



Effects of flood risk visualization format on house purchasing decisions

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3 **1 Effects of flood risk visualization format on house purchasing decisions**
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25 **Abstract**

26 We investigated how decision-making is affected by the visual presentation of flood risk
27 information. We exposed participants to different formats of flood risk information while
28 they simulated selecting a property to purchase. We compared three flood risk formats: (i)
29 maps currently used by the UK Environment Agency, (ii) tables that present flood level and
30 frequency information, and (iii) graphical representations depicting the level-frequency
31 combination using a cartoon house image as a physical referent. In the experiment
32 participants were presented, via computer screen, side-by-side information about two houses
33 in a series of trials. Participants made a forced choice preference judgement between 108
34 different pairs of houses to indicate which they would purchase. Our findings indicate that
35 when risk information is presented in map format, individuals are less accurate in selecting
36 lower-risk houses, compared to when the same information is presented as a graphic
37 representation of a house or as a table.

38 **Keywords chosen from Urban Water Keywords**

39 Urban Flooding, Flooding, Social Systems

40 **1. Introduction**

41 Stakeholder inclusion is becoming an important factor of flood risk management. As a result,
42 data itself is insufficient and we should begin to consider its presentation and communication
43 (Newman et al., 2011). While there is increasing recognition for the necessity of public
44 consideration, quantitative investigations into how humans make decisions in the context of
45 flood risk information are still limited; flood risk communication format is a commonly
46 recommended but rarely addressed research topic (Kellens et al. 2013). A key question in
47 this context is how to present flood risk information to members of the public so that they can
48 make informed decisions.

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3 49 Newman et al. (2011) also state that policy change in flood prevention has partially shifted
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5 50 responsibility for flood prevention away from the UK government. This change might be
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7 51 driven by the realisation that resources are insufficient to fully protect everyone. This
8
9 52 assumption is reinforced by ten Brinke et al.'s (2008) suggestion that, in flood risk
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11 53 management, the UK (as well as France and the USA) is more favourable to preparation,
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13 54 response and recovery than to prevention (as in the Netherlands or Japan). This may be
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15 55 because large-scale prevention projects are simply more cost effective in areas of higher
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17 56 exposure, e.g. for regions lying below sea level. Ten Brinke et al. (2008) also discuss the
18
19 57 increasing importance of pro-action, i.e. for reducing the need for defences by avoiding high-
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21 58 risk areas. If governments aim to move towards pro-action, with less need for prevention and
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23 59 increased individual responsibility, then they cannot hope to do so without sufficient
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25 60 consideration of the efficacy of communication with the public.
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30 61 The need for good public awareness regarding flood hazards is becoming increasingly
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32 62 evident, especially in the context of the ongoing environmental consequences associated with
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34 63 climate change (Solomon, 2007). Researchers and governmental bodies currently emphasise
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36 64 the necessity of publicly available flood risk information on which individuals can base
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38 65 appropriate flood mitigation strategies. In Europe, this information is typically provided in
39
40 66 the form of flood hazard maps, as per the requirements of the 2007 Flood Directive adopted
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42 67 by the European Parliament (Directive EU, 2007).
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46 68 Moel et al. (2009) examined in detail the extent of flood map coverage in the EU. They
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48 69 suggest that governmentally developed maps are created/used for emergency planning,
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50 70 spatial planning and for raising awareness. These are predominantly frequency extent maps,
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52 71 but occasionally flood level based ones are used (e.g. Netherlands, Germany and Beven et al.,
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54 72 2015). Despite such maps covering large areas and often containing extensive information, it
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56 73 appears that public awareness and appreciation of risk from flooding and its resultant
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3 74 preventative behaviour remains highly variable (US: Bell and Tobin, 2007; UK: Burningham
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5 75 et al., 2008; EU: Siegrist and Heinz, 2008).

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8 76 Many studies have provided possible explanations for this variability, such as previous
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10 77 experience with hazards (e.g. Siegrist and Gutscher, 2006; Pagneux et al., 2011), or socio-
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12 78 demographic variables including income (Lindell and Hwang, 2008) and home ownership
13
14 79 (Burningham et al., 2008). Although such studies have undoubtedly provided a wealth of
15
16 80 insight into the complexity of effective risk communication, implementation of their
17
18 81 contributions to risk communication media appears to be quite challenging. This perhaps lies
19
20 82 in the level of personalisation required to accommodate the variation in personality and
21
22 83 socio-demographic variables (Burningham et al., 2008). Another target for development that
23
24 84 has received relatively little attention in risk communication is the visual organisation of risk
25
26 85 communication media. There exists a considerable body of research that documents the
27
28 86 various biases of visual perception (i.e. gestalt principles) that facilitate the perception and
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30 87 interpretation of visual scenes (e.g. Pinker, 1990; Carpenter and Shah, 1998; Kelleher and
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32 88 Wagener, 2011), but which have been largely overlooked or underused by risk
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34 89 communicators.

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39 90 Bell and Tobin (2007) provide a notable exploration of different interpretations elicited
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41 91 through different ways of presenting flood risk information. They note that flood risk
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43 92 information is commonly based upon – and in many cases prescribed by – the 100-year return
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45 93 period (i.e. a 1 percent chance of a flood occurring in a given year), yet “the initial goal of
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47 94 adopting the 100-year flood criterion was not effective communication of risk or risk policy,
48
49 95 but efficient administration and implementation” (p. 302). Indeed, the use of this criterion
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51 96 continues to be debated (National Research Council, 2006), while it is also understandable
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53 97 that one way of communicating cannot be equally efficient for a range of purposes.

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3 98 Compounding this issue is Bell and Tobin's (2007) finding that, when asked to choose what
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5 99 aspects of flooding most concerns them – given the choices of flood water level, flooding
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7 100 frequency, a combination of the two, or other aspects – no participant chose the frequency of
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9 101 flooding alone as the most concerning aspect of a flood. This finding warrants concern
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11 102 regarding the widespread use of frequency-based flood-risk communication (i.e. the 100-year
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13 103 return period). Moreover, flood level, rather than flood frequency, emerged as the
14
15 104 predominant concern for 49 percent of participants, indicating that emphasising predicted
16
17 105 flood levels may be more relevant for public communication (a further 42 percent chose level
18
19 106 and frequency and none chose frequency alone). Developing this last point, Bell and Tobin
20
21 107 (2007) also found evidence to suggest that flood risk awareness is enhanced when physical
22
23 108 references (e.g. “the flood reaches up to the doorstep) are used to describe the extent of a
24
25 109 flood. The authors suggest, consistent with others (Smith, 2000), that including information
26
27 110 about flood extent in combination with flood frequency may prove effective. This finding
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29 111 reinforces the availability heuristic of the importance of personal experience. Given these
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31 112 study results, we expect that a dedicated communication method should involve a
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33 113 combination of physical reference (i.e. flood level) and frequency.
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38 114 Our study investigates decision-making in response to three different ways of presenting
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40 115 flood risk information: (i) the map format currently used by the UK Environment Agency, (ii)
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42 116 a table format that presents a matrix of flood level in combination with flood frequency, and
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44 117 (iii) a graphical representation depicting the level-frequency combination using a cartoon
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46 118 house image as a physical reference. The latter two formats were newly devised for this
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48 119 experiment, drawing on the suggestions made by Bell and Tobin (2007) as discussed above.
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50 120 Accordingly, we hypothesised that the formats utilising the combination of flood level and
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52 121 flood frequency would lead participants to more frequently reject the higher-risk option in a
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54 122 two-alternative forced-choice decision-making task. In our experiment, participants were
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3 123 asked to choose between two different houses available for sale. Details of the houses were
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5 124 presented to participants on an information sheet that was close to the kind of sheet routinely
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7 125 provided to home buyers (see following section). Across these sheets we manipulated how
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9 126 the flood risk information was presented and by systematically controlling across trials all the
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11 127 other information on the sheets we were able to measure the unique contribution the different
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13 128 ways of presenting the flood risk information to the decision.
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18 129 **2. Method**

20 130 **Experiment**

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23 131 The study was based on examining the response of participants to different types of flood risk
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25 132 information provided in the context of selecting a property to purchase. In the experiment
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27 133 participants were presented on a computer screen with a series of trials in which information
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29 134 about two houses were presented side by side (see Figure 1). Participants were asked to make
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31 135 a forced choice preference judgment between these pairs of houses to indicate which house
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33 136 they would consider purchasing. We manipulated the way in which the flood risk
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35 137 information was presented (Table, Graphic or Map; See Figure 2) and the severity of the
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37 138 flood risk (Low, Medium or High) to see how these two factors influenced the preference.
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41 139 All participants had corrected to normal vision. Participants were selected on the basis of
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43 140 being either previous home buyers or actively seeking to purchase a home at the time of
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45 141 testing. All lived in or near to the city of Bristol in the UK.
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48 142 For the *map* format, maps were taken from the UK Environment Agency (EA) flood risk map
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50 143 service. They were selected from the Birmingham area of the UK. This area has a range of
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52 144 flood risks with a relatively uniform housing style, which reduces the variability associated
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54 145 with house style preferences. House location crosses were randomly placed in pixels that met
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3 146 the appropriate risk level and contained a house (this was done by RGB pixel values). It
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5 147 should be noted that the EA does not publish precise details on how these risk levels are
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7 148 calculated, we are simply using the risk listed in their public flood maps.
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10 149 The remaining two display conditions in the experiment were *table* and *graphic*. In both
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12 150 cases the flood risk information was presented in a way that decoupled flood severity and
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14 151 recurrence interval. While the flood maps do not list depth, our study of the literature
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16 152 suggested recipients of flood risk information find depth to be a particularly motivating
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18 153 factor. As a result, based on correspondence with the EA, we translated these risk bands into
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20 154 estimated depth-probability terms. These novel display methods provided the user with more
21
22 155 granular information regarding the nature of the risk for a particular property. The table
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24 156 format aimed to mimic the European Union Energy Rating label, which is used, at least in the
25
26 157 UK, as part of the details published to advertise houses for sale. The graphic format was used
27
28 158 to give the flood risk levels a concrete perspective (Pappenberger, et al., 2013).
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32 159 Each of the three display formats were presented at three possible levels of risk (low,
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34 160 medium, high). The flood risk presentation format of any two pages in a comparison trial was
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36 161 always the same. This allowed flood presentation styles to be compared without any
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38 162 sensitivity bias from style (e.g. no comparison contained a table compared with a map). Other
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40 163 choices were made as follows:

- 44 164 • To ensure variation could only be attributable (besides individual preferences) to
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46 165 flood risk information only flood information on an estate agent page was altered
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48 166 between participants. There were 3 possible risk level pairings (low/medium;
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50 167 low/high; medium/high), 2 possible positions (right/left) and 3 formats
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52 168 (map/table/graphic). This requires 18 participants to ensure every possible
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54 169 combination for every possible estate agent page is viewed.
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3 170 • With 6 trials of every risk-position-format pairing, each participant viewed 108 trials,
4 thus 216 estate agent pages.
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7 172 • Houses were paired based on number of windows, colour and size to ensure they were
8 comparable aesthetically. Besides a picture of the house; price, estate agent logo,
9 173 three small adverts, energy rating and search criteria were also displayed on the estate
10 174 agent page. These additional details were randomly assigned and fixed (across
11 175 participants) to that page.
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14 177 • The picture of the house could be presented in the left or right hand side of the page.
15 178 The houses were selected from the suburbs of Birmingham so that they were
16 179 consistent with the map.
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19 180 • House prices displayed varied randomly on a trial by trial basis between £195,000 and
20 181 £205,000 which was realistic for this area at the time of testing.
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23 182 • We selected 2 different estate agent logos. Each different estate agent logo had a
24 183 different page layout (left aligned or right aligned) and advert associated with it.
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27 184 • Energy ratings for houses were displayed in standard UK Energy Performance
28 185 Certificates format. We chose 10 pairings of Current and Potential energy rating to
29 186 display (Current, Potential: B,A; B,B; C,B;C,C; D,C; D,D; E,D; E,E; F,E; F,F)
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32 187 • The search criteria were the same on every estate agent page in the experiment.
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35 188 • Trial order was randomised for each participant.
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38 189 • We made an *a-priori* decision to test 18 participants. To our knowledge there are no
39 190 previous studies that are similar enough to the current one to allow us to carry out a
40 191 formal power calculation. We selected 18 participants as this is a typical number of
41 192 participants testing in this broad type of behavioural experiments. As such this study
42 193 is exploratory.
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3 194 • Participants were presented with a comparison of two estate agent pages which
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5 195 simulated what they might see following a web search on a house purchase website.
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7 196 Every comparison had a different house image and flood risk level. The participant
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9 197 had to click on a ‘buy house’ button on one of the pages to proceed to the next
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11 198 comparison.
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13 199 • Participants carried out five practice trials followed by 108 comparisons that formed
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15 200 the basis of the analysis reported here. At the end of the testing session we also
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17 201 collected and recorded post experiment feedback which is reproduced in full in the
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19 202 appendix.
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203 **Analysis**

204 For the purposes of the current analysis, the response for each decision was classified as
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26 205 either ‘correct’ if the house with the lower flood risk was chosen and ‘incorrect’ if the house
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28 206 with the higher flood risk was chosen. A binary logistic regression analysis with ‘correct’ as
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30 207 the discrete dependent variable and participant, risk format, risk comparison, and a format-
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32 208 by-comparison interaction (e.g. map, low vs high risk) as explanatory factors was conducted
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34 209 to determine the effects of these variables on the probability of correct responses. ‘Incorrect’
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36 210 was defined as the dependent reference category and participant 18, map format, and
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38 211 medium-high comparison were entered as the reference categories for the factors.
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43 212 Binary logistic regression creates a model, based on explanatory factors, which predicts the
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45 213 dependent variable. For a vector of explanatory variables $x=(x_1, \dots, x_n)$, the model fits the
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47 214 probability of a *correct* answer to be $F(x)$, satisfying
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$$51 \ln\left(\frac{F(x)}{1-F(x)}\right) = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n. \quad (1)$$

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3 216 The coefficients, $\beta=(\beta_0, \beta_1, \dots, \beta_n)$ are the unknown parameters of the model and are
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5 217 estimated to best explain the observed data. These β coefficients can be interpreted as the ‘log
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7 218 odds ratio’; $\exp(\beta_i)$, which indicates how much more likely the model is to produce ‘correct’
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9 219 when the explanatory factor x_i takes a value of 1 compared with when it takes a value of 0;
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11 220 thus when $\beta_i>0$ the factor x_i increases the probability of seeing the *correct* response, and
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13 221 when $\beta_i<0$ the factor x_i decreases the probability of seeing a *correct* response.

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16 222 When fitting logistic regressions, the significance of a factor is assessed by a χ^2 statistic
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18 223 which measures the difference in the ability of the model to fit the data with or without that
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20 224 factor present in the model. Under a null hypothesis that a factor does not enhance the ability
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22 225 to fit the data, the χ^2 statistic has a χ^2 distribution with parameter equal to the number of
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24 226 parameters added to the model (thus when the presentation format factor is added the χ^2
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26 227 statistic has a $\chi^2(2)$ distribution, because 2 additional β parameters are added to the model
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28 228 corresponding to the two non-reference levels of this factor). We thus compare the calculated
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30 229 statistic to the distribution of the appropriate χ^2 random variable; if the observed value is
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32 230 extreme (indicated by a low p -value) then it is assessed that the factor is a significant
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34 231 contributor to model fit.

3. Results

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42 233 Figure 3 shows that the mean percentage correct was higher for the graphic and table
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44 234 representations compared to the more widely used map representation. While all presentation
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46 235 formats lead to a high percentage of correct choices, there is a large drop in performance if
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48 236 the map presentation format is used. Figure 4 further shows how often the participants
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50 237 selected correctly as a function of what risk levels the two houses were at. The graph shows
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52 238 that the percentage correct choices was higher if the choices were between low-high and
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54 239 between medium-high risk houses. In contrast, there was a decrease in percentage correct if

240 one house was low risk and the other medium. This result is in line with expectations given
241 flood risk is of less importance as a decision criterion in such cases.

242 The logistic regression, as specified above, allows us to investigate which of these differences
243 are statistically significant. The outcome of this modelling exercise is shown in Table 1.

244 Critically for the current study there was a reliable effect of the presentation format ($\chi^2(2) =$
245 $21.12, p < 0.001$) indicating that we have strong evidence that participants' responses were
246 affected by how the information was presented. There was also a robust effect of risk
247 comparison ($\chi^2(2) = 33.39, p < 0.001$) indicating that participants were sensitive to the
248 relative flood risk between the two houses presented in any given trial. There was no
249 evidence for a reliable interaction between these two factors ($\chi^2(4) = 0.95, p = 0.917$). This
250 suggests that the presentation type and the risk combine in an additive manner to affect the
251 choices made. Less centrally to the focus of this paper there was also a main effects of
252 participant ($\chi^2(17) = 102.01, p < 0.001$) indicating that there were reliable individual
253 differences between the participants in how they responded; these are among the strongest
254 effects and are account for personal differences (e.g. education or age) between participants.

255 As shown in Table 1 and Figure 3, graphic presentation ($\chi^2(1) = 4.45, p = 0.035$), and table
256 presentation ($\chi^2(1) = 7.70, p = 0.006$), are both significantly more likely to produce a correct
257 response than map presentation (the reference category). Low-medium comparisons ($\chi^2(1) =$
258 $4.43, p = 0.035$), were observed to produce significantly lower probabilities of correct
259 responses than medium-high comparisons (reference category), whilst low-high comparisons
260 were not found to differ, as also illustrated in Figure 4. Again, we found no evidence that the
261 format of presentation interacted with the risk difference to produce a greater effect of one
262 presentation mode at a particular risk level.

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3 263 At the end of the experiment participants were asked to provide comments about
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5 264 their experience. In particular, participants were asked what they thought about the
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7 265 flood-risk presentation formats and whether they adopted a particular strategy
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9 266 throughout the experiment. Though these comments have not been analysed
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11 267 quantitatively, a brief summary describing trends in the responses is provided below.
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13 268 Participant comments are also provided in Appendix A.

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16 269 In general, participants appeared to prefer the graphic and/or table presentation
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18 270 formats over the map format. Specifically, six out of 18 participants preferred
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20 271 graphic presentation, five of 18 preferred table format, whilst only three of 18
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22 272 described a preference for map format. Two of those preferring maps expressed
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24 273 confusion about frequency-based flood predictions in graphic and table
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26 274 presentations, whilst the third found it difficult to see the different flood levels
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28 275 presented in the graphic format. Four out of 18 participants did not express a clear
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30 276 preference for any one format.
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34 277 The map format was repeatedly described as causing confusion due to the extent of
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36 278 light and dark blue depicting relative risk; a lack of defining borders and the use of
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38 279 different hues of the same colour were reported to make certain areas appear more
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40 280 risky than they actually were, this is consistent with the results reported by (Ratwani
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42 281 & Trafton, 2008). Another recurrent theme in participants' comments was a feeling
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44 282 of lack of control in dealing with flood-risk level; participants often expressed that
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46 283 they could not "do anything" about flood-risk level or where they live, but that they
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48 284 can "do something" about, for example, poor energy performance (e.g. install
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50 285 insulation). Thus, poor energy performance was generally more acceptable to
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52 286 participants than high flood-risk.
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287 **4. Discussion**

288 The present experiment investigated how decision-making based on flood risk information is
289 affected by the way in which this information is visually presented. We compared three ways
290 of presenting the same flood risk information: (i) the map format of presentation currently
291 used by the UK Environment Agency, (ii) a table format that presents flood level information
292 in combination with flood frequency information, and (iii) a graphical representation
293 depicting the level-frequency combination using a cartoon house image as a physical referent.
294 Our findings indicate that when risk information is presented in map format, individuals are
295 less accurate in selecting lower-risk houses, compared to when the same information is
296 presented as a graphic representation of a house or as a table (Figure 1). In addition, we find
297 evidence for a reliable ability to avoid high-risk houses when they were presented jointly with
298 either low or medium risk houses (Figure 2). We find no evidence of an interaction between
299 these two effects.

300 This results pattern is consistent with previous research into presenting flood risk
301 information. For example, Bell and Tobin (2007) compared participants' responses to four
302 ways of presenting the risk of a 100-year flood event ('100-year flood' vs. '1 percent chance
303 in any given year' vs. '26 percent chance occurring in 30 years' vs. a flood risk map) and
304 found the 1 percent description to be consistently more effective in conveying uncertainty
305 than the 100-year description. Conversely, the 1 percent description was found to perform
306 worse than the 100-year description in motivating concern or protection (e.g. preventative
307 behaviour), a finding that indicates – as the present study does – that differing presentations
308 of risk elicit differing conclusions by the viewer; i.e. composition affects conclusion. This
309 result further highlights the need to consider what the intended message of a risk
310 communication medium is during its design already.

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3 311 In contrast to the wealth of research dedicated to investigating individual differences in flood
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5 312 risk communication and perception, there is markedly less attention focused on how the
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7 313 visual features of flood-risk presentation affect their interpretation, despite an extensive
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9 314 literature on the perception of graphical representations of quantitative information (e.g.
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11 315 (Carpenter & Shah, 1998), (Cleveland & McGill, 1986), (Shah & Freedman, 2011)). For
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13 316 example, models of visual display comprehension emphasise an interaction between top-
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15 317 down (e.g. content familiarity, graph skills; i.e. individual differences) and bottom-up (e.g.
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17 318 visual features of the display) processes when decoding information from visual displays
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19 319 (Hegarty, 2005), (Kriz & Hegarty, 2007). In the case of graph comprehension, for example,
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21 320 Shah and Freedman (2011) showed that the same quantitative information is interpreted
22
23 321 differently when presented in bar graphs as compared to line graphs, and prior knowledge
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25 322 (i.e. top-down processing) was found to interact with the influence of presentation format.
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27 323 The authors suggest that these systematic differences in interpretation can in part be
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29 324 understood in the context of Gestalt Laws of Perceptual Organisation (Wertheimer, 1938).
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31 325 Indeed, other researchers (Pinker, 1990) have provided detailed theories of how Gestalt
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33 326 principles such as those of similarity, proximity, and good continuity are used by viewers to
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35 327 manage the cognitive processing demands of graphical displays (Shah, et al., 1999). In light
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37 328 of this, it is surprising that the role of such bottom-up processing (and its interaction with top-
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39 329 down processing) has so far been largely under-studied in the context of flood-risk
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41 330 communication.

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46 331 The influence of the aforementioned Gestalt principles on interpretation is evident in the
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48 332 presentation formats used in the present experiment. The table format in particular is
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50 333 conducive to organising the displayed information based on the good continuity provided by
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52 334 its columns, whilst the principle of proximity is likely to facilitate flood level comparisons in
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54 335 the graphic format. These principles influence what inferences are made by directing
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3 336 attention toward and facilitating the processing of particular elements of the visual display. A
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5 337 possible explanation for the varied success of map presentations of flood-risk information
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7 338 may thus be the absence of these perceptual elements that direct, focus, and facilitate the
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9 339 cognitive processing of visual displays. It would therefore be useful in future studies to
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11 340 further explore visual elements of flood-risk presentation mediums that are particularly
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13 341 effective in encouraging appropriate inference generation.

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16 342 We have made the assumption that the desired impact on behaviour of flood risk
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18 343 communication is lesser acceptance of higher risks; we have treated flood communication as
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20 344 successful if the viewer accepts the lower-risk option. This was necessary to be able to
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22 345 measure participants' decision-making behaviour in response to the different presentation
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24 346 formats, although we acknowledge that this may not be the desired output of flood risk
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26 347 communication in all cases in the real world. Were this the case, there already exists evidence
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28 348 to suggest that an effective way to do this would be to communicate affect-laden flood-risk
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30 349 messages that induce, for example, fear of flood events (Keller, et al., 2006). However, such
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32 350 an approach is likely to leave viewers relatively over-sensitised to risk, and in reality it is not
33
34 351 the goal of flood-risk communication to 'scare' the public into avoiding all higher-risk
35
36 352 options but rather to make a more informed decision. As such, our simplifying assumption
37
38 353 may constrain generalisation to instances in the real world, and future research would benefit
39
40 354 from the adoption of paradigms that do not treat risk-aversion per se as the desirable
41
42 355 behavioural outcome. One possibility may be to frame similar experiments in the context of
43
44 356 an economic game, where participants would have the opportunity to make a profit based on
45
46 357 the odds of their decisions; in such cases, high-risk decisions may provide greater payoffs and
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48 358 so will not be ubiquitously avoided.

359 **5. Practical Relevance and Potential Applications**

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3 360 The present experiment evidences an important influence of the visual format of flood-risk
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5 361 communication mediums on viewers' interpretations. Our key finding – that participants are
6
7 362 more accepting of high probability flood risks when this information is presented in map
8
9 363 format as compared to the graphic and table format – is particularly relevant for flood-risk
10
11 364 communicators in countries that currently employ flood hazard maps as their primary method
12
13 365 for communication. For members of the European Union in particular, the finding that flood
14
15 366 hazard maps encourage greater risk acceptance than other types of (newly conceived) risk
16
17 367 presentation is potentially problematic in light of the fact that this method of communication
18
19 368 is currently prescribed by the 2007 Flood Directive of European Parliament (2007/60/EC). It
20
21 369 is possible that an over-focus on individual and socio-demographic variables and an under-
22
23 370 focus on visual presentation factors may in part explain why improving public risk awareness
24
25 371 is such a challenge. Further investigation of the influence of different formats of flood-risk
26
27 372 presentation may provide useful insight for flood-risk communicators, who may wish to
28
29 373 implement what is known about graphical representation and the influence of visual (bottom-
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31 374 up) elements of graphical displays in addition to tackling the variation resulting from (top-
32
33 375 down) socio-demographic and individual differences. The implications of our findings add to
34
35 376 those of others who have similarly identified issues with the use of the 100-year return period
36
37 377 (Bell & Tobin, 2007). These early-stage findings highlight a need for greater consideration of
38
39 378 presentation format in flood-risk communication, and future research in this area is likely to
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41 379 prove useful in improving public awareness and understanding of risk from flood events.
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48 **Table 1**

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50 381 Model parameter estimates of binary logistic regression analysis, showing parameter values
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52 382 of beta (β), standard error of beta (SE β), odds ratio ($\exp(\beta)$), and odds ratio confidence
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383 intervals, with 'correct' as the dependent variable and 'participant', 'presentation format', and
 384 'risk comparison' as factors.

Included	95% CI for Odds Ratio				
	β	SE β	Odds ratio	Lower	Upper
Constant	1.99	0.36	7.31	3.64	14.69
Participant					
1	-1.21*	0.39	0.30	0.14	0.64
2	-1.25*	0.39	0.29	0.13	0.61
3	-0.51	0.42	0.60	0.27	1.36
4	-0.51	0.42	0.60	0.27	1.36
5	-0.58	0.41	0.56	0.25	1.26
6	-0.89*	0.40	0.41	0.19	0.90
7	0.23	0.48	1.25	0.49	3.18
8	-1.78**	0.38	0.17	0.08	0.36
9	-0.36	0.43	0.70	0.30	1.61
10	-1.86**	0.38	0.16	0.07	0.33
11	0.35	0.49	1.43	0.55	3.72
12	-0.65	0.41	0.52	0.23	1.17
13	-0.51	0.42	0.60	0.27	1.36
14	-0.77	0.40	0.46	0.21	1.02
15	-0.44	0.42	0.65	0.28	1.48
16	-1.57**	0.38	0.21	0.10	0.44
17	-0.71	0.41	0.49	0.22	1.09
18 ^{REF}	0		1.00		
Format					
Graphic	0.54*	0.25	1.71	1.04	2.81
Table	0.73*	0.26	2.08	1.24	3.48
Map ^{REF}	0		1.00		
Comparison					

Low-Medium	-0.47*	0.22	0.62	0.40	0.97
Low-High	0.14	0.24	1.15	0.72	1.84
Medium-High ^{REF}	0		1.00		
Format-Comparison Interaction					
Graphic by Low-Medium	-0.17	0.34	0.84	0.44	1.63
Graphic by Low-High	0.05	0.37	1.06	0.51	2.17
Graphic by Medium-High ^{REF}	0		1.00		
Table by Low-Medium	-0.29	0.35	0.75	0.38	1.48
Table by Low-High	-0.06	0.38	0.95	0.45	1.98
Table by Medium-High ^{REF}	0		1.00		
Map by Low-Medium ^{REF}	0		1.00		
Map by Low-High ^{REF}	0		1.00		
Map by Medium-High ^{REF}	0		1.00		

385

386 *Note:* Model $\chi^2(25) = 158.46, p < .001$. * $p < .05$. ** $p < .001$. REF = Reference category.

387

388 **Appendix**

389 Participants' comments and opinions having completed the experiment.

<i>Participant</i>	<i>Comments</i>
1	<ul style="list-style-type: none"> • Map presentation easiest to use. • Experience of house being flooded. • Awareness of recent flooding events. • Strategy: Compared images, followed by energy, followed by flood risk.
2	<ul style="list-style-type: none"> • Graphic presentation very powerful.

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- Maps difficult to understand.
 - Strategy: Compared images, followed by energy, followed by flood risk, followed by price.
 - 3 • Flood risk had large influence on decisions.
 - Began to ignore price.
 - Aesthetics of the houses also had some influence.
 - 4 • Graphic presentation best.
 - Began to ignore energy performance information.
 - Also began to ignore flood-risk information as this participant had previous experience with unreliable flood-risk information.
 - 5 • Graphic and table presentations better than map presentation.
 - Map difficult to understand.
 - Strategy: Checked flood risk, followed by energy performance. If energy performance for a house was high it was further considered, even if it was at high risk of flooding. Price considered with respect to what improvements could be carried out on house (e.g. build an extension).
 - 6 • Graphic presentation best; easy to see flood levels.
 - Table presentation second best.
 - Maps hardest to use.
 - Strategy: At start compared all aspects (e.g. aesthetics, price, etc.) and compared flood-risk information last. Later started to compare flood-risk information first and then compared other things. Energy performance largely ignored. Willing to pay more for a lower risk house. Tendency to initially prefer aesthetically pleasing houses, but this

1
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3 preference reduced if house was at high risk.
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- 5 • Participant felt that flood risk information would be useful when buying
6 a house; had not previously considered this when buying a house.
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- 10 • Graphic presentation best.
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12 • Map presentation difficult to understand.
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14 • Strategy: Energy performance information ignored because one can "do
15 something" about poor energy performance but one cannot do anything
16 about the risk of flood. Aesthetic preference played a role, but swayed
17 by flood-risk level.
18
19 • Flood risk information should be provided with house information when
20 looking to buy so that a fully informed decision can be made.
21
22 • This participant independently investigated flood-risk information when
23 buying their house.
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- 31 • Table presentation best.
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33 • Graphic presentation second best.
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35 • Map presentation most difficult.
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37 • Strategy: Compared aesthetics, followed by price, followed by flood-
38 risk information. Ignored energy performance information because one
39 can "do something" about energy performance.
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42 • It would be useful if this information was provided on estate agent
43 websites.
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- 49 • Table presentation best.
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51 • Graphic presentation more difficult to use.
52
53 • Strategy: Largely influenced by flood-risk information. Ignored energy
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performance information because one can "do something" about it (e.g. insulation). Ignored price.

- 10 • No data available.
- 11 • Map presentation was easiest to use.
- Other presentation formats were more difficult because of use of fractions (frequency probabilities) to describe risk.
- 12 • Graphic presentation was easiest to use.
- Map presentation was hardest to use; crosses surrounded by lots of blue make it look more risky.
- Strategy: Largely influenced by aesthetics, followed by flood-risk information.
- 13 • Graphic presentation was most informative.
- Strategy: Compared energy performance and flood risk information. Participant noticed that these were the only factors that considerably changed.
- 14 • Table presentation easiest to use.
- Map presentation more difficult to use.
- "Fear factor" associated with picture; high flood level for a rare flood still appears off-putting.
- It would be useful for flood risk information to be provided when viewing houses.
- This participant has bought several houses in the past.
- 15 • Map presentation most difficult to use.
- Graphic and table presentations equally easy/difficult to use.

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- 16
- On first trial struggled slightly with understanding table presentation; fractions (flood frequencies) and flood level slightly confusing.
 - Didn't really like the look of the houses.
 - Flood risk information would be useful when looking at houses.
 - Map presentation easiest to use, although got confusing when close to boundaries.
 - Table and graphic presentations challenging because of the fraction descriptions of probability (flood frequencies).
 - People have so much information about buying houses that they become overwhelmed and prefer to ignore said information.
 - Strategy: Aesthetics were the main influence.
- 17
- Table presentation easiest to use.
 - Map presentation most difficult to use.
 - Strategy: Energy performance more likely to be compromised for better flood-risk odds, as you one cannot do anything about location of house but can do something about energy performance.
- 18
- Map presentation was most difficult to use and most concerning.
 - Graphic presentation was confusing because the lowest two flood level estimates were very close together and thus difficult to see.
 - Table presentation most useful.
 - Strategy: As experiment progressed participant tended to forget about attending to certain factors, including flood-risk information.
 - Flood-risk information would be useful to have provided when looking to buy a house.

1
2
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4

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6
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10
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12
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15 397 EP/I032622/1].
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21 461 **Figures**

22
23
24 462 Figure 1: Example display in the experiment that shows two different real estate
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26 463 advertisements including information on flood risk in the bottom left. Participants were
27
28 464 asked to select the house that they would prefer.

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31 465 Figure 2: The three ways of presenting the flood risk information that were used on the real
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33 466 estate advertisements: Table (top row); Graphic (middle row) and Map (bottom row) for the
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35 467 three levels of risk: Low Risk (first column); Medium Risk (second column); High Risk
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37 468 (third column).

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41 469 Figure 3. Mean percentage of trials in which the lower risk property was selected
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43 470 within each presentation format (N = 648 for each format; Total N = 1944). Error
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45 471 bars depict the standard error of the estimate of the mean.

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48 472 Figure 4. Mean percentage of trials in which the lower risk property was selected
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50 473 within each risk comparison (N = 648 for each comparison; Total N = 1944). Error
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52 474 bars depict the standard error of the mean.

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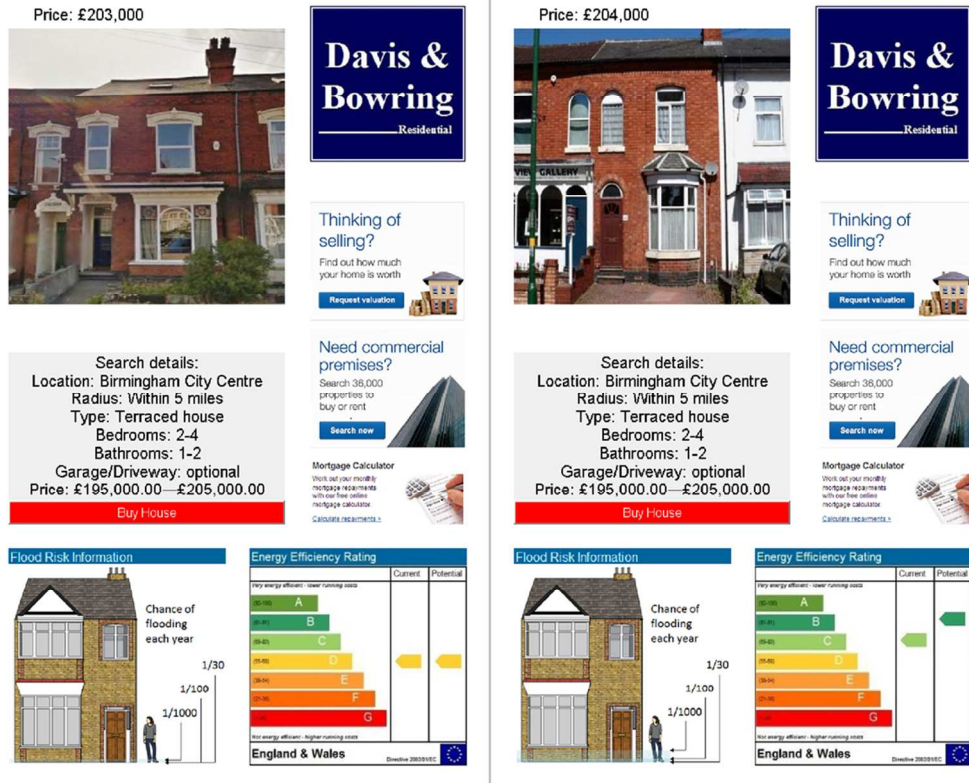


Figure 1: Example display in the experiment that shows two different real estate advertisements including information on flood risk in the bottom left. Participants were asked to select the house that they would prefer.

419x331mm (72 x 72 DPI)

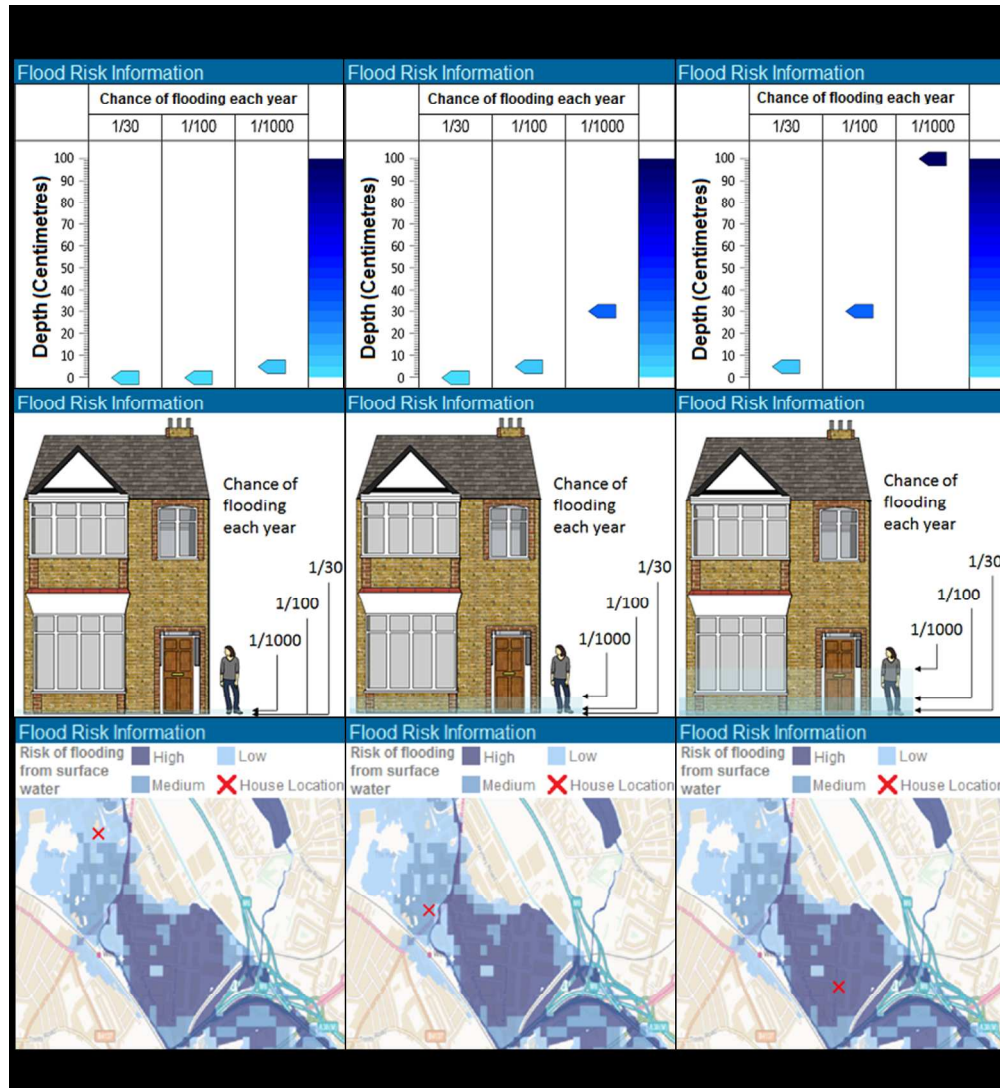


Figure 2: The three ways of presenting the flood risk information that were used on the real estate advertisements: Table (top row); Graphic (middle row) and Map (bottom row) for the three levels of risk: Low Risk (first column); Medium Risk (second column); High Risk (third column).

1335x1449mm (72 x 72 DPI)

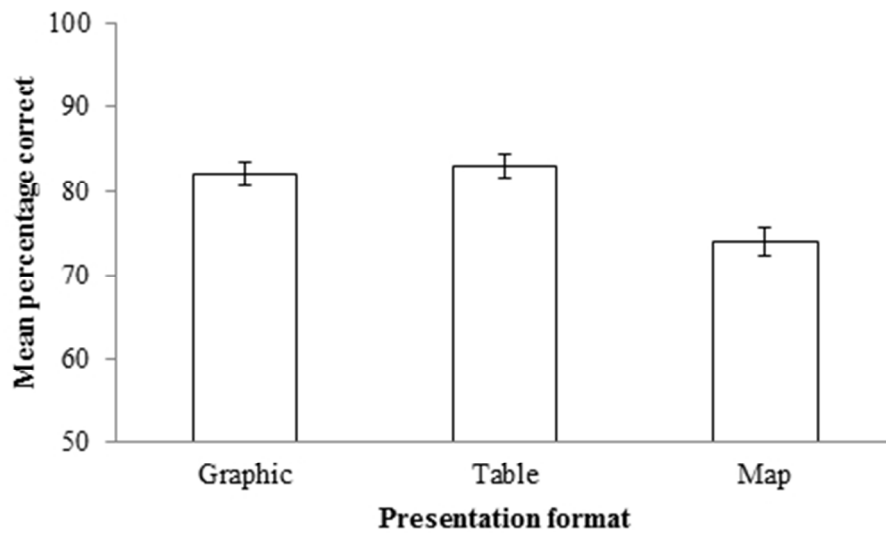


Figure 3. Mean percentage of trials in which the lower risk property was selected within each presentation format (N = 648 for each format; Total N = 1944). Error bars depict the standard error of the estimate of the mean.

178x99mm (72 x 72 DPI)

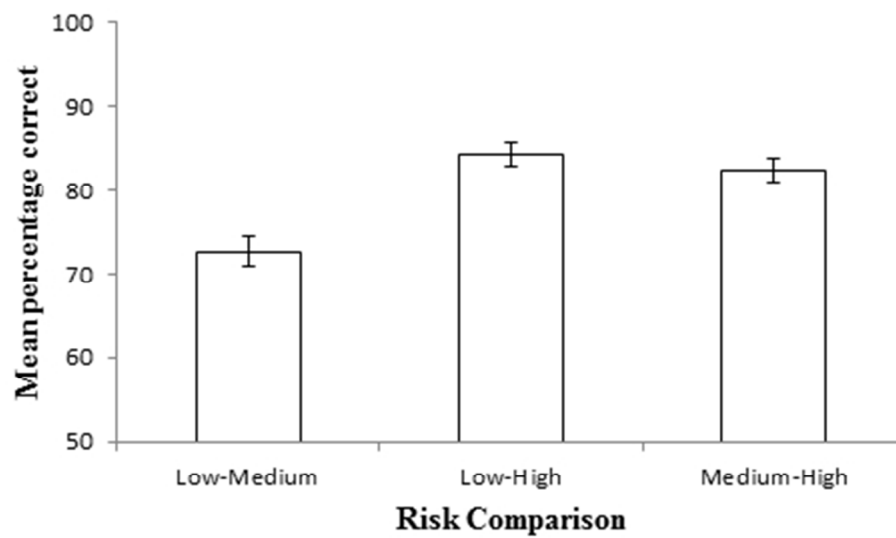


Figure 4. Mean percentage of trials in which the lower risk property was selected within each risk comparison (N = 648 for each comparison; Total N = 1944). Error bars depict the standard error of the mean.

169x101mm (72 x 72 DPI)