Climate Risk Management 34 (2021) 100366

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

# Risk communication nudges and flood insurance demand☆

Peter John Robinson[a,*], W.J. Wouter Botzen[a,b,c], Sem Duijndam[a], Aimée Molenaar[a]

[a] Department of Environmental Economics, Institute for Environmental Studies (IVM), VU University Amsterdam, De Boelelaan 1111, 1081 HV Amsterdam, the Netherlands
[b] Utrecht University School of Economics (U.S.E.), Utrecht University, P.O. Box 80125, 3508 TC Utrecht, the Netherlands
[c] Risk Management and Decision Processes Center, The Wharton School, University of Pennsylvania, Philadelphia, USA

ARTICLE INFO

*Keywords:*
Climate change perceptions
Insurance demand
Natural disaster events
Nudge
Risk communication

ABSTRACT

Losses caused by natural disasters have been increasing worldwide, and climate change is projected to continue this trend in the future. Insurance can be used by individuals to protect against the risk of natural disaster loss. However, individuals often purchase insufficient amounts of insurance against disaster risks, which may be due to them neglecting the likelihood of these risks which are perceived as falling below some threshold level of concern. Using choice architecture, such as alternative forms of risk communication, can nudge individuals to pay attention to natural disasters and increase insurance demand by raising perceived risk and facilitating the comprehension of low probabilities. In an online experiment, we tested whether reframing a low flood probability in terms of the cumulative likelihood across time, as well as whether visualizations of risk on ladders and grids may be effective in raising flood insurance demand. Our primary finding is that reframing of probabilities, especially in combination with the visual aids, generally raises (lowers) demand for flood insurance among younger (older) homeowners and those who are more (less) concerned about the consequences of climate change. Whereas, on average we find no significant impact on flood insurance demand of any of the risk communication tools tested either in isolation or combination. Based on these findings, we draw several lessons for risk communication.

## 1. Introduction

Natural disaster losses have been rising globally in recent decades (Cutter and Emrich, 2005; Hoeppe, 2016). Socio-economic development in hazard prone areas coupled with projected climate change trends means that losses from natural disasters are expected to continue to rise in many regions in the future (Changnon et al., 2000; Jongman et al., 2012; Vousdoukas et al., 2018). Furthermore, individuals can take measures to protect against financial losses caused by natural disasters, such as purchasing insurance.

Despite the availability of cost-effective measures that limit damage costs from natural disasters, many individuals in areas prone to disaster fail to take them (Meyer et al., 2014; Petrolia et al., 2015; Poussin et al., 2015). For example, it has been observed that individuals do not purchase flood insurance at premiums that are close to actuarially fair levels or subsidized (Anderson, 1974;

☆ This study received financial support from the Netherlands Organisation for Scientific Research (NWO) VIDI Grant No. 452.14.005.
* Corresponding author at: Room 8A-13, NU-building, Institute for Environmental Studies (IVM), De Boelelaan 1111, 1081 HV Amsterdam, the Netherlands.
*E-mail address:* peter.robinson@vu.nl (P.J. Robinson).

https://doi.org/10.1016/j.crm.2021.100366
Received 1 February 2021; Received in revised form 26 July 2021; Accepted 19 September 2021
Available online 30 September 2021
2212-0963/

Kunreuther and Pauly, 2004; Kunreuther et al., 1978). Based on nationwide estimates in the United States (US), the proportion of single-family homes residing within Special Flood Hazard Areas (SFHAs) (1/100-year flood zones) that have flood insurance is around one-half, even though many of these homes are required to purchase insurance according to mortgage conditions (Dixon et al., 2006). The same study found that outside SFHAs, in lower risk flood zones where flood insurance is voluntary, the market penetration rate is around 1 percent. Furthermore, in the Netherlands a recent study found that only 2 percent of homeowners currently hold voluntary flood insurance (Robinson et al., 2021).

The tendency of individuals to underestimate low-probability events, like natural disasters, is one reason why preparedness for these events is often low (Viscusi and Zeckhauser, 2006; Kunreuther et al., 2001). A variety of explanations have been proposed related to theory and empirical research from the psychological and behavioural economic literature why individuals underestimate these risks and fail to prepare for them (Friedl et al., 2014; Browne et al., 2015; Fehr-Duda and Fehr, 2016). Low demand for insurance can be caused by search costs associated with gathering information about insurance premiums, coverage and underlying probabilities of loss (Kunreuther and Pauly, 2004). Lack of loss experience has also been shown to be consistently related to low insurance demand, which is perhaps driven by low perceptions of risk (Robinson and Botzen, 2019).

Given that individuals generally find it difficult to process low probabilities (Viscusi, 1998), they may rely on mental shortcuts to make preparedness decisions less complex (Kahneman, 2003). That is, individuals perhaps simplify their assessment of risk by selectively attending to only a few of the relevant facts when making disaster preparedness decisions (Meyer and Kunreuther, 2017). It follows that when facing a potential disaster, individuals may use a threshold model decision heuristic (Slovic et al., 1977; Kunreuther and Pauly, 2004; Robinson and Botzen, 2018) which predicts that they dismiss low probability risks if the probability is deemed as falling below a certain threshold level of concern. Many governments are already informing individuals about annual disaster probabilities. For example, they can find this information according to Federal Emergency Management Agency (FEMA) flood zone classification maps in the US and the flood hazard zoning system (ZÜRS) in Germany. Potential clients of a Dutch insurer that covers flood risk (Neerlandse) could also access their annual likelihood of flooding in the past. Despite these efforts, the aforementioned insufficient levels of disaster preparedness can lead one to doubt the effectiveness of these communication strategies, which is perhaps due to individuals regarding the low annual probability of disaster as below their threshold level of concern.

Appropriately designed choice architecture, i.e., altering the ways choices are framed and presented, can be used to nudge individuals towards certain decisions (Thaler and Sunstein, 2008). For instance, several forms of risk communication as a form of choice architecture have been tested that encourage individuals to pay attention to low probabilities by raising perceived risk above the threshold level of concern. The threshold model decision heuristic is especially applicable to our study that is concerned with a low yearly probability of flood risk, since neglect of risk is common in this setting (Robinson and Botzen, 2018; Botzen et al., 2015). Moreover, one risk communication intervention tested in our paper, namely the reframing of a low likelihood of flood risk occurrence (1 in 100 yearly flood probability) in terms of the cumulative likelihood across time (1 in 3 over forty years) has been shown to increase flood insurance demand in the US (Chaudhry et al., 2020; Bradt, 2019). This effect is perhaps driven by individuals perceiving the flood probability to be above their threshold level of concern once it has been reframed because the cumulative likelihood has also been shown to elevate flood risk perceptions (Keller et al., 2006). While Botzen et al. (2016) found an overall insignificant effect of such framing on investment in flood-proofing measures in the US, certain political subgroups were more likely to invest under the longer time horizon framing, perhaps due to their climate change beliefs. More specifically, it was conjectured that expressing the low probability risk over a longer time period may make the risk more salient to Democrat voters, who already have elevated concern about climate change and therefore higher perceptions of long-term flood risk compared to non-Democrat voters (Guber, 2013; de Bruin et al., 2014). It seems that individuals in this setting selectively appropriate information in ways that reinforce pre-existing attitudes, and thereby exhibit confirmation bias (Lord et al., 1979; Nickerson, 1998).

Other ways of communicating risk aim to facilitate individuals' comprehension of probabilities by accompanying numerical information with visual aids, e.g., risk ladders that communicate baseline probabilities on a scale alongside other risks commonly faced by individuals in practice (Corso et al., 2001; Smith et al., 1990; Sandman et al., 1994; Williams and Hammitt, 2001), and risk grids that display probabilities using an array of shaded and unshaded icons on a rectangular grid (Jones-Lee et al., 1985; Krupnick et al., 2002). It has been shown that these methods of communicating risk can have a positive effect on demand for risk reduction and can increase the sensitivity of demand to probability changes (Botzen and van den Bergh, 2012; Kaplan et al., 1985; Loomis and DuVair, 1993; Dekker et al., 2011). This implies that risk ladders and risk grids may assist comprehension of risk and raise preparedness intentions, compared to providing numerical probability information without a visual aid (for counter evidence see Weinstein et al. (1994) regarding risk grids).

Although there have been several studies that include single risk communication tools, and test for their effect on risk reduction choices, it has to the best of our knowledge not been examined yet whether combining reframed numerical probability information and visual aids can impact protection decisions against natural disaster events. We suspect that combining risk communication that aims to increase risk perceptions with communication that aids in probability comprehension may drive a stronger positive effect on insurance

**Table 1**
Distribution of subjects over the experimental conditions.

| | No visualization | Risk ladder | Risk grid |
|---|---|---|---|
| Yearly 1 in 100 probability | 300 homeowners | 300 homeowners | 300 homeowners |
| 1 in 3 probability over forty years | 300 homeowners | 300 homeowners | 300 homeowners |

demand than either communication method in isolation. Methods that aim to increase perceptions of risk may have little effect on individuals who do not understand risk in the first place. Additionally, there is ample research showing that certain individuals require visual stimuli in order to learn about and retain new information, although the effects of visual stimuli differ among population groups (Hamdani, 2015; Ormrod, 2006), e.g., older vs. younger individuals (Rabbitt, 2017; McPhee et al., 2004; Mahmood et al., 2009; Humphrey and Kramer, 1997). Moreover, in light of evidence that prior beliefs interact with the way that new information is incorporated into subsequent decisions (Botzen et al., 2016; Kappes et al., 2020; Talluri et al., 2018), we expect that pre-existing attitudes, e.g., climate change beliefs, also relate to the effectiveness of communication strategies that frame risk over a longer time horizon.

We test whether reframing flood probabilities as well as communicating of probabilities using risk comprehension aids, can be used to raise insurance demand, both together and in isolation. Acknowledging that the effectiveness of risk communication may differ among certain socio-economic subgroups and individuals with different pre-held beliefs, it is also relevant to examine under what conditions risk communication can be used effectively. We study these themes in an experiment on insurance demand against flood risk conducted with 1,800 Dutch homeowners.

The focus on flooding is driven by floods being the costliest of all natural disaster related events worldwide (Miller et al., 2008; Kousky, 2018). In this respect, the risk communication methods studied in this paper are relevant for policymakers who aim to raise flood preparedness of inhabitants in areas prone to flooding around the world. The Netherlands is an exemplary area for such a study because of the low flood risk awareness of residents (Filatova et al., 2011; Botzen et al., 2009), and high vulnerability to climate change due to the country's low-lying delta (Katsman et al., 2011; Klijn et al., 2012). The aim of our study is to draw generalizable lessons for other regions that also face natural disaster risks.

The remainder of this paper is structured as follows: Section 2 presents the experiment method and descriptive statistics. Section 3 details the main results related to the impact of risk communication on flood insurance demand. Section 4 discusses these results in relation to other studies and lessons which can be drawn from the findings. Section 5 concludes the paper.

## 2. Experiment method

In total 1,800 Dutch homeowners were recruited via invitation emails for the experiment through random draws of members of the survey panel of Panel Inzicht (https://panelinzicht.nl) during June and July 2020. The email did not state the nature of the experiment to prevent selection bias. Overall, the experiment follows a similar framing to that of Robinson et al. (2021), whereby homeowners had to decide whether or not to include flood coverage in an insurance policy that covers fire and burglary related losses, under a specified probability of flooding and expected flood damage amount. We chose to implement our study in the Netherlands, where perceptions of flood risk and individual preparedness against flooding is generally low (Botzen et al., 2009; Terpstra and Gutteling, 2008; Robinson et al., 2021; Bosschaart et al., 2016; Kerstholt et al., 2017). This may partly be a consequence of the lack of recent flood experiences here, apart from a few small localized events (Wind et al., 1999; van Stokkom et al., 2005; Aerts and Botzen, 2011). Note that flood insurance is not included in homeowners policies in the Netherlands but this coverage has been offered by a private insurer, Neerlandse, since 2016 on a voluntary basis.

Prior to implementing the experiment, a pre-test was conducted among 298 students of Vrije Universiteit Amsterdam. Both the pre-test and the experiment among homeowners was conducted online which allowed for obtaining a large and diverse sample at a relatively low cost. Moreover, this method prevented communication between subjects and interviewer effects (Horton et al., 2011). We chose to implement the final experiment among homeowners rather than renters because they are more likely to be responsible for structural damage to their home if a flood occurs. The average age of these homeowners in our sample is close to 50 years and 51% are male. Furthermore, of those who were willing to reveal their education and income level, 81% hold either a Bachelor's degree, Master's degree or PhD, and the average household monthly after tax income level is between €3,000 and €3,999. In the actual Dutch population, the average age is 42 years as of 2020, 40% of Dutch adults (25–64 years) have higher education (2019), and average monthly disposable household income is €3,700 (2019).[1] Our sample over-represents older and highly educated individuals compared to the Dutch population, which may be due to the fact that we targeted homeowners.

After some initial socio-economic questions, subjects were asked to: "Imagine that you have just moved in to a new home in the Netherlands which you purchased for €260,000. Your new home is at risk of flooding. The government will **not** reimburse you for any flood damage you suffer if you do not insure your home."

Subjects were then randomly assigned to face one of six conditions: a condition in which the flood probability is described as a yearly 1 in 100 chance of flooding; a condition in which the yearly probability is described in terms of a 1 in 3 likelihood that at least one flood occurs over a forty-year time horizon; a condition in which the yearly flood probability is accompanied by a risk ladder that

[1] Age and income figures are retrieved from https://cbs.nl. Education attainment is retrieved from https://stats.oecd.org.

*Yearly flood probability*

Every year there is a **1 in 100** chance that your new home will be **flooded**. {If applicable additional text that describes the yearly probability of flooding according to the risk ladder or risk grid.}

*Flood probability over forty years*

Over the next forty years there is a **1 in 3** chance that your new home will be **flooded** at least once. {If applicable additional text that describes the probability of flooding over forty years according to the risk ladder or risk grid.}

The estimated damage from a flood to your new home is **€6,400**.

You have purchased an insurance policy from your insurance agent. This standard policy covers fire and burglary related losses for the price of **€128** per year.

You may add flood coverage to your insurance policy and it will increase your annual insurance premiums by **€64** (resulting in a total insurance cost of **€192**).

{If applicable insert risk ladder or risk grid}

Do you choose to add flood coverage to your insurance policy? Yes/No

**Fig. 1.** Flood insurance demand elicitation over the yearly flood probability and the flood probability framed over forty years.

communicates to subjects the risk of flooding alongside other risks that individuals typically face in the Netherlands;[2] a condition in which the flood probability over forty years is accompanied by the risk ladder; a condition in which the yearly flood probability is accompanied by a risk grid that communicates to subjects the risk of flooding according to an array of flooded and non-flooded houses; and a condition in which the flood probability over forty years is accompanied by the risk grid.[3] Appendix A displays the risk ladders and risk grids that were used to communicate the risk of flooding. Table 1 provides summary information regarding the numbers of subjects assigned to each experimental condition.

The following wording was used to describe the yearly flood probability: “Every year there is a **1 in 100** chance that your new home will be **flooded**.” The conditions that included the flood probability framed over forty years used the alternative text: “Over the next forty years there is a **1 in 3** chance that your new home will be **flooded** at least once.” Note that within conditions that included a risk ladder, additional text was included immediately following the description of the flood probability: “This means that every year [over the next forty years] 1 in 100 [1 in 3] homes in your neighborhood will flood (as you can see in the scale shown together with a number of other risks that a Dutch person faces on average).”[4] Within conditions that included a risk grid the following text was used instead: “This means that every year [over the next forty years] 3 out of 300 [100 out of 300] homes in your neighborhood will flood (as you can see in the picture where each blue-coloured home represents a flooded home).” The conditions asked subjects whether they would like to add flood coverage to a pre-purchased insurance policy which covers fire and burglary related losses. Fig. 1 presents the English translation of the way flood insurance demand was elicited.

The risk ladders use log-spacing, which results in an improvement in the communication of small probabilities over linearly-spaced risk ladders (Corso et al., 2001). Furthermore, flood risk is placed near the top of the ladder, behind the highest risk of bicycle theft. According to previous studies, perceived risk is greater for risks with such placing than for risk ladders that place the risk in question at the bottom of the ladder (Sandman et al., 1994; Logar and Brouwer, 2017). The risk grids employed an array of the same number of

[2] The values of these other risks were determined based on the most recent information available for the Netherlands (Statistics Netherlands, 2019).

[3] The homeowner sample size is of sufficient statistical power (power = 0.9 and significance level = 0.05) to detect the relevant main effect sizes for parameters of interest based on the pre-test, except for the main effect of accompanying the yearly flood probability with a risk grid. The possible impact of providing the risk grid on risk perceptions and flood preparedness was not clear according to previous literature (Dekker et al., 2011; Kaplan et al., 1985; Weinstein et al., 1994). The influence of the risk grid on flood insurance demand was also uncertain according to the results of the pre-test because the main effect of this variable on flood insurance demand is not close to significance. Therefore, our power analysis is based on the main effect sizes for the other parameters of interest only.

[4] We chose to communicate to respondents the proportion of homes in their neighborhood that will flood over the specified time period to simplify the decision environment, even though this is not strictly correct. In fact, there is an expectation of a proportion of homes that will flood within the time period. There is no guarantee that any homes will actually flood.

**Table 2**
Summary of variables for homeowner sample.

| Dependent variable | Measurement | Coding | M (SD)[a] |
|---|---|---|---|
| Flood insurance demand | Dummy variable measure of flood insurance demand | Insure = 1 and do not insure = 0 | 0.551 N = 1,800 |
| Yearly | Dummy variable measure of assignment to yearly 1 in 100 probability-no visualization condition | Assigned to yearly 1 in 100 probability-no visualization condition = 1 and otherwise = 0 | 0.167 N = 1,800 |
| Yearly ladder | Dummy variable measure of assignment to yearly 1 in 100 probability-risk ladder condition | Assigned to yearly 1 in 100 probability-risk ladder condition = 1 and otherwise = 0 | 0.167 N = 1,800 |
| Yearly grid | Dummy variable measure of assignment to yearly 1 in 100 probability-risk grid condition | Assigned to yearly 1 in 100 probability-risk grid condition = 1 and otherwise = 0 | 0.167 N = 1,800 |
| Forty-year | Dummy variable measure of assignment to 1 in 3 probability over forty years-no visualization condition | Assigned to 1 in 3 probability over forty years-no visualization condition = 1 and otherwise = 0 | 0.167 N = 1,800 |
| Forty-year ladder | Dummy variable measure of assignment to 1 in 3 probability over forty years-risk ladder condition | Assigned to 1 in 3 probability over forty years-risk ladder condition = 1 and otherwise = 0 | 0.167 N = 1,800 |
| Forty-year grid | Dummy variable measure of assignment to 1 in 3 probability over forty years-risk grid condition | Assigned to 1 in 3 probability over forty years-risk grid condition = 1 and otherwise = 0 | 0.167 N = 1,800 |
| Risk preference | General willingness to take risks | Completely unwilling to take risks = 0 to very willing to take risks = 10 | 4.979 (2.062) N = 1,800 |
| Flooding experience | Dummy variable measure of previous flood experience | Flooded in the past = 1 and not flooded in the past = 0 | 0.058 N = 1,800 |
| Ground floor | Dummy variable measure of ground floor home | Ground floor home = 1 and non-ground floor home = 0 | 0.858 N = 1,800 |
| Worry | I am worried about the danger of flood damage to my current house | Strongly disagree = 1 to strongly agree = 7[b] | 2.696 (1.570) N = 1,800 |
| Concern climate change | I am concerned about the consequences of climate change | Z-scored Likert scale responses (strongly disagree = 1 to strongly agree = 7) | 0.000 (1.000) N = 1,800 |
| Age | Continuous variable of age in years | Age in years | 49.854 (16.285) N = 1,800 |
| Male | Dummy variable measure of gender | Male = 1 and female = 0 | 0.510 N = 1,800 |
| Higher education[c] | Dummy variable measure of higher education | Higher education = 1 and non-higher education = 0 | 0.813 N = 1,585 |
| Income[d] | Ordinal variable measure of after tax household monthly income | Less than €1,000 = 1 to €10,000 or more = 9 | 4.724 (1.495) N = 1,446 |

Notes:
[a] The mean or proportion (M) is provided with the standard deviation (SD) in parentheses.
[b] Interior agreement categories are: disagree = 2; somewhat disagree = 3; neither disagree nor agree = 4; somewhat agree = 5; agree = 6.
[c] Higher education refers to: Bachelor's degree, Master's degree or PhD.
[d] Interior income categories are: between €1,000 and €1,499 = 2; between €1,500 and €1,999 = 3; between €2,000 and €2,999 = 4; between €3,000 and €3,999 = 5; between €4,000 and €4,999 = 6; between €5,000 and €6,999 = 7; between €7,000 and €9,999 = 8.

houses between the yearly flood probability and flood probability over forty years conditions. This counters the tendency for individuals to neglect denominators when making risky choices involving risk grids with different denominators (Garcia-Retamero and Cokely, 2017; Garcia-Retamero et al., 2010).

We chose one yearly probability (which is equivalent probabilistically to the probability of at least one flood occurring over forty years) and damage amount to compare the impact of risk communication over the various conditions. An annual flood probability of 1 in 100 was included in the experiment, since reframing of this probability in terms of the cumulative likelihood across time results in a relatively larger cumulative likelihood than if a lower annual probability had been adopted. For example, expressing a yearly probability of 1 in 1,000 in terms of at least one event occurring over a forty-year time horizon, results in a cumulative likelihood of around 1 in 25. This cumulative likelihood may not overcome individuals' threshold levels of concern. Moreover, it has been noted that on average the cumulative likelihood that we incorporate (1 in 3) is less likely to be subjectively distorted due to probability weighting, than any other likelihood in the probability space (Wakker and Deneffe, 1996). This entails that we compare behaviour under an annual probability that individuals may have a hard time processing (Tversky and Kahneman, 1992) to a cumulative likelihood that may be processed well. Moreover, including the 1 in 100 annual probability allows us to compare our findings to similar studies (Chaudhry et al., 2020; Bradt, 2019). The 1 in 100 probability is also commonly used in delineating flood inundation zones and for mapping and communicating flood risk. For example, the SFHAs used by FEMA in the US are defined as areas that will be inundated by a flood event with a 1 percent chance of being equaled or exceeded in any given year. Our decision to provide the flood risk in frequentist terms is driven by research that shows that individuals generally understand and process information better in frequency than e.g., percentage formats (Gigerenzer, 1996; Gigerenzer and Hoffrage, 1995).

Flood probabilities of 1 in 100 and higher in the Netherlands are found in areas where flood water depths as well as potential damage amounts are quite low on average (Ermolieva et al., 2017). We incorporated a damage amount of €6,400, which is less than the amounts used in similar studies, where lower probabilities were investigated (Botzen and van den Bergh, 2012; Robinson and Botzen, 2018). A damage of €6,400 would be more representative of a loss for a moderate to large pluvial flood event than catastrophic flooding that may result from dike failure (Spekkers et al., 2013; van Ootegem et al., 2015). The flood insurance premium was set at the actuarially fair (€64) level (equal to probability multiplied by damage).

**Table 3**
Probit model of the likelihood of flood insurance purchase.

| | Model I: Individual difference variables | Model II: Including condition variables | Model III: Including age category | Model IV: Including concern climate change |
|---|---|---|---|---|
| Risk preference | −0.042*** (0.01) *−0.016**** | −0.043*** (0.01) *−0.016**** | −0.047*** (0.02) | −0.042*** (0.02) |
| Flooding experience | 0.782*** (0.16) *0.293**** | 0.786*** (0.16) *0.294**** | 0.764*** (0.17) | 0.796*** (0.17) |
| Ground floor | 0.282*** (0.09) *0.106**** | 0.287*** (0.09) *0.107**** | 0.292*** (0.09) | 0.306*** (0.09) |
| Worry | 0.147*** (0.02) *0.055**** | 0.147*** (0.02) *0.055**** | 0.141*** (0.02) | 0.133*** (0.02) |
| Yearly ladder | | 0.111 (0.11) *0.042* | 0.447* (0.23) | 0.448** (0.23) |
| Yearly grid | | −0.047 (0.10) *−0.018* | −0.133 (0.22) | −0.128 (0.22) |
| Forty-year | | −0.037 (0.10) *−0.014* | 0.330 (0.23) | 0.335 (0.23) |
| Forty-year ladder | | −0.148 (0.10) *−0.055* | 0.105 (0.23) | 0.085 (0.23) |
| Forty-year grid | | 0.010 (0.10) *0.004* | 0.437* (0.23) | 0.471** (0.23) |
| Age category | | | 0.023 (0.03) | 0.023 (0.03) |
| Yearly ladder × age category | | | −0.061* (0.04) | −0.062* (0.04) |
| Yearly grid × age category | | | 0.015 (0.04) | 0.015 (0.04) |
| Forty-year × age category | | | −0.067* (0.04) | −0.067* (0.04) |
| Forty-year ladder × age category | | | −0.046 (0.04) | −0.043 (0.04) |
| Forty-year grid × age category | | | −0.078** (0.04) | −0.081** (0.04) |
| Concern climate change | | | | −0.037 (0.08) |
| Yearly ladder × concern climate change | | | | 0.074 (0.11) |
| Yearly grid × concern climate change | | | | 0.142 (0.11) |
| Forty-year × concern climate change | | | | 0.052 (0.11) |
| Forty-year ladder × concern climate change | | | | 0.215** (0.11) |
| Forty-year grid × concern climate change | | | | 0.218** (0.10) |
| Constant | −0.333*** (0.12) | −0.312** (0.14) | −0.401** (0.20) | −0.422** (0.20) |
| Observations | 1,800 | 1,800 | 1,800 | 1,800 |
| Pseudo-$R^2$ | 0.049 | 0.052 | 0.057 | 0.063 |
| Log-likelihood | −1,177.6 | −1,174.4 | −1,167.9 | −1,160.8 |

Notes:
***Significant at 1%; **Significant at 5%; *Significant at 10%.
Coefficient estimates are provided with standard errors in parentheses. The average marginal effects of *risk preference*, *flooding experience*, *ground floor*, *worry*, *yearly ladder*, *yearly grid*, *forty-year*, *forty-year ladder* and *forty-year grid* are italicized.

Following the flood insurance decision, subjects were asked a number of questions based on their risk preferences, current objective levels of flood risk and flooding experience, risk perceptions, as well as their socio-economic characteristics (Table 2).[5] Risk preferences were elicited following Dohmen et al. (2011): “How do you see yourself: are you generally a person who is willing to take risks or do you try to avoid taking risks? Please use a scale from 0 to 10, where a 0 means you are ‘completely unwilling to take risks’, and a 10 means you are ‘very willing to take risks’. You can also answer values in-between to indicate where you fall on the scale.” Their survey-based measure is strongly correlated with the way that individuals make choices in paid lottery decisions. Moreover, the authors showed that the measure is a good predictor of a range of risky behaviours in practice.

Indicators of subjects’ current flood risk and flooding experience were also derived. To determine whether subjects had experienced flooding at their home in the past (yes/no), we asked: “Has your home been flooded in the past when you were living in it?” Furthermore, to ascertain whether possible flood water levels may reach the current home of subjects (yes/no), they were asked: “Do you live on the ground floor?”

To gain insights into subjects’ perception of flood risk at the actual home they live in currently, we asked them to indicate the extent to which they agree with the following in line with Robinson and Botzen (2018) and Botzen et al. (2015): “I am worried about the danger of flood damage to my current house.” Moreover, risk perceptions related to climate change were derived according to the extent subjects agreed with: “I am concerned about the consequences of climate change.” This variable has been z-scored for the analysis in section 3. Appendix B displays the distribution of risk preferences, risk perceptions, age and income in our sample.

In the forthcoming results sections we adopt the Probit model to examine the relationship between flood insurance demand and variables of interest. Whereas, in general there are three statistical models used in applied microeconometrics where the dependent variable is a binary choice (such as ours): the Linear Probability model, the Logit model and the Probit model (Aldrich and Nelson, 1984). We prefer the Probit model to the Linear Probability model because the Probit model prevents predicted probabilities from falling outside the unit interval (Horowitz and Savin, 2001). The difference between the Logit and Probit model lies in the assumption

[5] All correlation coefficients among explanatory variables are lower than 0.5, therefore multicollinearity should not pose a problem for our analysis (Hensher et al., 2005).

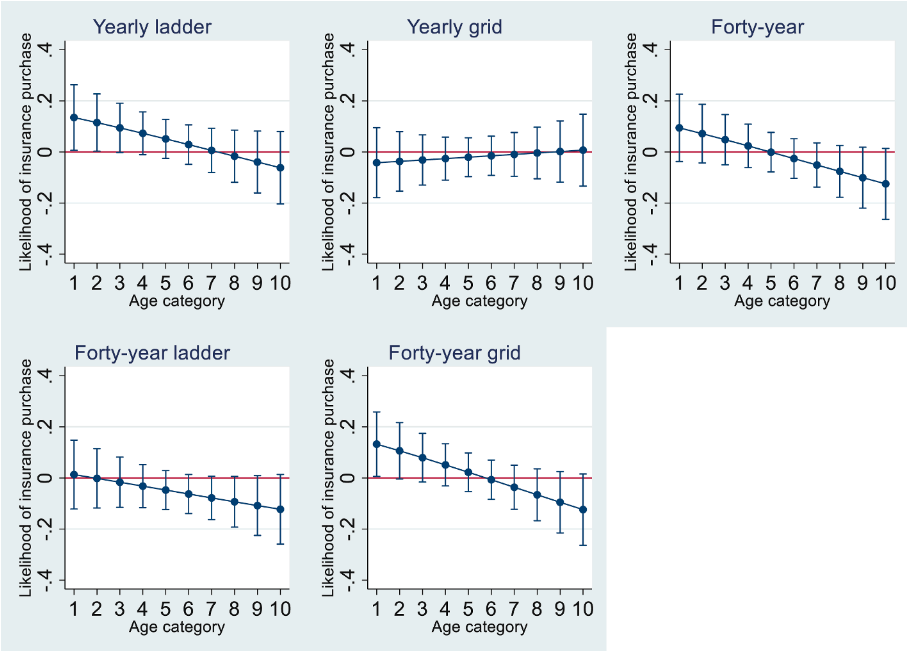


**Fig. 2.** ME of *yearly ladder*, *yearly grid*, *forty-year*, *forty-year ladder* and *forty-year grid* risk communication on the likelihood of flood insurance purchase across the *age category* variable.

about the distribution of the errors which are unobserved (Cameron and Trivedi, 2005). Nevertheless, predicted probabilities yielded from the Probit model and Logit model tend to be very similar (Wooldridge, 2010). In our experience, the Probit model is more widely accepted in the field of microeconomics, hence our decision to adopt the Probit model. However, applying either the Probit, Logit or Linear Probability model to our data provides almost identical qualitative results (see Appendix C).

## 3. Results

### 3.1. Regression analysis

Table 3 provides a Probit model analysis of the likelihood of flood insurance purchase. Model I contains significant individual difference variables, *risk preference*, *flooding experience*, *ground floor* and *worry*. As expected, more risk seeking homeowners are significantly less likely to demand flood insurance. Whereas, those who have experienced a flood at their home in the past, as well as individuals who currently live on the ground floor, are significantly more likely to purchase insurance. Apparently, individuals' previous flooding experiences and objective levels of flood risk enter into their flood insurance choices for the hypothetical new home we ask them to consider in the experiment (see Kusev et al. (2009)). This result may follow from the availability heuristic (Tversky and Kahneman, 1974). Higher levels of worry about flooding at one's current home is also associated with significantly increased demand for flood insurance.

Model II includes the risk communication condition dummy variables *yearly ladder*, *yearly grid*, *forty-year*, *forty-year ladder* and *forty-year grid*. The baseline reference category is *yearly*. The Probit model coefficient estimates of model II show that on aggregate the impact of risk communication on flood insurance demand is not significant.

Model III adds to the regression analysis a variable that represents age decile categories (1 = data $\leq$ the 1st age decile; 2 = data $>$ the 1st age decile and $\leq$ the 2nd age decile, etc.), i.e., *age category*, and interaction terms between *age category* and the risk communication conditions. For younger age categories there is a positive impact of variables *yearly ladder* and *forty-year grid* on demand for flood insurance. This positive impact is lower in magnitude for intermediate age categories. For higher categories of age the impact is negative, meaning that the *yearly ladder* and *forty-year grid* variables reduce demand for insurance among older homeowners. However, this latter effect is only significant (at the 10% level) with regards to the average marginal effect (ME) of *forty-year grid* for the oldest age category according to the fifth panel of Fig. 2.

There is also a negative effect (significant at the 10% level) of variable *forty-year* on flood insurance demand for older categories of age. Furthermore, there is a negative insignificant coefficient estimate on the interaction term between *forty-year ladder* and *age category*, although the graphical analysis in the proceeding section shows that the effect of this variable on flood insurance demand is

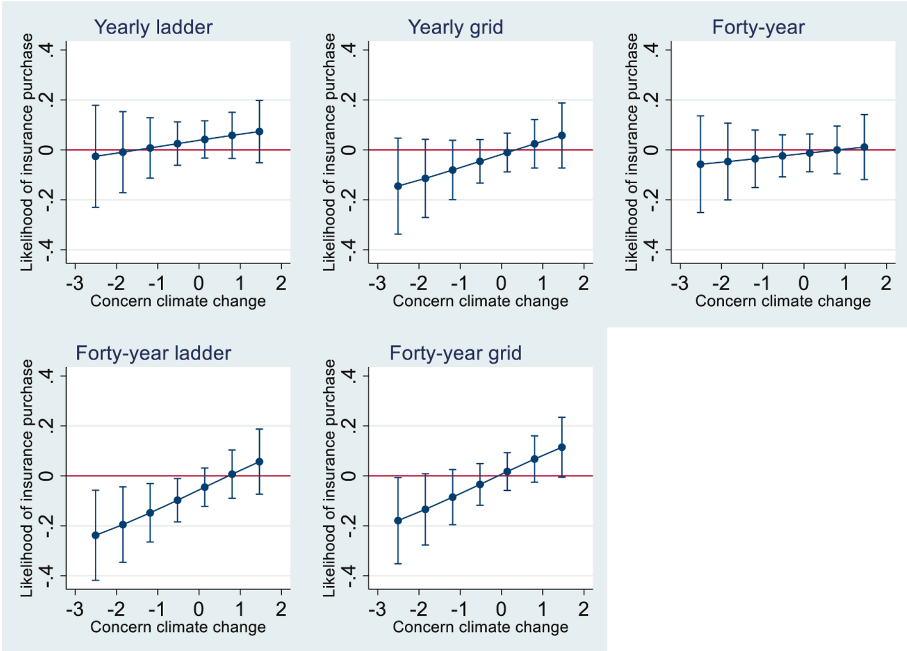


**Fig. 3.** ME of *yearly ladder*, *yearly grid*, *forty-year*, *forty-year ladder* and *forty-year grid* risk communication on the likelihood of flood insurance purchase across the *concern climate change* variable.

negative and significant at the 10% level among older age groups.[6] It is interesting that the sum of coefficient estimates on interaction terms between *yearly ladder* and *age category* as well as *forty-year* and *age category* is less than the coefficient estimate on the interaction term between *forty-year ladder* and *age category*. This implies that the negative dependency of the impact of the risk ladder and forty-year framing on flood insurance demand based on age, is stronger for the two components in isolation than when they are combined. Concerning the coefficient estimate on the interaction term between *yearly grid* and *age category*, the estimate and associated MEs are insignificant according to any standard significance level, as is the level-effect of *yearly grid* based on the coefficient estimate on this variable.

One may suspect that the correlation between age and risk communication effectiveness is partly related to concern about climate change. Because older individuals tend to be less concerned about the consequences of climate change (Andor et al., 2018; Shi et al., 2016; Kellstedt et al., 2008; McCright, 2010; Tjernström and Tietenberg, 2008; Duijndam and van Beukering, 2021),[7] this might make them less sensitive to some forms of risk communication, specifically the framing of flood probabilities over longer time horizons. We can look at this by examining the significance of the coefficient estimates on interaction terms between *age category* and the risk communication conditions once the *concern climate change* variable, as well as interaction terms between *concern climate change* and the conditions of risk communication are added to the model (model IV). If the coefficient estimates on interaction terms between *age category* and the risk communication conditions fall in magnitude and significance, this would imply that (some of) the correlation between age and the impact of risk communication is related to climate change concern. That is, there would be confounding effects between the two interaction terms. Nevertheless, according to model IV the magnitude of the coefficient estimates on interaction terms between *age category* and the risk communication conditions remain fairly stable, as do the coefficient estimates on the level-effects of the risk communication. It seems that age may be related to the effectiveness of risk communication through other mechanisms than concern about climate change.

There are positive coefficients (significant at the 5% level) on the *concern climate change* and *forty-year ladder* interaction as well as the *concern climate change* and *forty-year grid* interaction. This implies that *forty-year ladder* and *forty-year grid* communication raises (lowers) demand for flood insurance among those who are more (less) concerned about the consequences of climate change. According to the analysis of MEs in the next section, the relation between climate change concern and the risk communication is mainly that individuals with the lowest levels of concern about climate change are less inclined to insure under the *forty-year ladder* and *forty-year grid* conditions, relative to the baseline. Only among those who display the highest level of concern about climate change is there a positive (significant at the 10% level) impact of *forty-year grid* on the likelihood of insurance purchase.

[6] Note that statistical significance can change between calculation of coefficient estimates and MEs for binary choice models.

[7] Climate change impacts take a long time to manifest, so the likelihood that older individuals are not around when they do occur is higher. However, there is a negative insignificant coefficient estimate of −0.007 on *age category* in an Ordered Probit model of *concern climate change* (p-value > 0.1).

We have chosen to omit other socio-economic variables, *male*, *higher education* and *income*, because of the reduction in sample size that would result from including these variables and since they are not predictive of insurance demand. That is, insignificant coefficient estimates were found on these socio-economic variables in an extension to model IV that includes these variables as covariates. Moreover, in other exploratory analyses we tested whether the impact of risk communication on flood insurance demand is sensitive to these other socio-economic variables. We found no significant coefficient estimates on interaction terms between risk communication and *male*, *higher education* as well as *income* (p-values $> 0.1$).[8]

### 3.2. Graphical analysis

Figures 2 and 3 show the MEs of the risk communication on the likelihood of flood insurance purchase across age categories and concern about climate change, respectively. The figures are based on the most elaborate Probit model analysis of the likelihood of flood insurance purchase (model IV). There is overall a negative relationship between age and the effectiveness of the risk communication conditions (apart from *yearly grid*) in raising flood insurance purchase. Compared to the baseline, there is a positive significant effect of the *yearly ladder* variable on the insurance purchase likelihood among individuals aged $\leq$ the 4th age decile by 13 (standard error and p-value = 0.065 and 0.040), 11 (standard error and p-value = 0.057 and 0.044), 9 (standard error and p-value = 0.049 and 0.055) and 7 (standard error and p-value = 0.043 and 0.087) percentage points when *age category* = 1, 2, 3 and 4 respectively. There is also a positive significant impact of the variable *forty-year grid* for those aged $\leq$ the 2nd decile of age by 13 (standard error and p-value = 0.064 and 0.040) and 11 (standard error and p-value = 0.056 and 0.059) percentage points when *age category* = 1 and 2 respectively.

However, the effect of variables *forty-year*, *forty-year ladder* and *forty-year grid* is negative among individuals aged $>$ the 8th age decile by −10 (standard error and p-value = 0.061 and 0.098) and −12 (standard error and p-value = 0.071 and 0.077) percentage points when *age category* = 9 and 10, the 6th age decile by −8 (standard error and p-value = 0.043 and 0.071), −9 (standard error and p-value = 0.051 and 0.065), −11 (standard error and p-value = 0.060 and 0.070) and −12 (standard error and p-value = 0.070 and 0.078) percentage points when *age category* = 7, 8, 9 and 10, and the 9th age decile by −12 (standard error and p-value = 0.071 and 0.082) percentage points when *age category* = 10, respectively. Therefore, although in some conditions the risk communication leads to higher demand for flood insurance for younger individuals, in others it leads to lower levels of insurance demand among older individuals.

Among homeowners who have strong concern about the consequences of climate change, the variable *forty-year grid* raises the likelihood of flood insurance purchase by 11 (standard error and p-value = 0.061 and 0.061) percentage points compared to the baseline. Moreover, for individuals who strongly disagree, disagree, somewhat disagree and neither disagree nor agree with the concern about climate change statement, the *forty-year ladder* condition has a negative effect on flood insurance demand by −24 (standard error and p-value = 0.092 and 0.010), −20 (standard error and p-value = 0.077 and 0.011), −15 (standard error and p-value = 0.060 and 0.013) and −10 (standard error and p-value = 0.044 and 0.028) percentage points respectively. Among those who strongly disagree and disagree with the concern statement, the forty-year grid condition also has a negative effect on flood insurance demand by −18 (standard error and p-value = 0.088 and 0.042) and −13 (standard error and p-value = 0.073 and 0.066) percentage points respectively.

## 4. Discussion

### 4.1. Discussion of results in relation to previous studies

Natural disaster losses are rising under climate change and socio-economic developments in disaster-prone regions. However, individuals tend to dismiss risks posed by natural disasters because they have a low occurrence probability. Risk communication has the potential to stimulate behavioural change by encouraging individuals to pay attention to low probabilities and facilitating their comprehension. We studied whether the communication of risk using probability visual aids, i.e., risk ladders and risk grids, as well as reframing of probabilities in terms of the cumulative likelihood across time, can be effective in nudging individuals towards higher demand for insurance against disaster risk. We conducted an online experiment of flood insurance choices made by 1,800 homeowners in the Netherlands, who were randomly assigned to face several conditions of risk communication. Possible moderators of the effects of risk communication were investigated, i.e., age and concern in relation to climate change consequences.

Insights into effective risk communication are useful for many regions around the world that face flood risk, and at the same time low public awareness of flood risk and flood preparedness (Burningham et al., 2008; Scolobig et al., 2012; Ludy and Kondolf, 2012; Viscusi and Zeckhauser, 2006; Lo, 2013). Furthermore, strong population heterogeneity in terms of climate change concern is observed

[8] According to the suggestion of one reviewer, we examined whether for higher income individuals, older homeowners have different risk preferences, compared to younger homeowners. Since we find that among higher income homeowners, i.e., for those with *income* $>$ median income category (5), *age category* and *risk preference* are negatively correlated (Spearman's rho = −0.168, p-value $< 0.05$), older individuals with higher than median incomes are more risk averse. For these high income homeowners, we tested whether there is a change in the significance of coefficient estimates on interaction terms between risk communication and age after *risk preference* and its interaction effect with risk communication has been controlled for. There is no overall change in the significance of coefficient estimates on these interaction terms. Overall, this suggests that among high income homeowners, a difference in risk preferences is not driving a conditional effect of risk communication on flood insurance demand based on age.

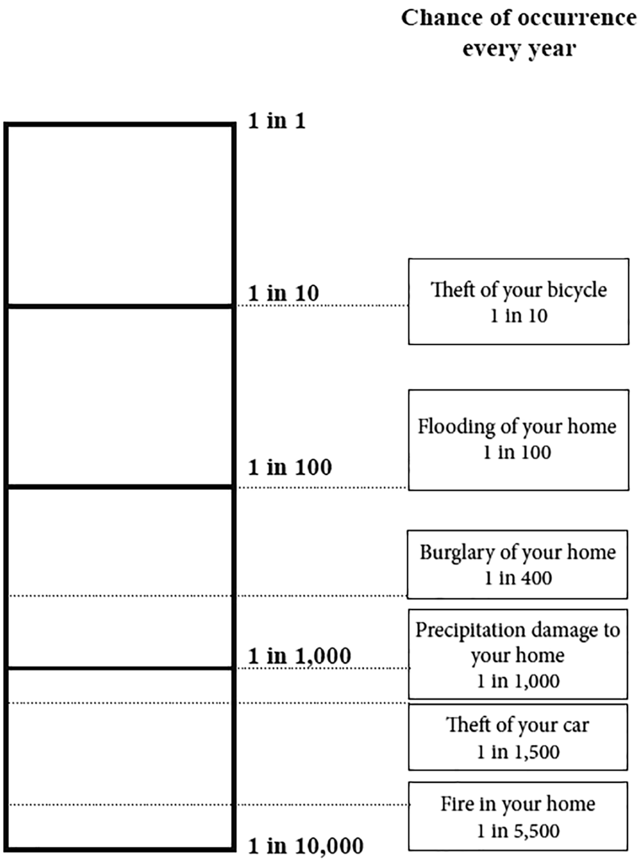


**Fig. A1.** The yearly flood probability accompanied by a risk ladder that communicates the risk alongside other risks in the Netherlands.

worldwide (Duijndam and van Beukering, 2021; Capstick et al., 2015; Brechin, and Bhandari, 2011). The same naturally holds for population variations in age, which demonstrates that the importance of age and climate change concern regarding the influence of risk communication strategies as found in this study has potentially much wider implications than for the Netherlands alone.

The main finding of this paper is that reframing of probabilities over longer time horizons, especially in combination with visual aids, tends to raise (lower) flood insurance demand among younger (older) homeowners and those who are more (less) concerned about the consequences of climate change. Our analysis that accounts for individual-level heterogeneity based on age and climate change concern does not completely contradict the results of Chaudhry et al. (2020) and Bradt (2019). Both authors find that in the US extending the time horizon over which the flood probability is framed raises demand for insurance against flooding. Furthermore, there are several differences between our study and theirs. First, their samples are more familiar with flooding events. Chaudhry et al. (2020) sampled coastal counties including a large proportion of individuals living in SFHAs, where the annual likelihood of flooding is 1 in 100. For the Netherlands 1 in 100 yearly flood probabilities and higher are only found in a few less populated areas (Rijkswaterstaat, 2016). Moreover, almost one-half of the individuals recruited for Bradt's (2019) study had experienced a natural disaster in the past.[9] Given the high risk of flooding within these two samples, individuals may be more likely to pay attention to flood risk in the first place than in our sample of Dutch homeowners who have very little experience with flooding. This would confirm the availability heuristic described earlier in this article, which predicts that individuals in the Netherlands are less likely to pay attention to the risk of flooding because they have less flood related experience. It has been shown empirically that flood experience positively impacts flood risk perceptions and flood preparedness (Osberghaus, 2017; Gallagher, 2014; Atreya et al., 2015; Robinson and Botzen, 2019).

In addition, we believe that perceptions of climate change which relate to perceptions of long-term flood risk are more salient to individuals who are more frequently exposed to natural disasters. In the sample of Bradt (2019) there is a high level of agreement that man-made climate change is occurring, and that sea-level rise is happening as a consequence of climate change. There is also a plethora of research showing that individuals selectively attend to information depending on whether the information reinforces their prior beliefs (Lord et al., 1979; Nickerson, 1998; Allahverdyan and Galstyan, 2014; Friedrich, 1993). This may also hold when individuals evaluate risk communication interventions, as it has been demonstrated that reframing flood probabilities over an extended time period effectively stimulates preparedness actions for individuals who likely already have high long-term flood risk perceptions

[9] Around 30% had experienced flooding in particular.

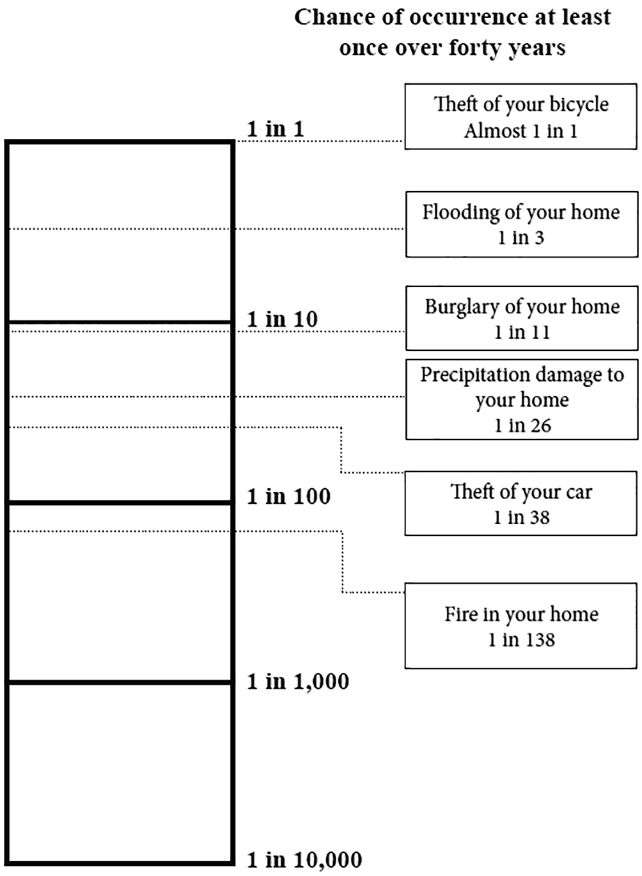


**Fig. A2.** The flood probability over forty years accompanied by a risk ladder that communicates the risk alongside other risks in the Netherlands.

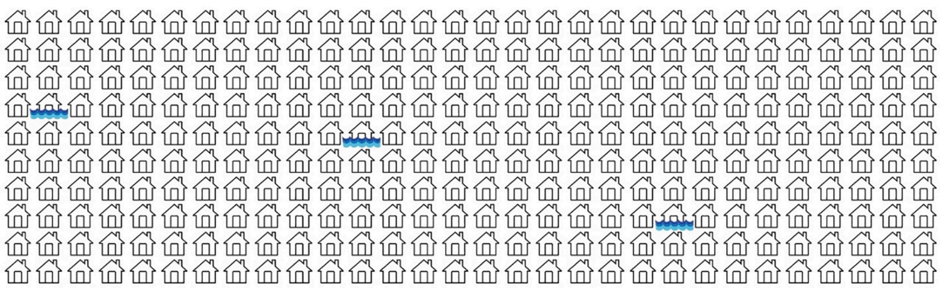

**Fig. A3.** The risk grid that communicates the yearly flood probability according to an array of flooded and non-flooded houses.

(Botzen et al., 2016). We find that framing of the flood probability over a longer time horizon in combination with visual aids reduces demand for flood insurance among homeowners with low concern about climate change, and raises demand among those with very high concern if a risk grid is used to communicate the flood probability.

Another difference between the Chaudhry et al. (2020) and Bradt (2019) studies and our study, is that on average their samples are younger than our homeowner sample.[10] Our analysis showed a moderating role of age on the impact of risk communication. It is important to mention that the younger and older homeowners in our sample may differ systematically regarding a range of characteristics and preferences, that may explain the interaction effect between the effectiveness of risk communication and age. For instance, Salthouse (2009) showed that some aspects of age-related cognitive decline begin in adults in their 20 s and 30 s. These cognitive declines and other perceptual limitations include: difficulty reading or perceiving pictures, reduced ability to search a visual

[10] Both samples are approximately 35 years old on average.

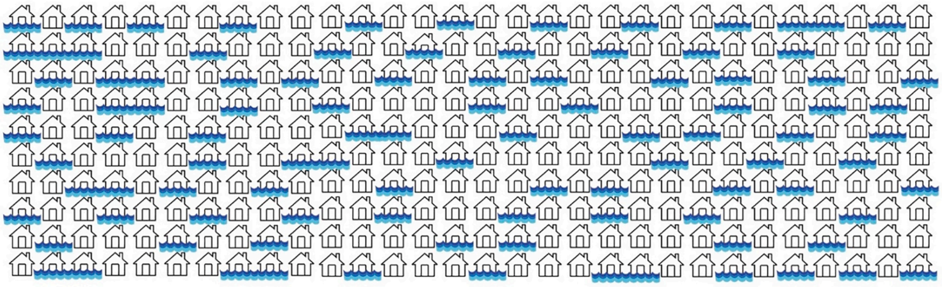

**Fig. A4.** The risk grid that communicates the flood probability over forty years according to an array of flooded and non-flooded houses.

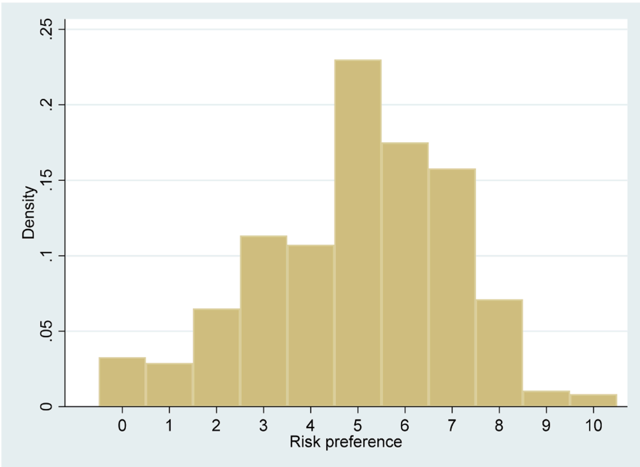


**Fig. B1.** Distribution of *risk preference.*

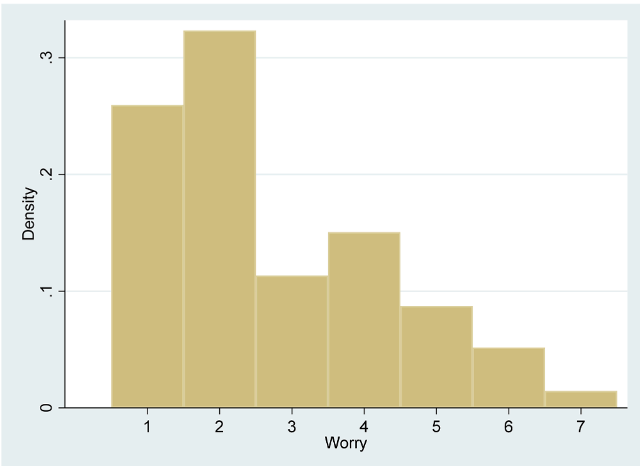


**Fig. B2.** Distribution of *worry.*

list for a target, lower capacity for filtering out other stimuli that is competing for the individual's attention and decreased working memory (McLaughlin and Mayhorn, 2014). Due to these limitations individuals tend to become more reliant on automatic processes, which can influence the way that risk communication messages are assessed and resulting behaviour (Finucane, 2008). Furthermore, it is uncertain to what extent the risk communication manipulations in our experiment created a demand effect to the socially desirable response. Age has been shown to be associated with social desirability (Hitchcott et al., 2020; Vigil-Colet et al., 2013), therefore it may also be the case that social desirability is driving the interaction effect. Another potential cause is related to differences in the expected

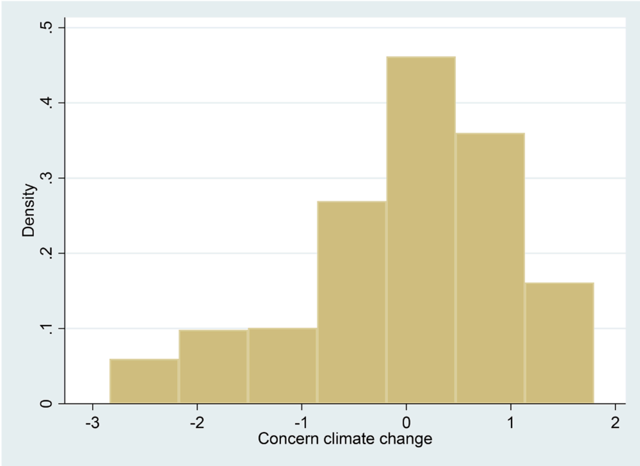


**Fig. B3.** Distribution of *concern climate change.*

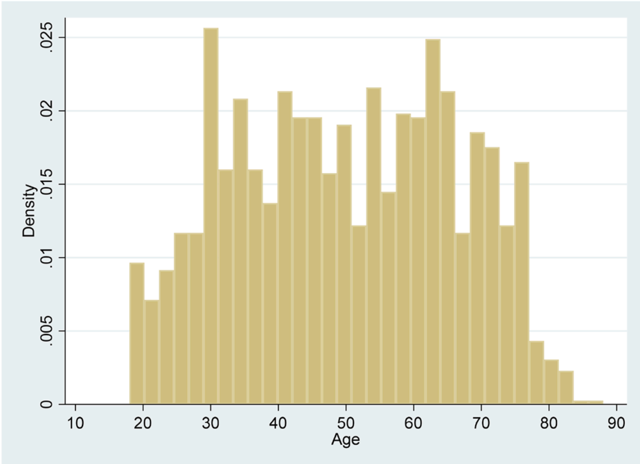


**Fig. B4.** Distribution of *age.*

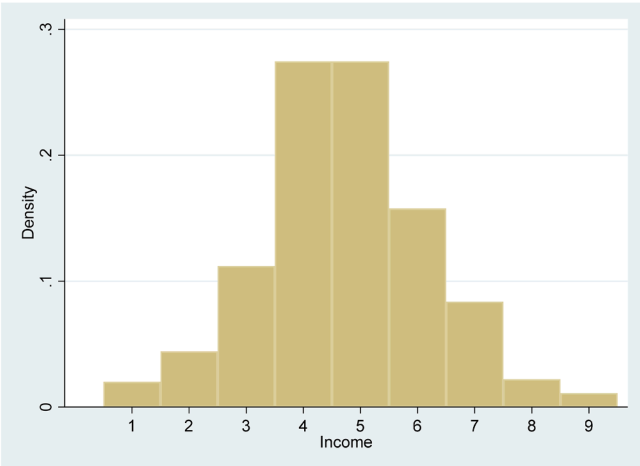


**Fig. B5.** Distribution of *income.*

**Table C1**
Logit model of the likelihood of flood insurance purchase.

| | Model I: Individual difference variables | Model II: Including condition variables | Model III: Including age category | Model IV: Including concern climate change |
|---|---|---|---|---|
| Risk preference | −0.068*** (0.02) *−0.016**** | −0.070*** (0.02) *−0.016**** | −0.077*** (0.02) | −0.069*** (0.02) |
| Flooding experience | 1.359*** (0.30) *0.315**** | 1.370*** (0.30) *0.316**** | 1.326*** (0.30) | 1.389*** (0.31) |
| Ground floor | 0.454*** (0.14) *0.105**** | 0.461*** (0.14) *0.107**** | 0.469*** (0.14) | 0.495*** (0.14) |
| Worry | 0.239*** (0.03) *0.055**** | 0.238*** (0.03) *0.055**** | 0.230*** (0.03) | 0.216*** (0.04) |
| Yearly ladder | | 0.179 (0.17) *0.041* | 0.745** (0.37) | 0.746** (0.37) |
| Yearly grid | | −0.071 (0.17) *−0.016* | −0.198 (0.37) | −0.196 (0.37) |
| Forty-year | | −0.065 (0.17) *−0.015* | 0.530 (0.37) | 0.538 (0.37) |
| Forty-year ladder | | −0.244 (0.17) *−0.056* | 0.169 (0.37) | 0.143 (0.37) |
| Forty-year grid | | 0.014 (0.17) *0.003* | 0.708* (0.37) | 0.761** (0.38) |
| Age category | | | 0.038 (0.04) | 0.039 (0.04) |
| Yearly ladder × age category | | | −0.103* (0.06) | −0.103* (0.06) |
| Yearly grid × age category | | | 0.022 (0.06) | 0.022 (0.06) |
| Forty-year × age category | | | −0.108* (0.06) | −0.109* (0.06) |
| Forty-year ladder × age category | | | −0.076 (0.06) | −0.071 (0.06) |
| Forty-year grid × age category | | | −0.127** (0.06) | −0.131** (0.06) |
| Concern climate change | | | | −0.055 (0.12) |
| Yearly ladder × concern climate change | | | | 0.121 (0.18) |
| Yearly grid × concern climate change | | | | 0.222 (0.17) |
| Forty-year × concern climate change | | | | 0.078 (0.17) |
| Forty-year ladder × concern climate change | | | | 0.350* (0.18) |
| Forty-year grid × concern climate change | | | | 0.360** (0.17) |
| Constant | −0.536*** (0.19) | −0.501** (0.22) | −0.657** (0.32) | −0.694** (0.32) |
| Observations | 1,800 | 1,800 | 1,800 | 1,800 |
| Pseudo-$R^2$ | 0.049 | 0.052 | 0.057 | 0.063 |
| Log-likelihood | −1,177.5 | −1,174.2 | −1,167.9 | −1,160.6 |

Notes:
***Significant at 1%; **Significant at 5%; *Significant at 10%.
Coefficient estimates are provided with standard errors in parentheses. The average marginal effects of *risk preference*, *flooding experience*, *ground floor*, *worry*, *yearly ladder*, *yearly grid*, *forty-year*, *forty-year ladder* and *forty-year grid* are italicized.

life remaining of older vs. younger homeowners. Older homeowners may not relate to framing of the flood probability over forty years because they do not expect to be living that long. Moreover, since the risk communication treatments altered the considered time horizon, time preferences may be influential as well, which can change over one's life cycle (Chao et al., 2009; Read and Read, 2004; Trostel and Taylor, 2001). One may examine in future research the precise cause of the conditional effect of risk communication on insurance demand based on age differences.

We tested whether the association between age and the impact of risk communication is partly related to concern about climate change. This does not appear to be the case, given that coefficient estimates on the risk communication variables as well as their interaction with age are rather robust to the inclusion of concern about climate change and its interaction with risk communication. Therefore, our findings reveal that the mechanisms through which age relates to risk communication effectiveness are likely different to climate change concern.

Before elaborating on several policy implications of our findings, it is important to mention that our study is not without limitations. The study did not utilize payments based on individuals' experimental insurance decisions. Incentive compatible rewards may more closely align choices with incentives faced in actual decisions and reduce the level of randomness involved in insurance decision making (Irwin et al., 1992; Robinson and Botzen, 2019). Whereas, we chose to adopt hypothetical incentives due to the practical difficulties associated with incentivizing losses in experiments (Etchart-Vincent, 2004; 2009). Another limitation of our study is the inherently artificial nature of the experimental environment used to elicit respondents' insurance choices (Harrison and List, 2004). Nevertheless, data on the actual flood insurance purchases of homeowners is not publicly available in the Netherlands (Robinson et al., 2021) which prevents us from examining such data. However, there are also clear advantages to our experimental approach given that we test risk communication strategies that have not been applied in practice yet, and reduce the potential for confounding factors through randomized control. Moreover, our survey allows us to elicit and control for other important variables which is more difficult if one were to examine actual market data on flood insurance demand.

### 4.2. *Lessons for risk communication*

Of policy relevance is how visual aids and framing of risk to enhance flood awareness and preparedness can be effectively

**Table C2**
Linear Probability model of the likelihood of flood insurance purchase.

| | Model I: Individual difference variables | Model II: Including condition variables | Model III: Including age category | Model IV: Including concern climate change |
|---|---|---|---|---|
| Risk preference | −0.016*** (0.01) | −0.016*** (0.01) | −0.018*** (0.01) | −0.016*** (0.01) |
| Flooding experience | 0.237*** (0.05) | 0.238*** (0.05) | 0.226*** (0.05) | 0.238*** (0.05) |
| Ground floor | 0.109*** (0.03) | 0.110*** (0.03) | 0.111*** (0.03) | 0.117*** (0.03) |
| Worry | 0.055*** (0.01) | 0.055*** (0.01) | 0.052*** (0.01) | 0.049*** (0.01) |
| Yearly ladder | | 0.040 (0.04) | 0.162* (0.08) | 0.164* (0.08) |
| Yearly grid | | −0.019 (0.04) | −0.047 (0.08) | −0.045 (0.08) |
| Forty-year | | −0.016 (0.04) | 0.120 (0.08) | 0.122 (0.08) |
| Forty-year ladder | | −0.057 (0.04) | 0.043 (0.08) | 0.037 (0.08) |
| Forty-year grid | | 0.002 (0.04) | 0.153* (0.08) | 0.163* (0.08) |
| Age category | | | 0.008 (0.01) | 0.009 (0.01) |
| Yearly ladder × age category | | | −0.023* (0.01) | −0.023* (0.01) |
| Yearly grid × age category | | | 0.005 (0.01) | 0.005 (0.01) |
| Forty-year × age category | | | −0.025* (0.01) | −0.025* (0.01) |
| Forty-year ladder × age category | | | −0.018 (0.01) | −0.017 (0.01) |
| Forty-year grid × age category | | | −0.028** (0.01) | −0.029** (0.01) |
| Concern climate change | | | | −0.013 (0.03) |
| Yearly ladder × concern climate change | | | | 0.027 (0.04) |
| Yearly grid × concern climate change | | | | 0.051 (0.04) |
| Forty-year × concern climate change | | | | 0.019 (0.04) |
| Forty-year ladder × concern climate change | | | | 0.079* (0.04) |
| Forty-year grid × concern climate change | | | | 0.082** (0.04) |
| Constant | 0.375*** (0.04) | 0.385*** (0.05) | 0.353*** (0.07) | 0.347*** (0.07) |
| Observations | 1,800 | 1,800 | 1,800 | 1,800 |
| Adjusted $R^2$ | 0.061 | 0.062 | 0.065 | 0.069 |

Notes:
***Significant at 1%; **Significant at 5%; *Significant at 10%.
Coefficient estimates are provided with standard errors in parentheses.

implemented in practice. Visual aids and framing can be implemented by governments in their risk communication strategies through information on websites, letters or brochures and through (required) information for individuals buying a new home in a flood-prone area. Nevertheless, it is important for top-down government campaigns to recognize heterogeneity in the population, as suggested in previous studies (Burningham et al., 2008; Haer et al., 2016; Maidl and Buchecker, 2015) and shown empirically in our study.

Our finding that risk communication strategies tend to work better for younger individuals can be seen as good news given that the literature has stressed the importance of triggering behavioural change among the youth (Cox et al., 2019; Haynes and Tanner, 2015). One way to reach younger individuals is through social media (Corner et al., 2015). Haer et al. (2016) using an agent-based modelling approach find that social networks can strongly influence individuals' behaviour, illustrating the potential of using social media to enhance social network effects.

Furthermore, political orientation has been shown to relate very strongly to climate change perceptions and concern in large datasets covering multiple countries (Marquart-Pyatt et al., 2014; Poortinga et al., 2019). We suggest that public policy should be careful implementing the types of risk communication tested in our study in politically conservative areas where climate change skepticism is likely to be higher than politically liberal areas (Dunlap and McCright, 2011).

## 5. Conclusion

Some studies have tested the influence of single risk communication tools, such as extending the time horizon over which the disaster probability is framed on insurance decisions. But, insofar as we are aware, no study has investigated whether combining reframed numerical probability information and visual aids, like risk ladders and risk grids, can nudge flood insurance demand. We examine potential moderators of the effectiveness of this type of risk communication, such as age and concern about the consequences of climate change.

Our results reveal that increasing the time period over which the flood probability is framed, combined with visual aids, tends to raise (lower) flood insurance demand among younger (older) homeowners and those who are more (less) concerned about the consequences of climate change. These findings indicate that the types of risk communication we tested are unlikely to facilitate preparedness on aggregate if they are applied uniformly across the entire population. On the contrary, flood risk communication should be carefully tailored towards subgroups that are responsive to such communication in terms of their preparedness choices, such as whether they decide to purchase flood insurance. Younger individuals may be reached through social media to utilize social network effects. Governments may refrain from implementing the risk communication tested in our study in politically conservative areas where climate change skepticism is often high.

## 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.

## Acknowledgements

This study received financial support from the Netherlands Organisation for Scientific Research (NWO) VIDI Grant No. 452.14.005.

## Appendix A:. Visualizations used to communicate the flood risk to subjects

Fig. A1. Fig. A2. Fig. A3. Fig. A4.

## Appendix B:. Distribution of risk preference, worry, concern climate change, age and income

Fig. B1. Fig. B2. Fig. B3. Fig. B4. Fig. B5.

## Appendix C:. Additional analyses

Table C1. Table C2.

## References

Aerts, J.C.J.H., Botzen, W.J.W., 2011. Climate change impacts on pricing long-term flood insurance: a comprehensive study for the Netherlands. Global Environ. Change 21 (3), 1045–1060.
Aldrich, J.H., Nelson, F.D., 1984. Linear Probability, Logit, and Probit Models. Sage, Beverley Hills.
Allahverdyan, A.E., Galstyan, A., 2014. Opinion dynamics with confirmation bias. PLoS One 9 (7), e99557. https://doi.org/10.1371/journal.pone.0099557.
Anderson, D.R., 1974. The National Flood Insurance Program. Problems and potential. J. Risk Insur. 41 (4), 579–599.
Andor, M.A., Schmidt, C.M., Sommer, S., 2018. Climate change, population ageing and public spending: evidence on individual preferences. Ecol. Econ. 151, 173–183.
Atreya, A., Ferreira, S., Michel-Kerjan, E., 2015. What drives households to buy flood insurance? New evidence from Georgia. Ecol. Econ. 117, 153–161.
Bosschaart, A., van der Schee, J., Kuiper, W., Schoonenboom, J., 2016. Evaluating a flood-risk education program in the Netherlands. Stud. Educ. Eval. 50, 53–61.
Botzen, W.J.W., Aerts, J.C.J.H., van den Bergh, J.C.J.M., 2009. Dependence of flood risk perceptions on socioeconomic and objective risk factors. Water Resour. Res. 45 (10) https://doi.org/10.1029/2009WR007743.
Botzen, W.J.W., Kunreuther, H., Michel-Kerjan, E., 2015. Divergence between individual perceptions and objective indicators of tail risks: evidence from floodplain residents in New York City. Judgm. Decis. Mak. 10 (4), 365–385.
Botzen, W.J.W., Michel-Kerjan, E., Kunreuther, H., de Moel, H., Aerts, J.C.J.H., 2016. Political affiliation affects adaptation to climate risks: evidence from New York City. Clim. Change 138 (1–2), 353–360.
Botzen, W.J.W., van den Bergh, J.C.J.M., 2012. Risk attitudes to low-probability climate change risks: WTP for flood insurance. J. Econ. Behav. Organ. 82 (1), 151–166.
Bradt, J., 2019. Comparing the effects of behaviorally informed interventions on flood insurance demand: an experimental analysis of 'boosts' and 'nudges'. Behav. Public Policy. https://doi.org/10.1017/bpp.2019.31.
Brechin, S.R., Bhandari, M., 2011. Perceptions of climate change worldwide. Wiley Interdiscip. Rev. Clim. Change 2 (6), 871–885.
Browne, M.J., Knoller, C., Richter, A., 2015. Behavioral bias and the demand for bicycle and flood insurance. J. Risk Uncertain. 50 (2), 141–160.
Burningham, K., Fielding, J., Thrush, D., 2008. 'It'll never happen to me': understanding public awareness of local flood risk. Disasters 32 (2), 216–238.
Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press.
Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N., Upham, P., 2015. International trends in public perceptions of climate change over the past quarter century. Wiley Interdiscip. Rev. Clim. Change 6 (1), 35–61.
Changnon, S.A., Pielke, R.A., Changnon, D., Sylves, R.T., Pulwarty, R., 2000. Human factors explain the increased losses from weather and climate extremes. Bull. Am. Meteorol. Soc. 81 (3), 437–442.
Chao, L.W., Szrek, H., Pereira, N.S., Pauly, M.V., 2009. Time preference and its relationship with age, health, and survival probability. Judgm. Decis. Mak. 4 (1).
Chaudhry, S.J., Hand, M., Kunreuther, H., 2020. Broad bracketing for low probability events. J. Risk Uncertain. 61 (3), 211–244.
Corner, A., Roberts, O., Chiari, S., Völler, S., Mayrhuber, E.S., Mandl, S., Monson, K., 2015. How do young people engage with climate change? The role of knowledge, values, message framing, and trusted communicators. Wiley Interdiscip. Rev. Clim. Change 6 (5), 523–534.
Corso, P.S., Hammitt, J.K., Graham, J.D., 2001. Valuing mortality-risk reduction: using visual aids to improve the validity of contingent valuation. J. Risk Uncertain. 23 (2), 165–184.
Cox, R.S., Hill, T.T., Plush, T., Heykoop, C., Tremblay, C., 2019. More than a checkbox: engaging youth in disaster risk reduction and resilience in Canada. Nat. Hazards 98 (1), 213–227.
Cutter, S.L., Emrich, C., 2005. Are natural hazards and disaster losses in the US increasing? Eos, Trans. Am. Geophys. Union 86 (41), 381–389.
Bruine de Bruin, W., Wong-Parodi, G., Morgan, M.G., 2014. Public perceptions of local flood risk and the role of climate change. Environ. Syst. Decis. 34 (4), 591–599.
Dekker, T., Brouwer, R., Hofkes, M., Moeltner, K., 2011. The effect of risk context on the value of a statistical life: a Bayesian meta-model. Environ. Resour. Econ. 49 (4), 597–624.
Dixon, L., Clancy, N., Seabury, S.A., Overton, A., 2006. The National Flood Insurance Program's Market Penetration Rate: Estimates and Policy Implications. RAND Corporation, Santa Monica, CA.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., Wagner, G.G., 2011. Individual risk attitudes: measurement, determinants, and behavioral consequences. J. Eur. Econ. Assoc. 9 (3), 522–550.
Duijndam, S., van Beukering, P., 2021. Understanding public concern about climate change in Europe, 2008–2017: the influence of economic factors and right-wing populism. Clim. Policy 21 (3), 353–367.
Dunlap, R.E., McCright, A.M., 2011. Organized climate change denial. In: Dryzek, J., Norgaard, R., Schlosberg, D. (Eds.), The oxford Handbook of Climate Change and Society. Oxford University Press.
Ermolieva, T., Filatova, T., Ermoliev, Y., Obersteiner, M., de Bruijn, K.M., Jeuken, A., 2017. Flood catastrophe model for designing optimal flood insurance program: estimating location-specific premiums in the Netherlands. Risk Anal. 37 (1), 82–98.
Etchart-Vincent, N., 2004. Is probability weighting sensitive to the magnitude of consequences? An experimental investigation on losses. J. Risk Uncertain. 28 (3), 217–235.
Etchart-Vincent, N., 2009. Probability weighting and the 'level' and 'spacing' of outcomes: an experimental study over losses. J. Risk Uncertain. 39 (1), 45–63.
Fehr-Duda, H., Fehr, E., 2016. Sustainability: game human nature. Nature 530 (7591), 413–415.
Filatova, T., Mulder, J.P.M., van der Veen, A., 2011. Coastal risk management: how to motivate individual economic decisions to lower flood risk? Ocean Coast. Manag. 54 (2), 164–172.
Finucane, M.L., 2008. Emotion, affect, and risk communication with older adults: challenges and opportunities. J. Risk Res. 11 (8), 983–997.
Friedl, A., Lima de Miranda, K., Schmidt, U., 2014. Insurance demand and social comparison: an experimental analysis. J. Risk Uncertain. 48 (2), 97–109.
Friedrich, J., 1993. Primary error detection and minimization (PEDMIN) strategies in social cognition: a reinterpretation of confirmation bias phenomena. Psychol. Rev. 100 (2), 298–319.
Gallagher, J., 2014. Learning about an infrequent event: evidence from flood insurance take-up in the United States. Am. Econ. J.: Appl. Econ. 6 (3), 206–233.
Garcia-Retamero, R., Cokely, E.T., 2017. Designing visual aids that promote risk literacy: a systematic review of health research and evidence-based design heuristics. Hum. Factors 59 (4), 582–627.
Garcia-Retamero, R., Galesic, M., Gigerenzer, G., 2010. Do icon arrays help reduce denominator neglect? Med. Decis. Making 30 (6), 672–684.
Gigerenzer, G., 1996. The psychology of good judgment: frequency formats and simple algorithms. Med. Decis. Making 16 (3), 273–280.
Gigerenzer, G., Hoffrage, U., 1995. How to improve Bayesian reasoning without instruction: frequency formats. Psychol. Rev. 102 (4), 684–704.
Guber, D.L., 2013. A cooling climate for change? Party polarization and the politics of global warming. Am. Behav. Sci. 57 (1), 93–115.
Haer, T., Botzen, W.J.W., Aerts, J.C.J.H., 2016. The effectiveness of flood risk communication strategies and the influence of social networks—Insights from an agent-based model. Environ. Sci. Policy 60, 44–52.
Hamdani, D.A., 2015. Exploring students' learning style at a Gulf University: a contributing factor to effective instruction. Procedia Soc. Behav. Sci. 176, 124–128.
Harrison, G.W., List, J.A., 2004. Field experiments. J. Econ. Lit. 42 (4), 1009–1055.
Haynes, K., Tanner, T.M., 2015. Empowering young people and strengthening resilience: youth-centred participatory video as a tool for climate change adaptation and disaster risk reduction. Children's Geogr. 13 (3), 357–371.
Hensher, D.A., Rose, J.M., Greene, W.H., 2005. Applied Choice Analysis: A Primer. Cambridge University Press.
Hitchcott, P.K., Penna, M.P., Fastame, M.C., 2020. Age trends in well-being and depressive symptoms: the role of social desirability. Psychiatr. Q. 91 (2), 463–473.
Hoeppe, P., 2016. Trends in weather related disasters–Consequences for insurers and society. Weather Clim. Extremes 11, 70–79.
Horowitz, J.L., Savin, N.E., 2001. Binary response models: logits, probits and semiparametrics. J. Econ. Perspect. 15 (4), 43–56.
Horton, J.J., Rand, D.G., Zeckhauser, R.J., 2011. The online laboratory: conducting experiments in a real labor market. Exp. Econ. 14 (3), 399–425.
Humphrey, D.G., Kramer, A.F., 1997. Age differences in visual search for feature, conjunction, and triple-conjunction targets. Psychol. Aging 12 (4), 704–717.
Irwin, J.R., McClelland, G.H., Schulze, W.D., 1992. Hypothetical and real consequences in experimental auctions for insurance against low-probability risks. J. Behav. Decis. Mak. 5 (2), 107–116.
Jones-Lee, M.W., Hammerton, M., Philips, P.R., 1985. The value of safety: results of a national sample survey. Econ. J. 95 (377), 49–72.
Jongman, B., Ward, P.J., Aerts, J.C., 2012. Global exposure to river and coastal flooding: long term trends and changes. Global Environ. Change 22 (4), 823–835.
Kahneman, D., 2003. Maps of bounded rationality: psychology for behavioral economics. Am. Econ. Rev. 93 (5), 1449–1475.
Kappes, A., Harvey, A.H., Lohrenz, T., Montague, P.R., Sharot, T., 2020. Confirmation bias in the utilization of others' opinion strength. Nat. Neurosci. 23 (1), 130–137.
Kaplan, R.M., Hammel, B., Schimmel, L.E., 1985. Patient information processing and the decision to accept treatment. J. Soc. Behav. Pers. 1 (1), 113–120.
Katsman, C.A., Sterl, A., Beersma, J.J., Van den Brink, H.W., Church, J.A., Hazeleger, W., Kopp, R.E., Kroon, D., Kwadijk, J., Lammersen, R., Lowe, J., 2011. Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta—the Netherlands as an example. Clim. Change 109 (3–4), 617–645.
Keller, C., Siegrist, M., Gutscher, H., 2006. The role of the affect and availability heuristics in risk communication. Risk Anal. 26 (3), 631–639.
Kellstedt, P.M., Zahran, S., Vedlitz, A., 2008. Personal efficacy, the information environment, and attitudes toward global warming and climate change in the United States. Risk Anal. 28 (1), 113–126.
Kerstholt, J., Duijnhoven, H., Paton, D., 2017. Flooding in the Netherlands: how people's interpretation of personal, social and institutional resources influence flooding preparedness. Int. J. Disaster Risk Reduct. 24, 52–57.
Klijn, F., de Bruijn, K.M., Knoop, J., Kwadijk, J., 2012. Assessment of the Netherlands' flood risk management policy under global change. Ambio 41 (2), 180–192.
Kousky, C., 2018. Financing flood losses: a discussion of the National Flood Insurance Program. Risk Manag. Insur. Rev. 21 (1), 11–32.
Krupnick, A., Alberini, A., Cropper, M., Simon, N., O'Brien, B., Goeree, R., Heintzelman, M., 2002. Age, health and the willingness to pay for mortality risk reductions: a contingent valuation survey of Ontario residents. J. Risk Uncertain. 24 (2), 161–186.
Kunreuther, H., Ginsberg, R., Miller, L., Sagi, P., Slovic, P., Borkan, B., Katz, N., 1978. Disaster Insurance Protection: Public Policy Lessons. Wiley, New York.
Kunreuther, H., Novemsky, N., Kahneman, D., 2001. Making low probabilities useful. J. Risk Uncertain. 23 (2), 103–120.
Kunreuther, H., Pauly, M., 2004. Neglecting disaster: why don't people insure against large losses? J. Risk Uncertain. 28 (1), 5–21.
Kusev, P., van Schaik, P., Ayton, P., Dent, J., Chater, N., 2009. Exaggerated risk: prospect theory and probability weighting in risky choice. J. Exp. Psychol. Learn. Mem. Cogn. 35 (6).
Lo, A.Y., 2013. The role of social norms in climate adaptation: mediating risk perception and flood insurance purchase. Global Environ. Change 23 (5), 1249–1257.
Logar, I., Brouwer, R., 2017. The effect of risk communication on choice behavior, welfare estimates and choice certainty. Water Resour. Econ. 18, 34–50.
Loomis, J.B., DuVair, P.H., 1993. Evaluating the effect of alternative risk communication devices on willingness to pay: results from a dichotomous choice contingent valuation experiment. Land Econ. 69 (3), 287–298.
Lord, C.G., Ross, L., Lepper, M.R., 1979. Biased assimilation and attitude polarization: the effects of prior theories on subsequently considered evidence. J. Pers. Soc. Psychol. 37 (11).
Ludy, J., Kondolf, G.M., 2012. Flood risk perception in lands "protected" by 100-year levees. Nat. Hazards 61 (2), 829–842.
Mahmood, O., Adamo, D., Briceno, E., Moffat, S.D., 2009. Age differences in visual path integration. Behav. Brain Res. 205 (1), 88–95.
Maidl, E., Buchecker, M., 2015. Raising risk preparedness by flood risk communication. Nat. Hazards Earth Syst. Sci. 15 (7).
Marquart-Pyatt, S.T., McCright, A.M., Dietz, T., Dunlap, R.E., 2014. Politics eclipses climate extremes for climate change perceptions. Global Environ. Change 29, 246–257.
McCright, A.M., 2010. The effects of gender on climate change knowledge and concern in the American public. Popul. Environ. 32 (1), 66–87.
McLaughlin, A.C., Mayhorn, C.B., 2014. Designing effective risk communications for older adults. Saf. Sci. 61, 59–65.
McPhee, L.C., Scialfa, C.T., Dennis, W.M., Ho, G., Caird, J.K., 2004. Age differences in visual search for traffic signs during a simulated conversation. Hum. Factors 46 (4), 674–685.
Meyer, R., Baker, J., Broad, K., Czajkowski, J., Orlove, B., 2014. The dynamics of hurricane risk perception: real-time evidence from the 2012 Atlantic hurricane season. Bull. Am. Meteorol. Soc. 95 (9), 1389–1404.

Meyer, R., Kunreuther, H., 2017. The Ostrich Paradox: Why We Underprepare for Disasters. Wharton School Press.
Miller, S., Muir-Wood, R., Boissonnade, A., 2008. An exploration of trends in normalized weather-related catastrophe losses. In: Diaz, H.F., Murnane, R.J. (Eds.), Climate Extremes and Society. Cambridge University Press.
Nickerson, R.S., 1998. Confirmation bias: a ubiquitous phenomenon in many guises. Rev. Gen. Psychol. 2 (2), 175–220.
Ormrod, J.E., 2006. Educational Psychology: Developing Learners. Pearson/Merrill Prentice Hall, Upper Saddle River, NJ.
Osberghaus, D., 2017. The effect of flood experience on household mitigation—Evidence from longitudinal and insurance data. Global Environ. Change 43, 126–136.
Petrolia, D.R., Hwang, J., Landry, C.E., Coble, K.H., 2015. Wind insurance and mitigation in the coastal zone. Land Econ. 91 (2), 272–295.
Poortinga, W., Whitmarsh, L., Steg, L., Böhm, G., Fisher, S., 2019. Climate change perceptions and their individual-level determinants: a cross-European analysis. Global Environ. Change 55, 25–35.
Poussin, J.K., Botzen, W.J.W., Aerts, J.C., 2015. Effectiveness of flood damage mitigation measures: empirical evidence from French flood disasters. Global Environ. Change 31, 74–84.
Rabbitt, P., 2017. Speed of visual search in old age: 1950 to 2016. J. Gerontol. B Psychol. Sci. Soc. Sci. 72 (1), 51–60.
Read, D., Read, N.L., 2004. Time discounting over the lifespan. Organ. Behav. Hum. Decis. Process. 94 (1), 22–32.
Rijkswaterstaat, 2016. The national flood risk analysis for the Netherlands. Available from: https://www.helpdeskwater.nl/onderwerpen/waterveiligheid/programma-projecten/veiligheid-nederland/.
Robinson, P.J., Botzen, W.J.W., 2018. The impact of regret and worry on the threshold level of concern for flood insurance demand: evidence from Dutch homeowners. Judgm. Decis. Mak. 13 (3), 237–245.
Robinson, P.J., Botzen, W.J.W., 2019. Economic experiments, hypothetical surveys and market data studies of insurance demand against low-probability/high-impact risks: a systematic review of designs, theoretical insights and determinants of demand. J. Econ. Surv. 33 (5), 1493–1530.
Robinson, P.J., Botzen, W.J.W., Kunreuther, H., Chaudhry, S., 2021. Default options and insurance demand. J. Econ. Behav. Organ. 183, 39–56.
Salthouse, T.A., 2009. When does age-related cognitive decline begin? Neurobiol. Aging 30 (4), 507–514.
Sandman, P.M., Weinstein, N.D., Miller, P., 1994. High risk or low: how location on a "risk ladder" affects perceived risk. Risk Anal. 14 (1), 35–45.
Scolobig, A., de Marchi, B., Borga, M., 2012. The missing link between flood risk awareness and preparedness: findings from case studies in an Alpine Region. Nat. Hazards 63 (2), 499–520.
Shi, J., Visschers, V.H., Siegrist, M., Arvai, J., 2016. Knowledge as a driver of public perceptions about climate change reassessed. Nat. Clim. Change 6 (8), 759–762.
Slovic, P., Fischhoff, B., Lichtenstein, S., Corrigan, B., Combs, B., 1977. Preference for insuring against probable small losses: insurance implications. J. Risk Insur. 44 (2), 237–258.
Smith, V.K., Desvousges, W.H., Johnson, F.R., Fisher, A., 1990. Can public information programs affect risk perceptions? J. Policy Anal. Manage. 9 (1), 41–59.
Spekkers, M.H., Kok, M., Clemens, F.H.L.R., ten Veldhuis, J.A.E., 2013. A statistical analysis of insurance damage claims related to rainfall extremes. Hydrol. Earth Syst. Sci. 17 (3), 913–922.
Statistics Netherlands, 2019. StatLine Database. Centraal Bureau voor de Statistiek, http://www.cbs.nl.
Talluri, B.C., Urai, A.E., Tsetsos, K., Usher, M., Donner, T.H., 2018. Confirmation bias through selective overweighting of choice-consistent evidence. Curr. Biol. 28 (19), 3128–3135.
Terpstra, T., Gutteling, J.M., 2008. Households' perceived responsibilities in flood risk management in the Netherlands. Int. J. Water Resour. Dev. 24 (4), 555–565.
Thaler, R.H., Sunstein, C.R., 2008. Nudge: Improving Decisions About Health, Wealth, and Happiness. Yale University Press, New Haven.
Tjernström, E., Tietenberg, T., 2008. Do differences in attitudes explain differences in national climate change policies? Ecol. Econ. 65 (2), 315–324.
Trostel, P.A., Taylor, G.A., 2001. A theory of time preference. Econ. Inq. 39 (3), 379–395.
Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: heuristics and biases. Science 185 (4157), 1124–1131.
Tversky, A., Kahneman, D., 1992. Advances in prospect theory: cumulative representation of uncertainty. J. Risk Uncertain. 5 (4), 297–323.
van Ootegem, L., Verhofstadt, E., van Herck, K., Creten, T., 2015. Multivariate pluvial flood damage models. Environ. Impact Assess. Rev. 54, 91–100.
van Stokkom, H.T., Smits, A.J., Leuven, R.S., 2005. Flood defense in the Netherlands: a new era, a new approach. Water Int. 30 (1), 76–87.
Vigil-Colet, A., Morales-Vives, F., Lorenzo-Seva, U., 2013. How social desirability and acquiescence affect the age-personality relationship. Psicothema 25 (3), 342–348.
Viscusi, W.K., 1998. Rational Risk Policy. Oxford University Press, Oxford.
Viscusi, W.K., Zeckhauser, R.J., 2006. National survey evidence on disasters and relief: risk beliefs, self-interest, and compassion. J. Risk Uncertain. 33 (1–2), 13–36.
Vousdoukas, M.I., Mentaschi, L., Voukouvalas, E., Bianchi, A., Dottori, F., Feyen, L., 2018. Climatic and socioeconomic controls of future coastal flood risk in Europe. Nat. Clim. Change 8 (9), 776–780.
Wakker, P.P., Deneffe, D., 1996. Eliciting von Neumann-Morgenstern utilities when probabilities are distorted or unknown. Manage. Sci. 42 (8), 1131–1150.
Weinstein, N.D., Sandman, P.M., Hallman, W.K., 1994. Testing a visual display to explain small probabilities. Risk Anal. 14 (6), 895–896.
Williams, P.R., Hammitt, J.K., 2001. Perceived risks of conventional and organic produce: pesticides, pathogens, and natural toxins. Risk Anal. 21 (2), 319–330.
Wind, H.G., Nierop, T.M., Blois, C.D., Kok, J.D., 1999. Analysis of flood damages from the 1993 and 1995 Meuse floods. Water Resour. Res. 35 (11), 3459–3465.
Wooldridge, J.M., 2010. Econometric Analysis of Cross Section and Panel Data. MIT Press.