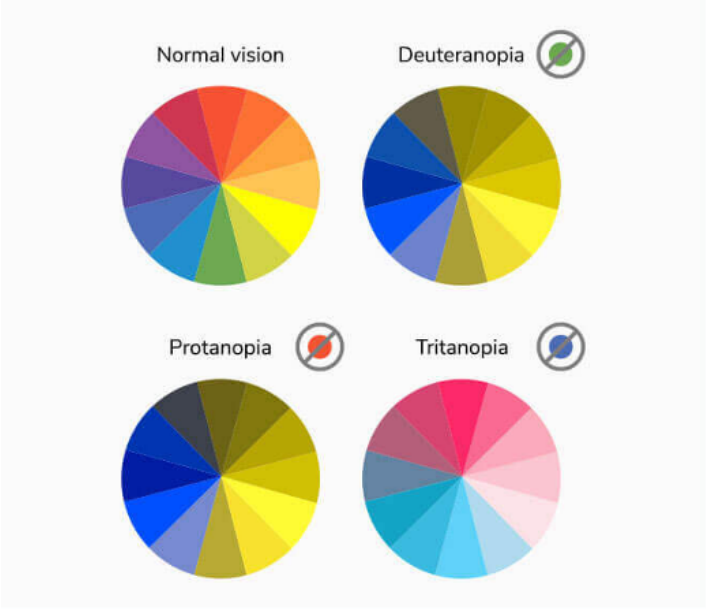

Figure S1. The color wheel under three color vision deficiencies (image from VisionCenter.org). Deuteranopia and protanopia, which are both red-green deficiencies, are the two most common ones (Birch 2012).

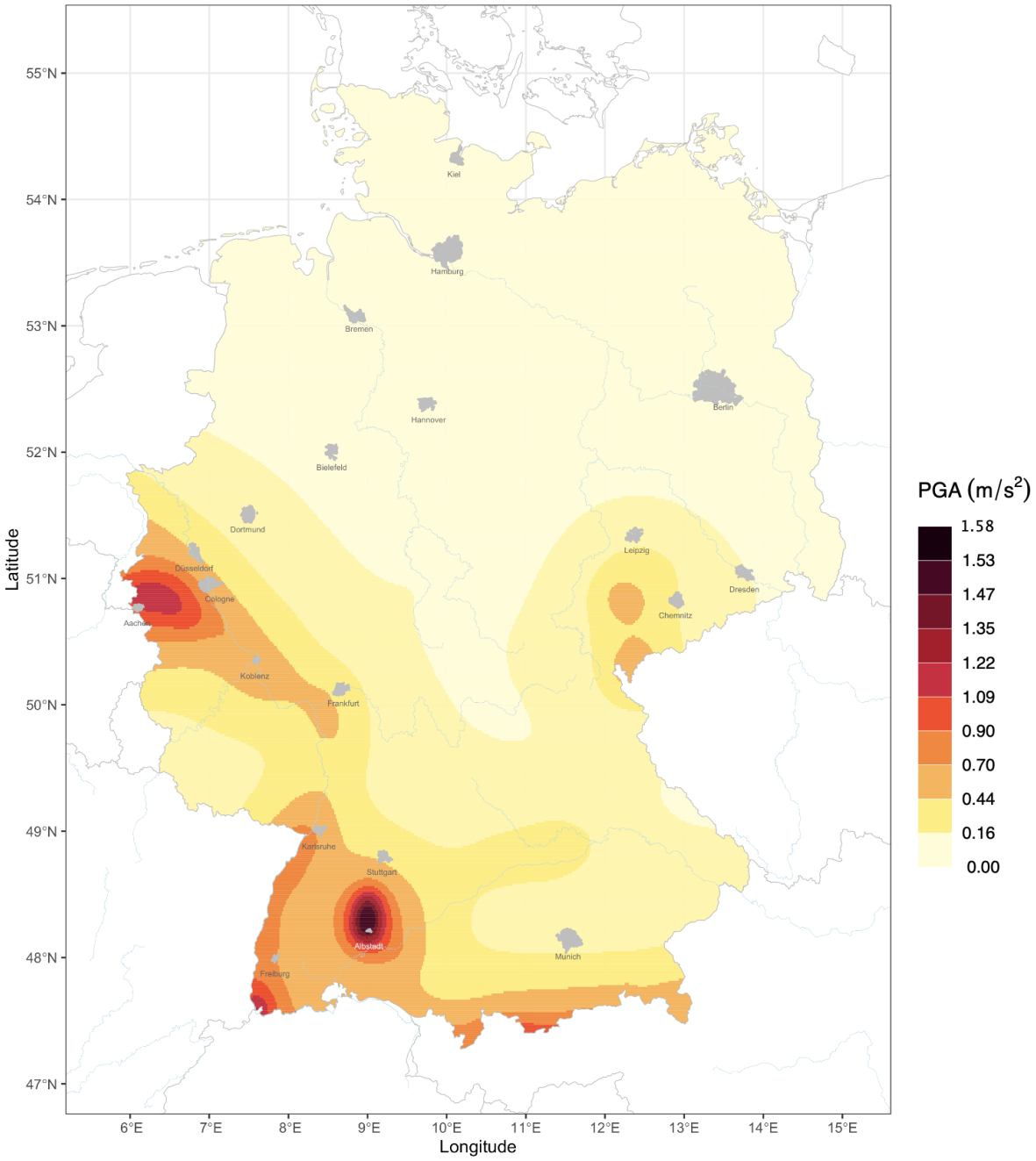

Figure S2. A prototype of the German seismic hazard map using Head-Tails class breaks for the "higher" part of the distribution (PGA > 0.4 m/s^2).

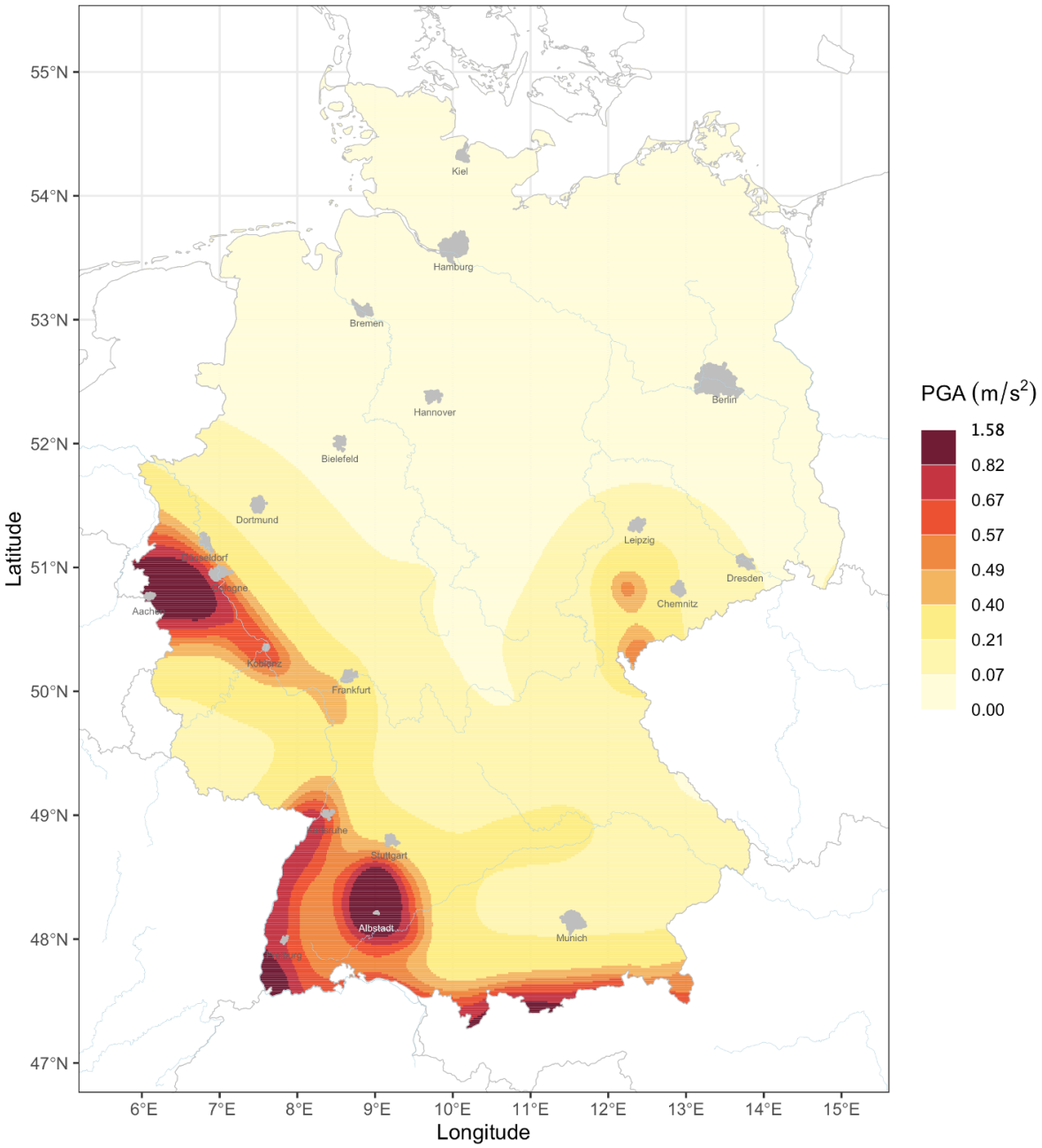

Figure S3. A prototype of the German seismic hazard map using equal quantile class breaks for the "higher" part of the distribution (PGA > 0.4 m/s^2).

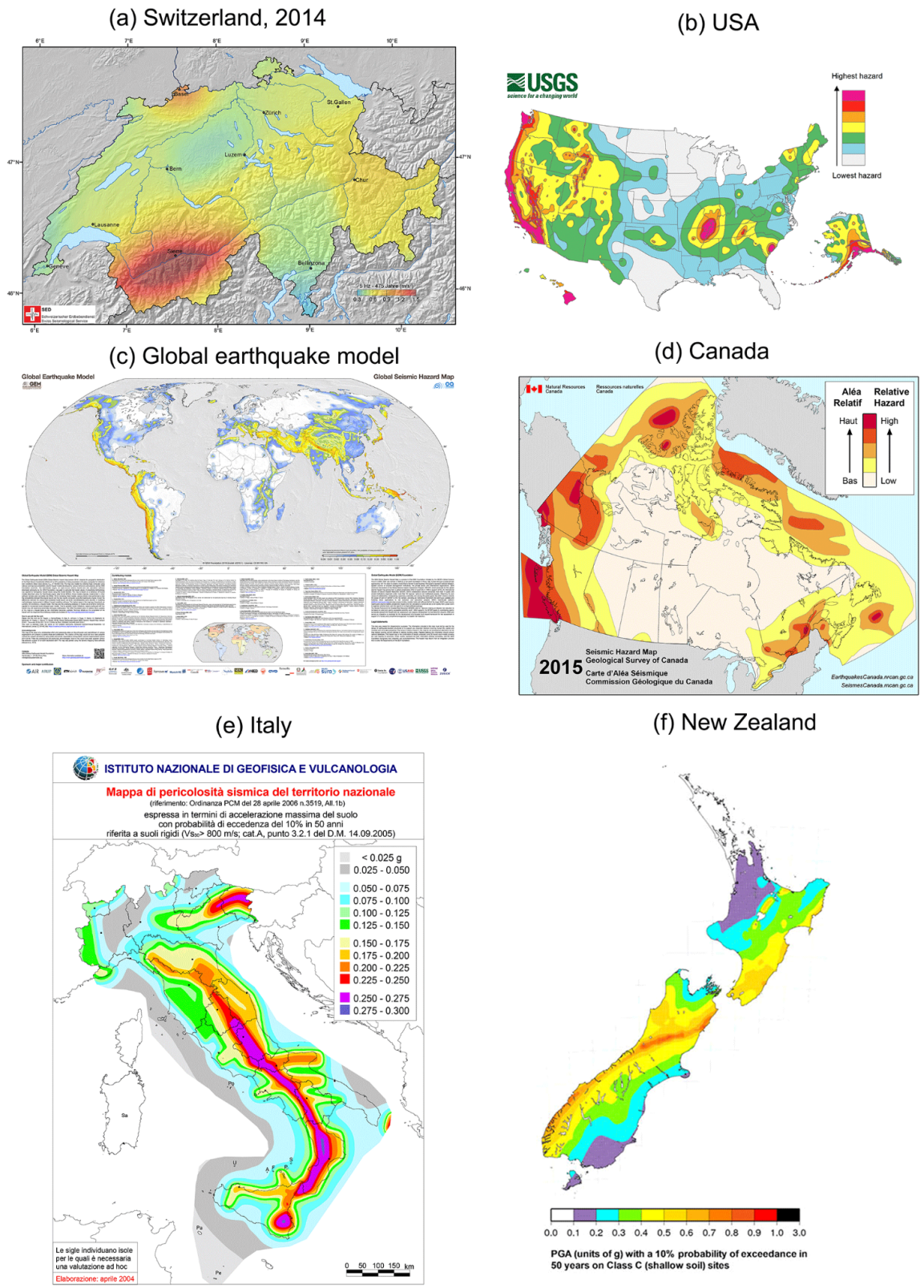

Figure S4. A selection of published seismic hazard maps (reproduced from Figure 1 from Marti et al., 2019).

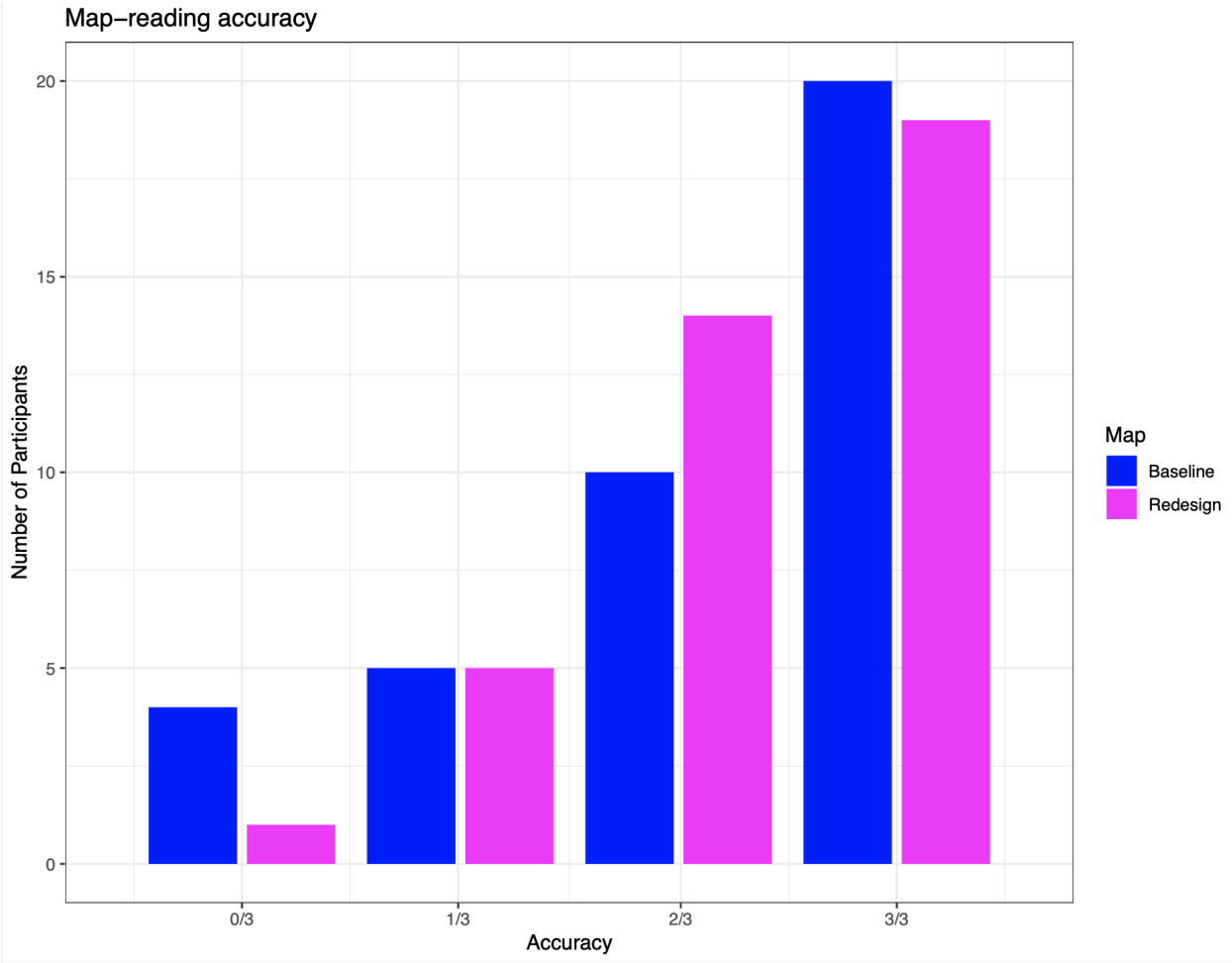

Figure S5. Results of map-reading evaluation questions. For each map, participants were asked to return the maximum hazard level of three cities (different between both maps) and several cities were chosen that crossed multiple hazard levels. See Supplement S7 for the set of map-reading questions.

Supplement S6 Expert evaluation of prototype seismic hazard maps

In the first phase of our evaluation, we recruited seven academic researchers in seismic hazard to review several prototypes for the redesigned hazard map. The researchers all worked at the German Research Center for Geosciences (Potsdam, Germany) and had different levels of experience (from a doctoral researcher to a former section leader with 40+ years of experience). The prototypes varied on the following design elements:

- classification scheme (Fisher or Head-Tails)
- hazard contour label annotations (included or not)
- how cities were marked on the map (polygon or point)
- how colors were labeled in the legend (either double labels, marking the bottom and top of each color swatch or a single label at its middle).

All other design elements of the maps, such as color palette, were held fixed across prototypes.

After asking the survey questions (see Supplement S7) for a single prototype, we presented each participant with each prototype and asked which design element they preferred. There was a common preference for double legend labels (rather than single) and cities marked by polygons (rather than points). Preferences differed regarding hazard labels, but we decided to omit these labels to keep maps uncluttered and to avoid hazard labels running into city labels. Experts also had differing opinions about the two classification schemes, though there was agreement that the Head-Tails scheme led to the appearance of very sharp gradation in the hazard levels surrounding Albstadt, while this appeared smoother with the Fisher scheme. Since we wanted to communicate that hazard changes continuously in space (property G1, see Section 1.2), we adopted the Fisher scheme for the final redesign, shown in Fig. 4.

Supplement S7 Questions in evaluation survey

There were two versions of the map-reading and hazard perception questions developed for the evaluation of the baseline and redesigned hazard maps. For most questions, agreement with the provided statement indicated awareness of the hazard property or threshold. For several questions, it was disagreement with the statement that indicated awareness and such responses were appropriately re-coded in our analyses.

Question Set 1

Map reading questions

Questions 1-3

1. What is the maximum hazard level in Dresden, in terms of peak ground acceleration (PGA)?
2. What is the maximum hazard level in Koblenz, in terms of peak ground acceleration (PGA)?
3. What is the maximum hazard level in Albstadt, in terms of peak ground acceleration (PGA)?

(NOTE: Questions 4-9 have the same 7-point multiple choice answer scale, which was recoded to numerical values as given in parentheses)

Property 1: Seismic hazard (shaking) is not spotty but rather, changes continuously in space in well-established gradients.

Question 4

Leipzig and Dresden have a similar seismic hazard, according to the map.

A. Strongly disagree (-3)

B. Disagree (-2)

C. Slightly disagree (-1)
D. Neither agree nor disagree (0)
E. Slightly agree (1)
F. Agree (2)
G. Strongly agree (3)

Property 2: Areas of high hazard are not limited to where earthquakes have occurred during time-limited earthquake catalogs.

Question 5

Damaging shaking may be expected in Koblenz, according to the map.

Property 3: The highest end of the hazard distribution has a large impact on expected losses and highest hazard differs from high hazard

Question 6

According to the map, there is a meaningful difference in hazard between Freiburg and Albstadt.

Critical threshold: Seismic building codes in Germany

Questions 7-8

The German seismic building codes committee requires seismic-resistant design for ordinary buildings in areas above a hazard threshold level. According to the map, Frankfurt am Main (question 7) / Albstadt (question 8) needs seismic-resistant design for ordinary buildings.

Property 4: Spreading awareness about spatial patterns of hazard may be more important than the specific magnitude of the hazard.
(this question came last, right before the open-ended questions, as the map was not shown)

Question 9

Munich is in a zone where damaging shaking may be expected, according to the previous map (no map shown).

Question Set 2

Map reading questions

Questions 1-3

1. What is the maximum hazard level in Aachen, in terms of peak ground acceleration (PGA)?
2. What is the maximum hazard level in Karlsruhe, in terms of peak ground acceleration (PGA)?
3. What is the maximum hazard level in Freiburg, in terms of peak ground acceleration (PGA)?

(NOTE: Questions 4-8 have the same 7-point multiple choice answer scale, which was recoded to numerical values as given in parentheses)
Property 1: Seismic hazard (shaking) is not spotty but rather, changes continuously in space in well-established gradients.

Question 4

Damaging shaking may be expected in Düsseldorf, according to the map.
A. Strongly disagree (-3)
B. Disagree (-2)
C. Slightly disagree (-1)
D. Neither agree nor disagree (0)
E. Slightly agree (1)
F. Agree (2)
G. Strongly agree (3)

Property 2: Areas of high hazard are not limited to where earthquakes have occurred during time-limited earthquake catalogs.

Question 5

Damaging shaking may be expected in Karlsruhe, according to the map.

Property 3: The highest end of the hazard distribution has a large impact on expected losses and highest hazard differs from high hazard

Question 6

According to the map, there is a meaningful difference in hazard between Aachen and Albstadt.

Critical threshold: Seismic building codes in Germany

Questions 7-8

The German seismic building codes committee requires seismic-resistant design for ordinary buildings in areas above a hazard threshold level. According to the map, Freiburg (question 7) / Leipzig (question 8) needs seismic-resistant design for ordinary buildings.

Property 4: Spreading awareness about spatial patterns of hazard may be more important than the specific magnitude of the hazard.

Question 9

Which proportion of Germany is in a zone where damaging shaking may be expected, according to the previous map (no map shown)?
A. 5% or less
B. 10%
C. 15%
D. 20%
E. 25%
F. 30%
G. 35% or more

(Note: this was the only question that did not use the 7-point disagreement/agreement scale. We compared the responses to the correct answer of 13% (the proportion of grid cells over Germany where PGA > 0.4 m/s^2). We recoded the responses as follows:
A: 2
B: 3
C: 3

D: 2
E: 1
F: 0
G: -1