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The cognitive and experiential effects of flood risk framings and experience, and their influence on adaptation investment behaviour

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A R T I C L E I N F O

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A B S T R A C T

This study explores how decision makers invest in adaptation to protect against flood risks in response to a) different framings of flood risk information, and b) after experiencing losses from a hypothetical flood event. An incentivised economic lab experiment is conducted on a sample of students in Bilbao (Basque Country, Spain). A 2 × 2 between-subject design is used to measure investment behaviour with and without exposure to a flood risk map and after exposure to impacts framed as economic losses versus number of persons affected. Experience is measured through a 2-period repeated game within-subject design. Flood risk maps and impacts framed as number of persons affected were conducive to more experiential forms of decision-making, while decisions based on impacts framed as economic losses were more cognitive in nature. Those that saw text-only framings used a combination of cognitive and experiential factors for making decisions. While exposure to maps evoked more affect-driven responses, they were associated with lower ratings of positive affect and self-efficacy, and resulted in lower investments in protection compared to text-only framings. Greater experiential processing was found for impact framings based on persons affected, but they were not especially effective at increasing personal relevance of the issue or in driving investments. Individuals who experienced losses from a hypothetical flood event had greater ratings of negative affect, and made subsequent decisions that were more affect-driven in nature. In contrast, individuals who did not experience losses had greater ratings of positive affect, and made subsequent decisions based on primarily cognitive factors. Investments in protection reduced for those who did not experience losses, and remained the same for those who did experience losses. Results suggest that changes in adaptation investments between decision points may be dependent on both the experience (or lack thereof) of losses, as well as the extent to which individuals were risk-averse or risk-taking in previous investment decisions.

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1. Introduction

The prevalence of climate change has become more apparent in recent years, with growing reports of more frequent and extreme weather events affecting many regions across the globe. Despite these effects, many studies have reported public disengagement with the issue of climate change, linked to a perception of impacts as being both psychologically and temporally distant in nature (Leiserowitz, 2007; Lorenzoni et al., 2007; Nicholson-Cole, 2005). For this reason, scientists have been stressing the importance of devising effective risk communication strategies for motivating action, both from citizens and policymakers alike, to help deal with the anticipated impacts of climate change. One of the most pressing areas of climate risk research, relates to the communication and management of flood risks (Forzieri et al., 2016; Winsemius et al., 2016). In the absence of future adaptation, a 1.5 °C warming is expected to dramatically worsen flooding impacts worldwide, with recent estimates suggesting an increase in human losses by 70–83%, direct flood damage by 160–240%, and a reduction in relative welfare by 0.23–0.29% (Dottori et al., 2018).

In light of this, traditional engineering-based approaches are being replaced by more integrated risk-based management techniques, which consider social aspects such as flood preparedness and response, to help deal with impacts (Kellens et al., 2013). This shift has led to a growing body of research exploring the effects of flood risk communications on aspects such as risk perceptions, behavioural responses and institutional management. Studies suggest that normative approaches to flood risk communication, which centre around transmitting objective expert assessments of so-called 'risk-statistics', have been largely ineffective at motivating the public to respond. Some argue that the dichotomy between expert assessments of risks and public understandings of risk, may be responsible for a deficit model of public (mis)understanding and engagement (Demeritt and Nobert, 2014). This leads to poor risk governance strategies, which may only be enhanced by making the very technical risk management discussions more widely accessible (Galarraga et al., 2018). Indeed, it is reasonable to assume that audiences with different analytical and cognitive capabilities will interpret the richness of flood risk information, which often involves complex descriptors such as uncertainties, probabilities and impacts, in different ways, with reports of public confusion over items such as return periods (Bell and Tobin, 2007; Highfield et al., 2013) and the probabilities associated with precipitation forecasts (Gigerenzer et al., 2005). Even commonly used communication devices such as flood risk maps, which have been argued to make the global, complex and chronic hazards of climate change more local, tangible and personally relevant (Retchless, 2018), are based on design recommendations and consultations with experts (Kunz et al., 2011; Meyer et al., 2012; Van Alphen et al., 2009), despite indications that such maps may lead the public to underestimate their risk exposure or to ignore risks entirely (Burningham et al., 2008; Harvatt et al., 2011; Roth, 2009).

For climate risks in general, communicators have recommended using issue framings that make climate impacts feel more personally relevant. As Moser (2014) asserts, personal connection and feelings of being at risk increase when a hazard feels personalised as opposed to abstract. Casting climate change as a public health issue for example, has been shown to elicit positive emotional responses, increase public engagement and understanding, and promote support for climate change mitigation and adaptation (Maibach et al., 2010; Myers et al., 2012; Petrovic et al., 2014). Other studies report an increased likelihood to engage in pro-environmental behaviours when individuals feel that climate change could affect or endanger their way of life (Semenza et al., 2011). While the evidence seems convincing, some authors stress that attempts to frame climate policy in relation to non-climate issues in a way that makes people feel personally affected may fail if the issue is not seen as being sufficiently relevant (Walker et al., 2018), and there is still insufficient evidence to support the use of personally relevant framings for flood risk communications specifically. Nevertheless, the need for risk communication devices that move away from purely cognitive interpretations of risk, towards more experiential forms of information processing, that are more intuitive and affect-driven, so-called risk as feelings, is advocated for by authors such as Slovic et al. (2004) and Loewenstein et al. (2001). Supporters of formal risk analysis argue that this could lead to cognitive biases and errors in judgment that may induce irrational forms of decision-making, while others theorise that communications that help to recall past experiences and trigger affective responses are necessary for helping individuals to understand the moral impact of risks, and that this may lead to decisions based on a different form of (practical) rationality, one which uses a combination of both emotional and logical reasoning for making decisions (Roeser, 2012, 2010).

There is certainly ample evidence pointing to the influence of experiential factors on risk perceptions and behavioural responses. Many have documented that personal experience with previous flood events, for example, can increase feelings of concern and efficacy, as well as strengthening the perceived salience and response to risk communications (Burningham et al., 2008; Harvatt et al., 2011; Kellens et al., 2011; Lawrence et al., 2014; Siegrist and Gutscher, 2008, 2006; Spence et al., 2011). There are however, some conflicting results on the effects of previous flood experience on risk behaviour and responses (Soane et al., 2010; Whitmarsh, 2008). The emotions aroused when recalling past experiences may be transient rather than conducive to long-term behavioural changes, and it remains unclear how best to stimulate the effect of experience within flood risk communications. Some scholars propose the use of communications that seek to access the negative emotions associated with experiencing a flood (Miceli et al., 2008; Siegrist and Gutscher, 2008; Takao et al., 2004; Terpstra, 2011; Zaalberg et al., 2009), and many studies have demonstrated the potential for negative affect to motivate action on climate change in general (Cooper and Nisbet, 2016; Leiserowitz, 2006; Otieno et al., 2014; Smith and Leiserowitz, 2012; Spence and Pidgeon, 2010; van der Linden, 2014). Consequently, fear appeals have been employed extensively in risk communication efforts for various climate change hazards, despite indications that protection motivation may be more complex than this. Studies have shown that discrete emotions, such as feelings of worry, interest and hope, may have stronger effects on behavioural change and climate policy support than negative affect alone (Smith and Leiserowitz, 2014). Discrete emotions can also influence an individual's predisposition to take risks, and similar emotions (i.e. distress and anger) can have opposite effects, acting to either amplify or depress the impact of certain risk framings (Druckman and McDermott, 2008). Risk behaviour could also be directly affected or mediated by aspects such as feelings of personal efficacy (Brody et al., 2008; Fox-Rogers et al., 2016; Hidalgo and Pisano, 2010), trust in scientists and governments (Kellstedt et al., 2008), place attachment (Bonaiuto et al., 2016; De Dominicis et al., 2015;

Mishra et al., 2010), and social norms and value systems (van der Linden et al., 2014).

Some have stressed that the balance of experiential factors with other important cognitive aspects necessary for processing risk information must also be considered. In line with dual process theories (Chaiken and Trope, 1999; Epstein, 1994; Kahneman and Frederick, 2002; Sloman, 1996), Marx et al. (2007) discover that experiential and analytic systems compete when processing uncertain climate information, but compared to purely statistical presentations of information, descriptions which are designed to help decision-makers recall relevant personal experience and elicit affective responses are more effective at attracting attention, heightening perceptions of risks, and influencing both individual behavioural intentions and public policy preferences in relation to climate change. The authors argue that while experience- and affective-based communications are more salient and motivating, the many abstract aspects of climate variability and change require a certain level of analytical understanding for making decisions.

As it stands, attempts to establish best-practice guidelines for flood risk communications are hindered by the lack of experimental and randomised trials necessary for testing preferences and communication formats across different audiences (Demeritt and Nobert, 2014; Spiegelhalter et al., 2011). While some new studies are emerging (Markanday et al., 2020), there is especially weak empirical evidence on the experiential and cognitive effects of different types of flood risk framings, and their impact on behaviour (Kellens et al., 2013). Controlled experiments that examine commonly used components of flood risk communications (such as maps and impact descriptors), their effect on cognitive and experiential information processing, and ultimately on behaviour, could help in building a necessary theoretical framework for identifying and selecting design features most conducive to effective risk communication.

1.1. Current study

The hilly terrain, steep valleys, high precipitation levels, and densely urbanised low-lying areas of the Basque Country, make it an area extremely prone to flooding (Basque Government, 2007). With climate change, the average sea-level is expected to rise between 29 and 49 cm by the end of the 21st century, eroding beaches and increasing the risk of flooding in estuaries throughout the region (Chust et al., 2011). The economic impact of floods on infrastructures, transport and communication networks, clean-up efforts, and emergency services, is estimated to cost over €62 million annually (Gobierno Vasco, 2015). Following the establishment of the EU floods Directive (2007/60/EC), the Basque government called for an assessment of climate change induced sea-level rise and flooding in the region and produced flood risk maps to better visualise vulnerable coastal and inland flood zones. Although these maps are publicly available, there is no evidence on their effectiveness as risk communication devices and for motivating preparedness behaviour. In addition, these maps are accompanied by a wealth of (relatively complex) information related to various types of impacts (i.e. economic, environmental, social) and with respect to different return periods (T10, T100 and T500), which may be difficult for users to interpret.

Based on this, this study sets out to explore the effectiveness of flood maps and risk information provided for the Basque Country as communication devices for motivating preparedness behaviour. Different risk framings have been designed to test differences in cognitive and experiential modes of information processing, and the effect that this may have on adaptation decision-making under risk and uncertainty, based on the following research questions:

Does seeing a map of flood risk zones (compared to a text-only frame) induce greater experiential processing of risk information, leading to higher investments in adaptation?
Does framing impacts caused by a flood event as number of persons affected (compared to to economic losses) induce greater experiential processing, leading to higher investments in adaptation?

The subsequent research hypotheses have been constructed to facilitate an answering of these questions:

H1. There is ample evidence that visual framings of climate change may evoke different forms of experiential processing, which can make the issue more personally relevant and thus can stimulate public willingness to engage and respond to the issue (Hart and Feldman, 2016; Nicholson-Cole, 2005; O'Neill et al., 2013; O'Neill and Smith, 2014; Sheppard, 2005). Of particular interest in this respect are commonly used visual devices for communicating scientific information: graphs, charts, models and maps. In the context of flood risks, maps are one of the most frequently employed tools in decision-making, due to their ability to condense complex information and present impacts across a range of scenarios, temporal and spatial scales, in a visually appealing way. By presenting information in this way, flood risk maps have been argued to make complex and abstract information more local, tangible and personally relevant (Retchless, 2018). However, there is also evidence that maps may lead users to underestimate risks or ignore them entirely (Burningham et al., 2008; Harvatt et al., 2011; Roth, 2009). If we follow the general premise that visual tools are effective at provoking experiential responses, and that experiential responses are effective at stimulating engagement and action, then maps, as a visual tool, could offer a means for interpreting abstract scientific information in a more personally relevant way, thus motivating users to act. Based on this notion, we hypothesise: seeing a map of flood risk zones will reduce the psychological distance of flooding impacts, making them seem more local and personally relevant. As a result, participants that only see text are expected to use primarily cognitive forms of information processing, while those who also see a map are expected to use a combination of both cognitive and experiential types of reasoning. In the case of the latter, experiential processing may trigger a recollection of past experiences, causing more affect-driven responses, and a moral reasoning of climate risks, which will lead to higher investments in protection compared to text-only framings.

H2. Previous studies suggest that communicating risks in more personal, as opposed to abstract, terms can encourage experiential processing of information leading to an increased personal connection to the issue and feelings of being at risk (Maibach et al., 2010; Moser, 2014; Myers et al., 2012; Petrovic et al., 2014; Slovic et al., 2004), which in turn may motivate willingness to act. Increased likelihood to engage in positive behavioural changes has also been found in cases where individuals feel that their personal way of life may be affected or endangered (Semenza et al., 2011). In the context of flood risks, two common terms are often used for communicating risks: economic losses (or expected damages) and number of affected people. By following the assumption that conveying risks as people, as opposed to money, will spark experiential processing that leads to a more personal connection with the issue, then we can hypothesise that risk perceptions and motivations to act will be higher for those that see impacts framed as persons affected compared to those that see impacts framed as economic losses. In addition to personal relevance, framing risks as persons affected may also provoke a concern for victims driving a sense of moral responsibility which leads to a lower acceptance of risks. Of course one can argue that economic losses may also provide relevant information causing high levels of experiential processing. But there is some evidence to suggest that non-economic framings are more effective at encouraging public support for environmental management than economic framings (DeGolia et al., 2019). In addition, previous studies have shown that individuals may have difficulty in understanding numerical descriptions of climate change (Bell and Tobin, 2007; Hart, 2013; Highfield et al., 2013), especially since they tend to be combined with high levels of uncertainty, which places greater cognitive demand on audiences (Morton et al., 2011). Greater cognitive difficulty may also reduce personal relevance of an issue, since it makes it harder for individuals to draw parrallels with their own personal experiences. This leads us to hypothesise that exposure to this type of information will cause higher levels of cognitive processing, and lower levels of experiential processing in individuals, leading to more objective appraisals of risks and reduced motivations to act.

The aforementioned risk framings are expected to elicit decisions based on objective (cognitive) and practical (cognitive and emotional) forms of rationality. All framings require an analytical assessment of the same risk statistics; therefore, no framing is expected to induce decision-making based purely on emotion, which as some have suggested, may lead to cognitive bias and errors in judgement. In order to assess the difference in actions based on objective or practical forms of rationality, and actions prone to more irrational (or cognitively biased) forms of decision-making, a third research question is proposed:

If risk statistics remain unchanged, does ‘experiencing’, or similarly, ‘not experiencing’ a (hypothetical) flood event lead to differences in initial investments in adaptation?

H3. If the information pertaining to a certain risk is equivalent at two decision points, then rational choice theory dictates that preferences should stay the same between the two points irrespective of whether an event occurs or not. In reality, experiencing a flood event may evoke transient (likely negative) emotional responses (i.e. post-traumatic stress, anxiety, fear) (Foudi et al., 2017) that may cause one to perceive risks as more severe (or less acceptable) than once thought and to take on precautionary measures to prevent the same outcome from happening in the future. Experiencing a flood event may also lead people to draw parallels with past experiences, increasing personal connection with the issue and leading to more experientially-based decision-making. By comparison, investing in protection and not experiencing a flood event may evoke (likely positive) emotional responses (i.e. empowerment, pride) associated with feelings of success. This may lead to more risk-taking behaviour in subsequent decision-making, and a reduction in precautionary actions as a response. For these reasons, we expect that a recollection of past experiences and the influence of (primarily) negative emotions will lead to greater risk aversion and an increase in adaptation investments for participants that experience losses, while more positive associations with success will lead to more risk-taking behaviour and a decrease in invesments for those that do not experience losses.

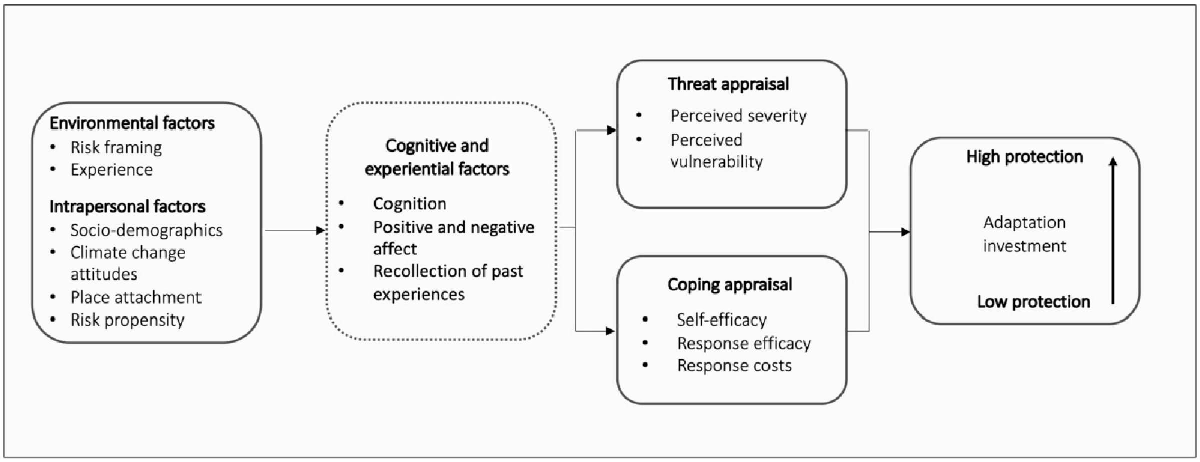

Fig 1. Extension of protection motivation theory considering various cognitive and experiential factors adapted from Bubeck et al. (2018) and Oakley et al. 2020.

1.2. Assessment framework

The aim of this study is to assess how different flood risk framings and experience of impacts influence cognitive and experiential processes, and to determine the effect that this may have on investments in adaptation. An extension of Protection Motivation Theory (PMT) is considered to help capture the main cognitive processes that lead to adaptation investments. PMT has been used extensively in different settings such as health and disaster response, to help understand what motivates individuals to act in the context of a threat. The theory is founded on the principle that investment decisions rely on two main processes: threat appraisal and coping appraisal. The former relates to perceptions of risks and consists of two main elements: i) perceived vulnerability, that is, perceptions of how likely the threat is to occur, and; ii) perceived severity, that is, perceptions of how severe the effects of that threat will be. The latter relates to how effectively individuals feel they would be able cope with a threat, and is comprised of three features: i) self-efficacy, which refers to the extent to which individuals feel their actions will make a difference; ii) response efficacy, which relates to how effective a response is perceived to be, and; iii) response costs, that is, how much it would cost to respond to a threat. The consideration of threat and coping appraisals alone, however, has been found in practice to be an inadequate explanation of individual protection motivation and policy responses to flooding. Previous studies have shown that perceptions of risk and willingness to adapt are also driven by a multitude of experiential and cognitive factors, such as past experiences, concern, beliefs, knowledge, trust, the temporal and psychological distance of impacts, as well as certain sociodemographic factors, i.e. political orientation, age, gender, and education (van der Linden, 2015). Extensions of PMT have since been proposed to consider how different experiential and cognitive processes may play a role in this process (Oakley et al., 2020). In this paper, we consider an extended PMT framework that looks at how environmental factors, such as risk framing and experience, alongside intrapersonal factors, such as socio-demographics, climate change attitudes, place attachment and risk propensity, drive cognitive and experiential processes (cognition, recollection of past experiences, positive and negative affect). We then consider the influence that this may have on threat and coping appraisals, which in turn may affect motivations to invest in adaptation (Fig. 1).

2. Materials and methods

An incentivised computerised economic lab experiment was designed to answer and test the aforementioned research questions and hypotheses. The experimental approach consisted of three distinct parts; i) a risk-elicitation task for testing participants' risk propensity, ii) a role-playing exercise to measure levels of adaptation investment in response to different flood risk framings and experience, and iii) a post-experiment survey for assessing cognitive and experiential factors involved in the decision-making process, as well as effects pertaining to various intrapersonal factors. The specific measures assessed under the extended PMT framework are explained below.

2.1. Environmental factors

2.1.1. Risk framing

Participants were asked to assume the role of a policy-maker responsible for the Basque coastal town of Zarautz. Zarautz was chosen for this part of the experiment, since it is a well-known area at risk of climate impacts in the region, with extensive media coverage of past extreme storm events and coastal flooding. A 2×2 between-subject design was used to measure the effects of different visual (map vs. no map) and impact (economic vs. persons affected) risk framings. Participants were randomly allocated to one of the four treatment groups and were given information related to the impacts and probabilities of a flood event. Depending on the treatment group, participants saw impacts framed as either economic losses in terms of damage costs to infrastructures, or as the number of people that would be affected if a flood event occurred. Both types of impacts were described to participants in real terms, based on actual figures from the Basque Government. As with the impact framings, half of the participants saw a map of flood zones while the other half did not. Flood maps were simplified, such that all accompanying information was removed leaving just the image of flood zones depicting low, medium and high-risk areas[3].

2.1.2. Experience

A 2-period repeated-game design was used to measure investments in adaptation in response to experiencing or not experiencing a hypothetical flood event. Participants were asked to make an investment in protection at two decision points, Period 1 and Period 2, based on a set of protection levels presented to them (see Section 2.1.4 below for a detailed account of how investments in adaptation were made). Each protection level had its own respective investment cost and probability of impacts assigned to it. The actual impact (economic loss or number of persons affected) remained fixed across all options. The levels of protection were designed such that the more participants invested in adaptation, the less likely they were to experience impacts. All protection levels, their respective costs, as well as the probabilities and costs of impacts remained the same across the two decision points. Depending on the chosen investment level and the probability of impact assigned to it, a random generator would determine whether participants experienced impacts or not after their initial investment in period 1. Participants were then asked to make the same decision again for Period 2. They were instructed to assume that all previous protection had been stripped, the only difference in Period 2 being the experience they had

[3] The original version of the map depicts zones at risk of 10, 100 and 500-year flood events, but for simplistic purposes and to reduce the potential for confounding effects, these were shown as high, medium and low-risk areas, respectively, instead.

gained from their decision in Period 1. The difference in level of investment between Period 1 and Period 2 for those who experienced impacts and for those who did not experience impacts, was used to measure the effect of experience.

2.2. Intrapersonal factors

2.2.1. Risk propensity

Risk propensity was measured using a staircase risk-elicitation procedure established by Falk et al. (2016) (Supplemental File 1). This task consisted of asking participants to make five consecutive choices between a lottery, which stays the same for each decision, and a sure payment, which changes after each decision. After the first choice has been made, the sure payment is adjusted in each subsequent decision to be higher (when the lottery is chosen) or lower (when the sure payment is chosen), in order to arrive at the implied switching row of the individual, that is, the point at which the sure payment is preferred to the lottery. Based on this implied switching row, risk scores are estimated for each individual, ranging from 1 (very risk-averse) to 31 (very risk-taking).

2.2.2. Climate change attitudes

A series of measures were used to determine feelings and attitudes towards climate change. These were studied in two different ways. First, measures were assessed individually, in order to provide a qualitative descriptive summary of the sample pertaining to their general beliefs and perceptions about climate change. Second, certain items were then used to develop a combined measure of climate change attitudes for the purposes of analysing how emotional attachment to the issue may act as a driver of protection motivation. The development of this indicator is explained further below.

Beliefs about climate change were assessed by asking participants to select which of the following best described their thoughts on climate change: “I don’t think climate change is happening”, “I have no idea whether climate change is happening or not”, “I think that climate change is happening, but it’s just a natural fluctuation in Earth’s temperatures”, “I think that climate change is happening, and I think that humans are largely causing it”. Risk perceptions were measured by assessing the perceived psychological and temporal distance of climate change risks. Psychological distance was measured by asking participants to rate, using a 7-point likert scale (1 = low impact, 7 = high impact), the extent they thought climate change would impact “them personally”, “their family”, “people in their region”, “people in Spain”, “people in industrialised countries”, “people in developing countries”, “future generations”, and “plant and animal species”. Temporal distance was measured by asking participants to select when they thought climate change would impact people, i) in Spain and, ii) in other parts of the world, out of the following items: “they are being harmed now”, “in 10 years”, “in 25 years”, “in 50 years”, “in 100 years”, and “never”.

The level of importance that individuals place on climate change was measured using a 7-point likert scale, which asked participants to rate how important the issue of climate change was to them personally. Level of concern was determined by asking participants to rate how concerned they were about the impacts of climate change in Zarautz. Participants were also asked how responsible they thought different actors (government, industry, individuals, scientists, NGOs) were for solving the issue of climate change. The extent that participants felt a moral responsibility towards climate change was determined by asking them how much they agreed with the statement: “We have a moral duty to act on climate change for our planet, its animals, its plants and its people.” Lastly, levels of self-efficacy were measured by asking participants to what extent they agreed with the following statement: “The actions I take won’t make any difference to climate change.” All rating scores for the aforementioned items were measured using a 7-point Likert scale.

A combined indicator for climate change attitudes was then developed based on five measures: climate change beliefs, issue importance, concern, individual responsibility, and moral responsibility. This measure was intended to assess how emotionally attached participants were to the issue of climate change, with low scores indicating low emotional attachment and high scores indicating high emotional attachment. Scores were adjusted to ensure an equivalent weighting of each of the five measures, then summed to obtain a measure of climate change attitudes from 0 to 100, where scores closer to 0 reflected less emotional attachment and scores closer to 100 reflected greater emotional attachment to the issue of climate change.

2.2.3. Place attachment and socio-demographics

Feelings of place attachment were measured by asking whether, and if so how many times, participants had visited Zarautz in the last 12 months, as well as asking participants the extent to which they agreed (using a 7-point Likert scale) with the following 4 items: “Zarautz is a very special place to me”, “I identify strongly with Zarautz”, “I am very attached to Zarautz”, and “no other place can compare to Zarautz”. A final item was included which asked participants whether they thought they would invest “more”, “less”, or “the same amount”, if the exercise was focused on a region outside of the Basque Country. Finally, potential explanatory measures related to participants’ nationality, age, and gender, were collected at the end of the post-experiment survey.

2.3. Experiential and cognitive reasoning

A post-experiment survey measured factors related to the experiential and cognitive processing of flood risk information. For experiential processing, the psychological positive and negative affect scales developed by Watson et al. (1988) were employed as a measure of participants’ level of emotional reasoning. Participants were asked to rate their level of affect related to the experiment, based on a selection of 9 positive affect items (enthusiastic, interested, determined, emotional, inspired, concentrated, active, empowered, proud) and 9 negative affect items (scared, afraid, upset, distressed, tense, nervous, guilty, irritable, vigilant). Both discrete emotions, as well as grouped positive and negative affect scores, were assessed. Participants were also asked whether they felt they had personally experienced the effects of extreme climate events (e.g. flooding, extreme storms, heat waves and/or drought) in the past. This measure was used to assess the extent to which recollection of past experiences could be driving adaptation behaviour after exposure to different risk framings and experience.

For a measure of cognitive and analytical reasoning, participants were asked to rate how difficult they found the task. In line with dual process theories, the level of cognitive effort was assumed to be related to the level of analytical (or cognitive) reasoning. Such that, the higher the level of difficulty, the higher the cognitive effort spent, and the more objective or analytical the decision-making process. This measure was also used as a proxy for scientific and numerical literacy, since previous studies have asserted that the difficulty of processing technical climate change information, which is remote and abstract, can lead to an underestimation of risks, compared to other more emotionally charged risks (i.e. terrorism), which people are thought to overestimate (Sunstein, 2007; Weber and Stern, 2011). In addition, risk propensity scores (see Section 2.1.2) were also used to measure cognitive processing of information, based on the logic that if adaptation decisions are driven by largely cognitive processes, then we can expect investments in adaptation to be more or less in line with general risk-taking behaviour.

2.4. *Threat appraisal, coping appraisal and investments in adaptation*

Participants were given a budget (in experimental tokens) out of which any investment in protection and any losses from impacts suffered would be deducted. To maintain consistency between treatments and reduce the potential for confounding effects, impacts were translated to a fixed value in experimental points, equivalent between treatments, which represented potential losses in the game.

As mentioned above, participants were presented with a series of protection levels and asked how much they were willing to invest in protection to reduce their risks (probability of experiencing impacts) in the future. Protection options consisted of 19 solutions ranging from no-protection at all (95% chance of experiencing impacts) to maximum protection (5% chance of experiencing impacts). The options were designed such that each equivalent increase in the cost of protection (option 1 costing nothing, and option 19 being the most expensive), resulted in the same reduction in the likelihood of experiencing impacts (option 1 having the greatest exposure to risks, option 19 having the least exposure to risks). To simplify the concept of probabilities, and to increase the feeling of trust that the likelihood of experiencing flooding impacts was based purely on chance, probabilities of experiencing losses were explained to participants through a 20-sided die. Two sets of outcome ranges between 1 and 20 were provided alongside each option on the table, one set representing a failure to the protect the town, and the other set representing the successful protection of the town. Depending on which investment option participants chose, the ranges assigned to protection and no-protection varied. Once participants decided on an option, a computerised die randomly generated a number between 1 and 20, which depending on the option, meant they either managed to protect or failed to protect the town from flooding. The cost of protection and impacts (if any) suffered, was then deducted from their initial budget. Protection motivation was determined based on how much participants invested in protection. Option 1 represented a very low protection motivation with no investment in adaptation, and option 19 represented a very high protection motivation with a very high level of investment in adaptation.

Due to the design constraints of the experiment, it was very difficult to establish relevant indicators for threat and coping response. Participants were presented with a pre-determined list of adaptation costs, probabilities, and outcomes, which made it difficult to develop real measures of threat and coping appraisal since these were largely already established within the constructs of the game. Thus, we explore in a qualitative sense how threat and coping appraisals may be affected by different risk framings and experience, but focus on investments in adaptation as our main dependent variable.

2.5. *The sample*

The experiment was conducted at the economic lab of the University of the Basque Country in Bilbao, in October 2019. One-hundred-sixty students participated in the experiment, with each treatment group consisting of around 40 participants. The experiment was translated to and conducted in Spanish. The sample comprised 54% female, 45% male, and $< 1\%$ non-binary individuals, with ages ranging from under 18 to over 45, with the majority of participants aged between 18 and 24 (82%). The large majority of participants were Spanish (94%), of which, 85% identified as Basque. The experiment was incentivised so participants could experience real gains and losses during the experiment, by earning experimental tokens (€1 = 50 tokens) during the first two tasks (the risk elicitation task and the role-playing exercise). Participants were able to earn a total maximun of 750 experimental tokens (15€ equivalent) distributed as 150 experimental tokens (€3 equivalent) during the first task, and a maximum of 600 experimental tokens (€12 equivalent) during the second task.

3. Analysis and results

This section describes the results of a series of Analyses of Variance (ANOVA) tests (Lindman, 1974) used to test the aforementioned research questions and hypotheses. Logistic regressions have also been conducted to study the strength of predictor variables. Descriptive statistics pertaining to the individual treatment groups is also provided (Appendix I). All statistical tests and analyses have been conducted using the statistical software package R.

3.1. *Beliefs, attitudes and perceptions about climate change*

On the whole, results support findings from previous studies, which show a general perception of climate change impacts as being psychologically distant in nature (Fig. 1). Perceptions of threat increase with the spatial and temporal distance of affected groups, with those judged as proximally close (oneself and family) perceived as being less severely impacted than those judged to be proximally distant (future generations and plant/animal species).

Contrastingly, climate change was generally perceived as being temporally close, with the majority of respondents agreeing that climate impacts are already being felt across many parts of the world (Fig. 2). Yet, judgements of temporal distance were also sensitive to proximal distance, such that participants expected climate change to affect Spain later than it would the rest of the world.

The majority of participants believed in anthropogenic climate change (95% of respondents), and most felt that climate change is an either very or extremely important issue (approx. 63% of respondents). In addition, most participants agreed that humans have a moral responsibility to solve climate change (86% of respondents), but felt that on the whole, governments and industry were most responsible for solving the issue.

Using perceptions of personal (individual + family) climate change risks and perceived temporal distance of impacts in Spain as a proxies for perceived severity and vulnerability, we can explore how risk framings and experience, as well as different intrapersonal factors may be influencing threat appraisal[4]. We find that appraisals of threat are driven primarily by climate change attitudes and gender, where those more emotionally attached to the issue and women, have greater perceptions of risks. To a lesser degree, some cognitive effects are also present, with greater cognitive effort and risk propensity also linked to slightly higher perceptions of risks (see model 1, Appendix II). If we exclude any explanatory factor related to the experiment and include psychological distance[5] in the model, this significantly improves its predictive power. Greater psychological distance is found to significantly reduce inidividual appraisals of threat (model 2, Appendix II).

3.2. *Cognitive and experiential effects of flood risk framings and experience*

Findings show that affect is largely driven by experience of a hypothetical flood event and exposure to map framings of flood risks, both of which decrease overall ratings of affect (Table 1). Focusing on intrapersonal factors does not greatly improve the predictive power of the model, however past experience is found to decrease ratings of affect (Appendix III). Positive affect in turn is found to be a primary determinant of adaptation investments for period 1, with higher ratings leading to higher investments in protection. Investments in period 1 also seem to be shaped by cognitive factors, such that investments were aligned with general risk taking behaviour (lower risk aversion led to lower investments in adaptation).

ANOVA results indicate, contrary to hypothesis H1, that participants who were exposed to a map of flood zones invested less in protection, compared to those in text-only treatment groups, $F(1,158) = 4.158$, p-value = 0.0431. Those that saw a map also reported lower ratings of self-efficacy, $F(1,158) = 6.683$, p-value = 0.011, and lower levels of affect, $F(1,158) = 6.01$, p-value = 0.0153, related to their extent of interest, $F(1,158) = 4.168$, p-value = 0.0429, activeness, $F(1,158) = 4.15$, p-value = 0.0433, and concentration, $F(1,158) = 4.005$, p-value = 0.0471. When looking at the specific drivers of investments for those exposed to map framings, we that affect plays a fundamental role. Certain negative and positive discrete emotions (nervousness, enthusiasm, inspiration) are decreasing investments, while other types of affect (feelings of emotion, tension and concentration) are increasing investments. By comparison, investments in text-only treatments seem to be driven by both cognitive- and experiential factors. When compared to map framings, we find some of the same discrete emotions having opposite effects on investments (Table 2).

In terms of impact framings, ANOVA results show no significant difference in levels of investment between participants that saw impacts framed as economic losses and those that saw impacts framed as number of persons affected, $F(1,158) = 0.105$, p-value = 0.747. Similarly, no significant differences in perceptions of risk, $F(1,158) = 0.018$, p-value = 0.894, affect, $F(1,158) = 0.197$, p-value = 0.658, sense of moral responsibility, $F(1,158) = 0.064$, p-value = 0.8, or concern, $F(1,158) = 0.818$, p-value = 0.367, were detected between the two impact framings. We do however find that adaptation investments for those exposed to impacts framed as economic losses are driven by primarily cognitive factors (risk propensity, concentration), while those exposed to impacts framed as persons affected show investments driven by primarily experiential factors (levels of interest are increasing investments while feelings of agitation are decreasing investments) (Table 2).

A paired *t*-test was used to test the effects of experience on levels of adaptation investment[6]. No significant difference in levels of investment between period 1 and period 2 was found for participants who experienced losses (p-value = 0.3039). However, as hypothesised, ANOVA results show that participants who experienced losses had greater ratings of negative affect. In particular, they reported feeling more irritated, $F(1,158) = 4.661$, p-value = 0.0324, and more guilty, $F(1,158) = 6.549$, p-value = 0.0114, than those that did not experience losses in the game. Consistent with hypothesis H3, participants who did not experience losses invested less in adaptation (p-value = 0.0002) in period 2 (mean investment in protection = 92.65, sd = 29.06) compared to period 1 (mean investment in protection = 101.3, sd = 25.32), and had greater levels of positive affect on the whole, $F(1,158) = 16.31$, p-value =

[4] This was done as a qualitative exercise to explore potential drivers of climate threat appraisal. The results provide some insight into threat appraisals of climate risks in general, but do not necessarily translate to the specific context of flood risks, which may offer different findings.

[5] Measured through the standard deviation of psychological distance items

[6] While there is doubt in research practice about the reliability of difference scores, this is often based on notions of classical reliability, which hold if the focus of measurement is the individual. When the focus of measurement is the group, as in our experiment, then classical reliability is an inappropriate means for assessing the utility of difference scores (Thomas and Zumbo, 2012). In such cases, if difference scores make sense from a subject-matter perspective, and if the corresponding analysis is likely to have an appropriate power, then there is no reason why they should not be used.

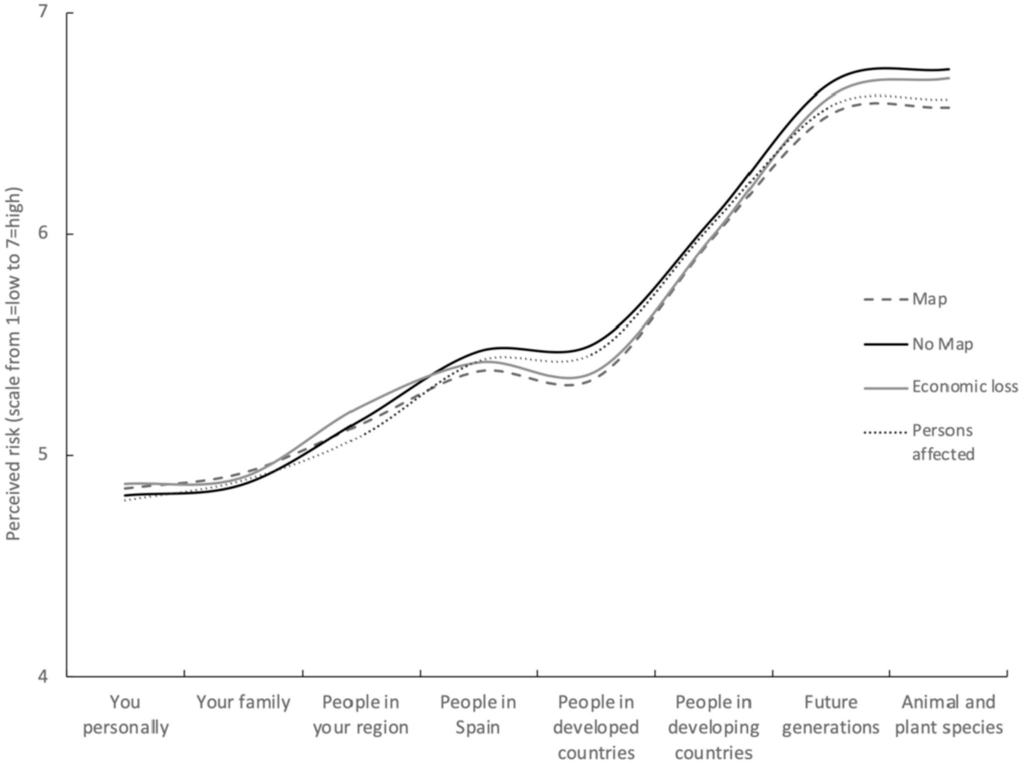

Fig 2. Perceived psychological distance of climate impacts for differrent treatment groups.

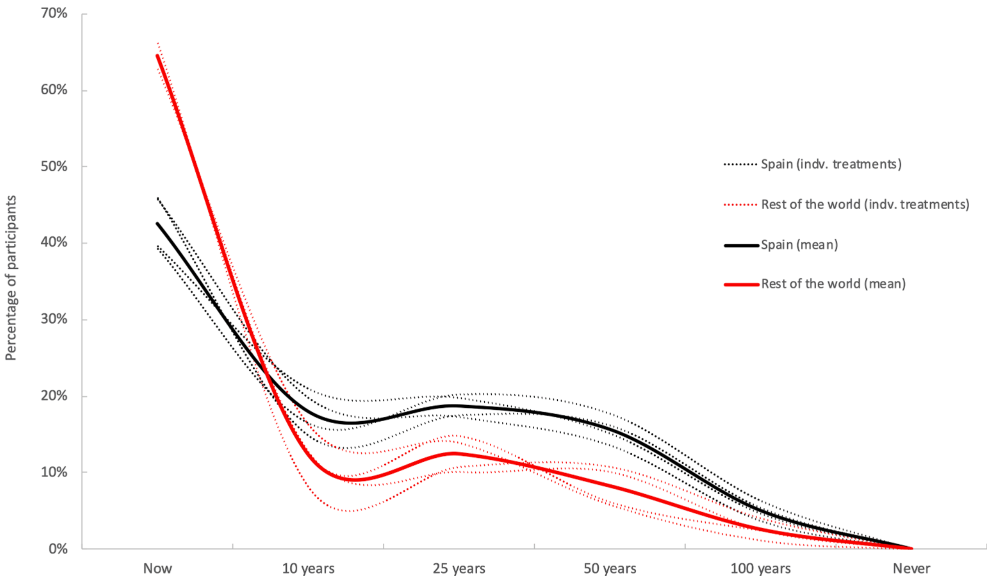

Fig 3. Perceived temporal distance of climate impacts for distant ('rest of the world') and proximal ('Spain) impacts.

8.37e05. In particular, they felt more interested, $F(1,158) = 10.71$, p-value = 0.00131, more emotional, $F(1,158) = 8.937$, p-value = 0.00324, more empowered, $F(1,158) = 9.658$, p-value = 0.00224, more inspired, $F(1,158) = 6.554$, p-value = 6.554, more active, $F(1,158) = 7.591$, p-value = 0.00656, and more concentrated, $F(1,158) = 12.37$, p-value = 0.000571, than those who experienced losses.

Based on traditional concepts of rationality, one would expect risk behaviour in period 2 to be shaped primarily by decisions in period 1, since there was no difference in risk and adaptation information between the two decision points. While a regression analysis

Table 1
The influence of flood risk framings and experience on affect (model 1), and the strength of affect against other cognitive and intra-personal factors for driving adaptation investments (model 2).

	Affect (1)	Investment (Period 1) (2)
Visual framing (map = 1, no map = 0)	−4.52* (1.75)	
Impact framing (persons = 1, econ = 0)	−0.18 (1.76)	
Experience (loss = 1, no loss = 0)	−6.94*** (1.81)	
Risk propensity		−1.25** (0.39)
Cognitive effort		−1.88 (1.63)
Positive affect		0.69** (0.24)
Negative affect		−0.16 (0.23)
Climate change attitudes		0.26 (0.20)
Psychological distance		−0.30 (3.87)
Place attachment		1.73 (1.09)
Gender		6.81 (4.95)
Constant	18.89*** (1.77)	67.59*** (19.74)
Observations	160	159
R2	0.12	0.18
Adjusted R2	0.10	0.14
Residual Std. Error	11.04 (df = 156)	25.89 (df = 150)
F Statistic	7.14*** (df = 3; 156)	4.12*** (df = 8; 150)

Note: *p< <0.05; **p < 0.01, ***p < 0.001.

Table 2
Reduced model showing statistically significant drivers of adaptation investments after exposure to flood risk framings.

	Visual framing:		Impact framing:	
	Map (1)	Text-only (2)	Persons affected (3)	Economic losses (4)
Cognition				
Risk propensity		−1.19* (0.52)		−1.52** (0.53)
Affect				
Emotional	8.75*** (2.59)	−7.55** (2.58)		
Nervous	−5.49** (1.78)	−4.60* (1.77)		
Enthusiastic	−7.03** (2.55)			
Inspired	−4.87** (1.66)			
Tense	5.98** (1.83)			
Concentrated	6.36*** (1.64)	7.69** (2.20		5.28** (1.89)
Interested		6.37* (2.47)	8.49*** (1.98)	
Agitated			−4.42* (1.76)	
Socio-demographics				
Gender		20.96** (6.06)	12.98* (5.60)	
Constant	64.92** (8.77)	73.12*** (14.40)	53.91*** (11.57)	91.87*** (14.68)
Observations	86	73	80	79
R^2	0.36	0.35	0.27	0.22
Adjusted R^2	0.31	0.29	0.24	0.20
Residual Std. Error	22.40 (df = 79)	23.92 (df = 66)	24.92 (df = 76)	24.39 (df = 76)
F Statistic	7.37*** (df = 6; 79)	5.89*** (df = 6; 66)	9.43*** (df = 3; 76)	10.56*** (df = 2; 76)

Note: *p< <0.05; **p < 0.01, ***p < 0.001.

confirms this (model 2, Table 3), results show that investments in period 2 for those that experienced losses are also driven by other forms of cognitive and experiential factors. Greater cognitive effort (task difficulty) was found to increase period 2 investments. The same effect was found for previous experience of climate change and feelings of fear, consistent with our third hypothesis. In contrast, results show that other types of feelings, namely empowerment and tension, acted to decrease investments (model 3, Table 3). For those with no experience, we expected more positive affect-led responses associated with feelings of success to lead to more risk-taking behaviour and decreases in protection investments. While there is some evidence of positive affect-based decision-making, results show contrasting effects, with feelings of inspiration and feelings of pride leading to increases and decreases in invesments, respectively (model 4, Table 3).

It is important to note that both those participants who experienced and those who did not experience losses invested above the middle protection level in period 1 (this had a 50% chance of experiencing losses). In other words, both groups were generally risk-averse in period 1. However, those who experienced losses invested significantly less (mean = 80.52) in period 1 compared to those that did not (mean = 101.3), F(1,158) = 24.12, p-value = 2.24e-06. This makes sense, such that the probability of experiencing losses increased with more risk-taking behaviour (model 1, Table 3). For period 2 however, there was no significant difference in levels of investment between the two groups, F(1,158) = 3.027, p-value = 0.0839. As mentioned above, this is primarily because those without experience became more risk-taking in period 2, while risk behaviour for those with experience remained unchanged.

Table 3
Regression analysis of factors affecting investments in period 2 with and without the experience of losses.

	Dependent variable:			
	Experience (loss = 1, no loss = 0) (1)	Investment P2 (2)	Investment P2 (with experience) (3)	Investment P2 (without experience) (4)
Investment P1	−0.01** (0.001)	0.78*** (0.07)	0.80*** (0.10)	0.79*** (0.08)
Experience (loss = 1, no loss = 0)		7.48 (4.02)		
Cognitive effort			8.59*** (2.28)	
Affect				
Tense			−5.07* (2.20)	
Empowered			−5.33** (1.99)	
Afraid			5.89* (2.34)	
Inspired				2.95* (1.38)
Proud				−3.36* (1.31)
Past experience				
Experience			16.95** (5.77)	
Constant	0.98** (0.13)	14.05 (7.51)	12.41 (10.66)	15.64 (10.44)
Observations	160	160	62	98
R2	0.13	0.45	0.62	0.51
Adjusted R2	0.13	0.44	0.58	0.49
Residual Std. Error	0.46 (df = 158)	23.09 (df = 157)	21.37 (df = 55)	20.68 (df = 94)
F Statistic	24.13*** (df = 1;158)	63.34*** (df = 2;157)	15.12*** (df = 6;55)	32.51*** (df = 3;94)

Note: *$p < 0.05$; **$p < 0.01$, ***$p < 0.001$.

3.3. *Gender effects*

Findings indicate no difference in general risk-taking behaviour between women and men, $F(1,157) = 0.141$, p-value = 0.708, but women on the whole had higher perceptions of risk, $F(1,157) = 18.69$, p-value = 2.72e-05, and higher levels of investment in adaptation, compared to men, $F(1,157) = 6.621$, p-value = 0.011. In addition, women reported having greater concern about the impacts of climate change in Zarautz, $F(1,157) = 8.863$, p-value = 0.00337, felt a greater sense of moral responsibility towards climate change, $F(1,157) = 11.51$, p-value = 0.000876, attributed greater importance to the issue of climate change in general, $F(1,157) = 14.12$, p-value = 0.000242, felt more emotional, $F(1,157) = 4.932$, p-value = 0.0278, and perceived climate change as being more psychologically, $F(1,157) = 19.86$, p-value = 1.58e-05, and temporally close, $F(1,157) = 14.28$, p-value = 0.00022, compared to men. As reported in Table 2, gender effects were also evident in two of the four risk framings. Women exposed to text-only treatments and those that saw impacts framed as persons affected led to higher investments in adaptation.

4. Discussion

4.1. *Climate change attitudes and perceptions*

As evidenced by previous studies (Gifford, 2011; Gifford et al., 2009; Schultz et al., 2014; Spence et al., 2012; Uzzell, 2000), our findings suggest that people have a general perception of climate change as being a psychologically distant issue, viewing proximal climate impacts as less severe than those further away in space and time. Scientists have attributed this to a spatial optimism bias, linked to positive feelings about one's self and community, which causes people to view distant conditions as less attractive than those closer to home (Kunda, 1990). There is some evidence that psychological distance may affect threat appraisal in our study, with greater distance decreasing perceptions of personal climate risks. While we cannot reliably conclude the relationship between threat appraisal and investment behaviour when it comes to flood risks, recent research seems to indicate that reducing psychological distance in climate risk communications could offer a promising strategy for increasing concern, encouraging support for adaptation, and improving overall engagement on the issue (Jones et al., 2017; Singh et al., 2017; Wang et al., 2019).

While previous research has reported a discounting of climate impacts, such that people expect impacts to occur in the distant, rather than in the near future (Leiserowitz, 2007; Lorenzoni et al., 2007; Nicholson-Cole, 2005), our results show that climate change was generally perceived as being temporally close. The more frequent reporting of climate change related weather events across news and media outlets in recent years, as well as more widespread coverage of major and youth-led climate campaigns such as the Fridays for Future school strikes and global climate strikes spearheaded by Swedish climate activist Greta Thunberg, will undoubtedly have contributed to an increasing knowledge and public awareness of climate change, particularly among younger generations (such as that of our sample), likely lessening the perceived temporal distance of climate related impacts at the same time. In fact, while previous polling data has indicated relatively low levels of public agreement on the anthropogenic nature of climate change (Leiserowitz et al., 2013), over 90 percent of participants in this study believed that climate change is caused by humans, and the large majority rated it as being a highly important issue.

4.2. Effectiveness of flood risk framings

Findings support those of previous studies (Burningham et al., 2008; Harvatt et al., 2011; Roth, 2009), which point to the potential ineffectiveness of maps as flood risk communication devices. While the inclusion of a map in risk communications evoked decision-making based on positive and negative affect-based reasoning, discrete emotions similar in nature were found to compete, acting to either amplify or depress framing effects. Moreover, those exposed to flood maps were found to have lower levels of positive affect and ratings of self-efficacy, with decisions largely driven by experiential, rather than cognitive forms of information processing. In general, these effects prompted more risk-taking behaviour, and lower investments in adaptation as a result. In contrast to previous assertions that maps may help to make risks more local and personally relevant (Retchless, 2018), maps were generally ineffective at helping participants to recall past experiences, and those exposed to them reported having lower levels of positive affect (interest, activeness, concentration) and self-efficacy compared to the text-only treatment. Having said that, a larger proportion of respondents reported never having visited Zarautz, and on the whole lower feelings of place attachment were observed for participants in map (compared to text-only) treatment groups. An interesting next step would be to replicate the experiment with people from or living in Zarautz to assess whether this may yield different results.

As expected, framing impacts as persons affected was found to evoke more experiential forms of information processing, compared to those presented with impacts framed as economic losses, which was largely cognitive in nature. However, this type of framing did not evoke comparatively higher perceptions of personal risks, moral responsibility, or levels of concern, and ultimately did not induce more precautionary behaviour as a result. As Walker et al. (2018) suggests, this could be due to the fact that participants did not consider these impacts to be sufficiently relevant, at least not enough to warrant significant changes in action responses. As with map framings, future research should assess whether the personal relevance of these types of impact framings changes according to various levels of place attachment. Similarly, it would be interesting to test whether the extent of personal relevance in these framings relates to the actual number of people affected. Slovic et al. (2007) finds that people are more likely to feel compassion and donate to starving children in Africa when shown a picture of one starving child compared to when the same photo is accompanied by statistical information about the millions of starving children in Africa. In the same way, risk communications that include a narrative about a person or family that has been affected by flooding in the past may increase affective reasoning as well as precautionary behaviour as a result.

It seems that finding the right balance between cognitive and affective reasoning is an important constituent of risk communications. Indeed, the risk framing that resulted in the highest average protection in investment (the text-only framing) evoked a combination of both cognitive and emotional forms of information processing for making decisions. While not statistically significant, participants in this treatment group displayed higher levels of concern, feelings of moral responsibility, positive affect, perceptions of risks, self-efficacy, and sense of climate importance, as well as lower levels of negative affect compared to any other treatment group (Appendix I).

4.3. Cognitive and experiential effects of experience

It is reasonable to assume that lower investments in protection increase the likelihood of suffering some loss or impact as a result. This is consistent with our findings, which show that those that experienced losses between the two decisions points had lower initial investments in protection than those that did not experience losses. Results support the hypothesis (H3) that experiencing losses evokes greater levels of negative affect, while not experiencing losses evokes greater levels of positive affect. Decisions made after the experience of losses were driven by both cognitive factors and experiential factors. Items such as cognitive effort, previous experiences, and fear were found to increase investments for period 2, while discrete emotions such as tension and empowerment led to decreases in investments. Not experiencing losses on the other hand, led to decisions based on primarily cognitive forms of information processing. For this reason, one might expect a form of objective rationality, resulting in more or less equivalent protection behaviour between

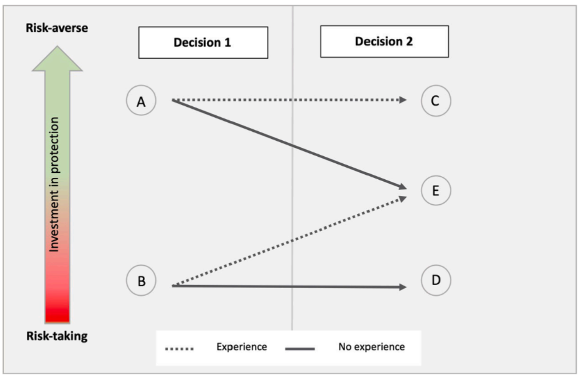

Fig. 4. Potential changes in initial appraisals of risk acceptability for risk-averse and risk-taking Individuals with (A–C, B–E) and without (A–E, B–D) the experience of losses between decision points.

decision points. Investments in adaptation however, were found to decrease between decision points for those who did not experience losses. This may be due to the higher ratings of positive affect observed in this group, i.e. feelings of empowerment, activeness, and concentration, which may bestow upon individuals an increased sense of security or feelings of success that led to more risk-taking behaviour. Interestingly, participants that did experience losses had more or less equivalent investments between rounds. This could relate to the generally high levels of initial investment in protection, combined with more risk-taking behaviour, which prevents individuals from investing greater amounts in protection. In both cases, individuals could be regulating decision-making with the intention of optimising future investments. As shown in Fig. 3, if one perceives their initial investment to be risk-averse (A), then their second decision is likely to be similarly risk-averse if they experience losses (C), but more risk-taking if they do not experience losses (E). In the same way, if one perceives their initial investment to be risk-taking (B), then their second decision is likely to be similarly risk-taking if they do not experience losses (D), but more risk- averse if they do experience losses (E). Fig. 4.

Thus, in the case of this experiment, those that experienced losses were generally risk-averse in in their first decision, and therefore continued to be risk-averse in their second decision (they moved from A to C). Those that did not experience losses were also generally risk-averse in their first decision, but the resultant positive outcome leads them to be more risk-taking in their second decision (they moved from A to E).

4.4. *Study limitations*

While the experiment reveals several noticeable effects of different flood risk framings and experience on risk behaviour, there are some limitations that should be highlighted, as well as areas to be considered for future research. Firstly, the effect of flood risk framings (particularly of map and impacts framed as persons affected) may be influenced by how attached individuals feel to the area under consideration (Scannell and Gifford, 2013). Re-testing the experiment with a sample of the population from Zarautz for example, would help to identify the extent to which place attachment may influence the effect of different risk framings. Furthermore, the predictive power of the psychological models employed in this study would likely be improved by the inclusion of further cognitive variables, such as previous knowledge on climate change (or floods specifically), which may help to better explain investment appraisals and precautionary behaviour. Future research should also explore the effect of experience across different timescales (i.e. through a measure of posttest and delayed posttest responses), to assess whether experiential effects are transient or conducive to long-term behavioural changes. Although conducting the experiment on students allows for better control of certain factors, results are reflective of a homogeneous sample (i.e. of similar ages and education levels), and it is unclear to what extent effects are synonymous with actual policy-makers. Conducting the experiment on policy-makers is not without its own challenges, and also raises questions as to which policy-makers would be suitable for this type of testing, especially given the numerous actors involved in the decision-making process across varying levels of governance and with different capabilities and responsibilities. Repeating the experiment with a representative sample of the general population may help to address some of these issues and provide insight into more widespread sociodemographic effects. Finally, much of the previous literature on climate change risk communication draws a relationship between items such as risk perceptions, concern, fear or worry and hypothetical behavioural or action responses (Cooper and Nisbet, 2016; Graham and Abrahamse, 2017; Hartmann et al., 2014; Mossler et al., 2017; Newman et al., 2012; Stevenson et al., 2014; Wiest et al., 2015). However, results of this study demonstrate that neither risk perceptions nor concern among participants were strong predictors of investment in protection. Future research should acknowledge the distinct differences between hypothetical and actual behaviour, since the former may not always be a reliable proxy for studying real responses.

5. Conclusions

This study demonstrates how diverse flood risk framings and experience of flood events can induce differences in the cognitive and experiential processing of risk information, which can ultimately impact the risk and precautionary behaviour of individuals. Flood risk maps and impacts framed as number of persons affected were conducive to more experiential forms of decision-making, while decisions based impacts framed as economic losses were more cognitive in nature. Those that saw text-only framings used a combination of cognitive and experiential factors for making decisions. While exposure to maps evoked more affect-driven responses, they were associated with lower ratings of positive affect and self-efficacy, and resulted in lower investments in protection compared to text-only framings. Thus, maps were generally found to be an ineffective feature of risk communications in this study, but their effectiveness may depend on the extent to which place attachment mediates the personal relevance of risk framings. While greater experiential processing was found for impact framings based on persons affected, they were not especially effective at increasing personal relevance of the issue. Indeed, investments in adaptation were similar to those in the economic framing, wherein decisions were largely cognitive-based. As with flood risk maps, place attachment may influence judgments of personal relevance, which in turn may act to mediate the effectiveness of personally relevant impact framings. Individuals who experienced losses from a hypothetical flood event had greater ratings of negative affect, and made decisions that were more affect-driven in nature. In contrast, individuals who did not experience losses had greater ratings of positive affect, and made subsequent decisions based on primarily cognitive factors. Investments in protection reduced for those who did not experience losses, and remained the same for those who did experience losses. Results suggest that changes in adaptation investments between decision points may be dependent on both the experience (or lack thereof) of losses, as well as the extent to which individuals were risk-averse or risk-taking in previous investment decisions.

Declaration of Competing Interest

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

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Appendix 1. Summary statistics showing average adaptation investments, cognitive effort, concern, moral responsibility, affect, self-efficacy, importance and risk perceptions for visual and impact treatment groups

	Visual framing		Impact framing	
	Map	Text-only	Economic	Persons affected
Investment (period 1)	89.12 (26.97)	98.05 (28.40)	93.97 (27.22)	92.54 (28.73)
Task difficulty	2.36 (1.46)	2.07 (1.24)	2.11 (1.30)	2.33 (1.43)
Concern	5.15 (1.66)	5.41 (1.36)	5.38 (1.29)	5.16 (1.74)
Moral responsibility	6.41 (0.95)	6.55 (0.88)	6.49 (0.88)	6.48 (0.96)
Positive affect	35.21 (9.49)	37.85 (9.76)	35.70 (9.82)	37.15 (9.54)
Negative affect	23.88 (10.73)	22.73 (9.12)	22.92 (10.11)	23.77 (9.95)
Self-efficacy	5.40 (1.74)	6.04 (1.35)	5.57 (1.69)	5.82 (1.51)
Climate importance	5.55 (1.38)	5.97 (1.01)	5.73 (1.03)	5.75 (1.41)
Risk perceptions	5.59 (1.08)	5.67 (1.00)	5.64 (0.98)	5.61 (1.10)

Note: Values represent the mean with standard deviations in brackets

Appendix II. Potential factors affecting threat appraisal of personal climate change risks

	Threat appraisal (perceived threat and vulnerability)	
	M1	M2
Visual risk framing (map = 1, no map = 0)	0.03 (0.03)	
Impact framing (persons affected = 1, economic = 0)	0.02 (0.03)	
Experience (loss = 1, no loss = 0)	−0.04 (0.03)	
Task difficulty (as a proxy for scientific and numerical literacy)	0.02* (0.01)	
Risk propensity	0.01* (0.002)	0.01* (0.002)
Affect	−0.00 (0.001)	0.001 (0.001)
Climate attitudes (excl. temporal and psychological risk perceptions)	0.68*** (0.12)	0.53*** (0.10)
Past experience	−0.02 (0.03)	−0.01 (0.02)
Place attachment	−0.002 (0.01)	−0.005 (0.01)
Gender	0.09** (0.03)	0.04 (0.02)
Psychological distance		−0.17*** (0.02)
Constant	−0.02 (0.12)	0.33***(0.09)
Observations	159	159
R2	0.34	0.55
Adjusted R2	0.30	0.53
Residual Std. Error	0.16 (df = 148)	0.13 (df = 151)
F statistic	7.62*** (df = 10; 148)	26.42*** (df = 7; 151)

Note: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Appendix III. The influence of environmental (m1) and intrapersonal (m2) factors on affect.

	Affect (Environmental) (1)	Affect (Intrapersonal) (2)
Visual framing (map = 1, no map = 0)	−4.52* (1.75)	−3.40* (1.82)
Impact framing (persons = 1, econ = 0)	−0.18 (1.76)	−0.47 (1.79)
Experience (loss = 1, no loss = 0)	−6.94*** (1.81)	−6.76** (1.81)
Risk propensity		0.17 (0.17)
Cognitive effort		−0.77 (0.66)
Past experience		−4.10* (1.79)
Climate change attitudes		11.02 (8.06)

(*continued on next page*)

(*continued*)

	Affect (Environmental) (1)	Affect (Intrapersonal) (2)
Psychological distance		1.73 (1.52)
Place attachment		0.15 (0.48)
Gender		0.37 (1.97)
Constant	18.89*** (1.77)	7.57 (8.25)
Observations	160	159
R2	0.12	0.18
Adjusted R2	0.10	0.13
Residual Std. Error	11.04 (df = 156)	10.92 (df = 148)
F Statistic	7.14*** (df = 3; 156)	3.32*** (df = 10; 148)

Note: *p< <0.05; **p < 0.01, ***p < 0.001.

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