Chapter 2

CLIMATE RISK COMMUNICATION: EFFECTS OF COST, TIMING, AND PROBABILITY OF CLIMATE CONSEQUENCES IN DECISIONS FROM DESCRIPTION AND EXPERIENCE

Varun Dutt[1,*] and Cleotilde Gonzalez[2]

[1]School of Computing and Electrical Engineering and School of Humanities and Social Sciences, Indian Institute of Technology, Mandi, India

[2]Dynamic Decision Making Laboratory, Department of Social and Decision Sciences, Carnegie Mellon University, Pittsburgh, US

ABSTRACT

Decisions from description and experience impact the psychology of policymaking on climate change. Yet, experiencing climate change consequences in movies and reading descriptive messages about the consequences in newspapers and reports seem to have fallen on deaf ears. This study investigates how a description or experience of cost, timing, and probability of future climate consequences affects people's risky behavior for climate change. In a laboratory experiment, carbon-tax consequences were presented to participants in one of two forms: a written description, where the cost, timing, and probability were explicitly provided; or experience, where the cost, timing, and probability were sampled through unlabeled buttons. Eight problems, each with a safe option and a risky option, were presented in description and experience such that the probability of consequences on the risky option was low or high, the timing was early or late, and the cost was small or large. Results indicate that while in both experience and description, the proportion of risky choices was greater when the probability was low rather than high, the difference between low and high probability was amplified in experience and attenuated in description.

[*] Corresponding author: Varun Dutt, Dynamic Decision Making Laboratory, Carnegie Mellon University, 4609 Winthrop Street, Pittsburgh, PA 15213. E-mail: varundutt@yahoo.com.

Also, the proportion of risky choices was greater when the timing was late than early, and when the cost was small than large; however, the effects of timing and cost were absent in experience. These results are explained by people's risk- and time-preferences, and the moderating effects of experience of climate consequences. Implications of these findings for climate risk communication are discussed.

Keywords: Time, probability, cost, decisions from experience, decisions from description, climate change

INTRODUCTION

Unlike other global problems with risky outcomes (e.g., poverty, education, and war etc.), climate change is unique: It affects us all alike, and its future consequences might be costly, delayed, and uncertain (Sterman, 2008; Weber, 2006). Climate change is a serious problem needing immediate attention.

The Intergovernmental Panel on Climate Change (IPCC) (2007), the Joint Science Academies (JSA) (2007), and the World Meteorological Organization (WMO) (2006) have jointly concluded that the current levels of greenhouse-gas emissions far exceed historic levels and that these emissions must be urgently and significantly reduced. Failing to do so, the world could face catastrophic consequences in the future.

Although climate change is a serious problem, there are uncertainties in climate change about the future cost (how much?), timing (when?), and probability (with what chance?) of occurrence of consequences (IPCC, 2007). For policymaking, these uncertainties are communicated using both descriptive and experiential methods (Dutt and Gonzalez, 2012a; Dutt and Gonzalez, 2012b).

According to Dutt and Gonzalez (2012b), the descriptive methods include descriptive climate models, newspaper reports, or other institutional reports (e.g., a news item in a newspaper or the IPCC report); in contrast, the experiential methods include personal day-to-day experiences, experiences gained through movies, or experiences gained through video games (e.g., movies like *An Inconvenient Truth* or *The Day After Tomorrow*, or a dynamic simulation game).

Although the both the descriptive and experiential methods seems to be common, decisions made from experience or description on climate change seems to have fallen on deaf ears (CRED, 2009; Dutt and Gonzalez, 2012a). A large number of people, including citizens, policymakers, and scientists, prefer to take risks and wait, rather than act now to reduce emissions, i.e., they exhibit a risk-seeking behavior for climate change (Dutt and Gonzalez, 2012a, 2012b, 2012c; Leiserowitz, 2007; Nordhaus, 1994; Sterman, 2008; Sterman and Booth Sweeney, 2002, 2007).

There is evidence that the use of descriptive and experiential methods seem to create differences between economists and climate scientists on policy estimates about the cost, timing, and probability of future climate consequences (Nordhaus, 1994). For example, when economists from the National Academy of Sciences (NAS) were asked to assess the cost of damages in gross world product (GWP) for a rapid 6°C rise in average earth's temperature by 2090, the estimates varied between 0.8% of GWP (for economists) and 62% of GWP (for climate scientists) (Nordhaus, 1994).

Similarly, when asked to assess the probability of damages occurring under the same scenario, estimates varied between 0.3% (for economists) and 95% (for climate scientists). Moreover, the study admitted to being uncertain about the timing of climate consequences and gave different scenarios to the NAS panel. For example, one scenario was projected more than 100 years from now in the year 2175, and another less than 100 years from now in the year 2090. Generally, the economists' predictions seem to *underweight* the cost and probability; whereas, the natural scientists' predictions seem to *overweight* the same cost and probability. According to Nordhaus (1994), the climate scientists' overweighting was due to their widespread exposure to *descriptive* models of climate change; whereas, economists' underweighting was driven by their widespread reliance on their current *experiences* of climate change in the absence of descriptive climate knowledge.

In fact, recent research in judgment and decision making (JDM) has revealed that decisions made from a description (like those of climate scientists) overweight low probability consequences; whereas, decisions made from experience (like those of economists) underweight low probability consequences (Hertwig, Barron, Weber, and Erev, 2004). There is not yet an empirical study that has evaluated the influence of descriptive and experiential probability of climate consequences in combination with their cost and timing on people's risk-seeking behavior for climate change. Thus, the effects of communicating the uncertainties in cost, timing, and probability of climate consequences through descriptive and experiential methods on people's risk-seeking behavior is less understood and needs to be systematically investigated. In this book chapter, we test how people's risky decisions made from description or experience differ according to the cost, timing, and probability of climate consequences.

BACKGROUND AND HYPOTHESES

Literature in JDM has studied people's risk-seeking choices in decisions made from a written description or from experience (Hertwig, in press; Hertwig et al., 2004; Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). In decisions from description, people are asked to choose between two options in which all consequences and their probabilities are stated (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). In contrast, in decisions from experience, people are provided with two blank buttons (representing the two options) where they can first sample the consequences by clicking the buttons as many times as they wish (with no costs) before deciding which option to choose for real (Hertwig, in press; Hertwig et al., 2004).

People's risk-seeking choices in decisions from description and experience are a function of both the probability (low or high) and the sign of the consequence (loss or gain) (Kahneman and Tversky, 1979; Tversky and Fox, 1995; Tversky and Kahneman, 1992). The basic finding is a "fourfold pattern" (Hertwig, in press): In decisions from description, people are risk-seeking when the probability of a loss is high and when the probability of a gain is low, while people are risk-averse when the probability of a gain is high and when the probability of a loss is low (Tversky and Fox, 1995). This fourfold pattern in decisions from description has been replicated in many studies in the past (Cohen, Jaffray, and Said, 1987;

Fishburn and Kochenberger, 1979; Hershey and Schoemaker, 1980; Kahneman and Tversky, 1979), and it has been explained by prospect theory (Kahneman and Tversky, 1979).

In contrast, a reversal of the fourfold pattern appears when people make decisions from experience (Hertwig, in press; Hertwig and Erev, 2009; Hertwig et al., 2004): People are risk-seeking when the probability of a gain is high, but risk-averse when it is low. At the same time, they are risk-seeking when the probability of a loss is low, but risk-averse when it is high (Hertwig, in press). Although people's behavior in decisions from experience may be difficult to explain according to the original parameters of prospect theory (Kahneman and Tversky, 1979), researchers have found that by recalibrating the theory's weighting and value function parameters with human data, it is possible to account for risky choices in decisions from experience. However, the recalibration also turns the weighting function into an identity function of probability, which sheds light on the boundaries of prospect theory's applicability in its original form (Hau, Pleskac, Kiefer, and Hertwig, 2008; Hertwig, in press).

In previous research, we have presented an explanation of risk-seeking behavior for climate change when the information about probability and consequences was presented as a description or as experience (Dutt and Gonzalez, 2012a). We presented participants with choice problems as experience or as a written description with two options: safe (risk-averse) and risky (risk-seeking). The safe option entailed paying a cost (e.g., a carbon tax of certain magnitude) right now; whereas, the risky option entailed losing a larger cost (as a tax) compared to the safe choice with some probability (low or high) in the future. It was found that the difference in proportion of risky choices between a low and high probability tax payment was amplified in experience; whereas this difference was attenuated in description. The amplification in experience was explained by the four-fold pattern: people prefer to be risk-seeking when they experience a carbon tax (a loss) that has a low probability, but prefer to be risk-averse when they experience one that has a high probability. Similarly, the reason for the attenuation of the difference in description is due to the exact opposite effects of low and high probability carbon taxes compared to those in experience. Thus, a first goal in the current chapter is to replicate this result. For the risky choices for climate change we expect:

H1: The difference in the proportion of risky choices between a low probability and a high probability consequence will be greater when making decisions from experience than from description.

As mentioned earlier, there is currently uncertainty about when or how soon climate consequences are expected to appear (Nordhaus, 1994; Öncüler, 2010).

We have also investigated the effects of timing of future cost consequences (as carbon taxes) on people's risk-seeking behavior (Dutt and Gonzalez, 2012a). In previous research, we manipulated the timing on the risky option such that for an early occurrence of climate consequences (10 years in the future), the associated cost was smaller compared to that for a late occurrence of climate consequences (100 years in the future) (the cost increased directly as a result of timing with a smaller cost for early timing and a larger cost for late timing). Results revealed that the proportion of risky choices was not influenced by timing, early or late, and it was similar in both experience and description. One reason for this result is that the time delay was perceived only as a cost; however, in reality people might be able to earn salaries and might reap incentives during the time they wait to act on climate change. For example, some policymakers think that risk-seeking behavior to climate mitigation actions *will enable* people and industry to reap greater economic benefits in the time they wait to act on climate change through interest on savings in banks (Schoof, 2011).

Therefore, there is a possibility that the accrued incentives in waiting would balance out the costs of future climate consequences, especially if these consequences occur late in the future. Motivated by these arguments, we modified our previous paradigm by making the time delay costly but also beneficial.

According to literature on inter-temporal choice, people's repeated choices for risky and safe options in both experience and description under a time delay depend on whether the delay provides an incentive (Luhmann, Chun, Yi, Lee, and Wang, 2008; Wu, 1999). Therefore, people would prefer to choose a risky option which produced a time delay between repeated choices so long as they could derive an incentive during the waiting time.

For climate, if the climate consequences occur early in the future (e.g., 10 years from now), then the cost (carbon tax) of consequences may outweigh the gains that people make while waiting for a short time. However, if the climate consequences occur later in the future (e.g., 60 years from now), the economic gains people make while waiting may outweigh the cost (carbon tax). If people's time-preferences are driven by the option that provides them with a greater incentive in both experience and description (Dutt and Gonzalez, 2012a; Luhmann et al., 2008; Wu, 1999), then we expect a greater proportion of risky choices for later climate consequences than earlier consequences. We hypothesize that:

H2: The proportion of risky choices will be greater when consequences are expected to occur late rather than early in the future, and this effect should not differ whether the time is experienced or described.

Aside from the timing, there is also uncertainty and lack of consensus on the magnitude of costs (or magnitude of taxes) that future climate consequences will bestow on people (Nordhaus, 1994; Öncüler, 2010; The Economist, 2010). According to a popular climate economic model (Stern, 2006), the cost of future climate consequences, if left unmitigated, could vary between 5% and 20% of global GDP (a large range of variation). Also mentioned above, the NAS panel's estimates varied between 0.8% and 62% of GWP when the panel was asked to access the cost for a scenario with a rapid 6 degree centigrade rise in the earth's average temperature by 2090 (Nordhaus, 1994).

Although we did not evaluate the effects of costs on people's risky behavior in our previous study (Dutt and Gonzalez, 2012a), cost has been shown to have an effect as strong as that produced by time delay (Benzion, Rapoport, and Yagil, 1989; Thaler, 1981). The basic finding is that for problems involving descriptive or hypothetical inter-temporal choices (i.e., between paying now and paying in the future), people's discount rate falls sharply when costs increase (Holcomb and Nelson, 1992; Thaler and Loewenstein, 1992). This observation means that given a choice to pay a $10 carbon tax now or a $15 carbon tax in a year from now, a majority of people might prefer to pay the later $15 tax; however, if given a choice to pay a $100 carbon tax now or a $150 tax in a year from now, a majority of people might prefer to pay $100 right now. The main reason for this observation is that people are not only sensitive to relative differences in amounts they have to pay now and in the future, but they are also sensitive to the *absolute differences* in magnitudes between what they pay now and in the future (Prelec and Loewenstein, 1991). Thus, we hypothesize:

H3a: In description, the proportion of risky choices *will be greater* when the cost of consequences is small rather than large. In addition, although people's discount rate falls sharply when cost increases in *both* experience and description (Johnson and Bickel, 2002); some other studies have also documented a *lack of the effect* of cost in experience (Green, Myerson, Holt, Slevin, and Estle, 2004).

Similarly, studies with animals, which only give animals an experience of a cost or reward, seem to find no effect on animals' discount rates (Jimura, Myerson, Hilgard, Braver, and Green, 2009). The main reason for this lack of consistency of the effect in experience is that an animal or human has to actually *wait* to pay a cost or to receive a reward, and such time delays are absent in a descriptive account of the same choice problem (Jimura et al., 2009). Thus, we hypothesize that:

H3b: In experience, the proportion of risky choices should not differ when the cost of consequences is either small or large.

METHOD

Participants were randomly assigned to one of two conditions: *description* or *experience*. In the *description* condition, participants read a written description of climate consequences and were asked to choose between two options that were each associated with a particular cost, timing, and probability values (N = 43). In the *experience* condition, participants sampled two different options that were presented as unlabeled buttons as many times as they wanted to (with no costs), and were then asked to choose one of the two options as their real choice (N = 44). Thus, in the experience condition, the cost, timing, and probability of climate consequences were not explicitly provided but were experienced according to the participants' sampling. In both conditions, one option reflected the risky (risk-seeking) choice and the other option, the safe (risk-averse) choice. These description and experience conditions are meant to be a proxy for the descriptive and experiential methods of climate risk communication.

In both experience and description conditions, each participant received eight problems in random order, where the risky option in different problems differed according to the cost, timing, and probability of future climate consequences. The cost could be small (c=$18) or large (c=$36), the timing could be early (n=10 years) or late (n=60 years), and the probability could be low (p=0.20) or high (p=0.80). In all eight problems, the safe option always presented participants with a $6 carbon tax which they would need to pay immediately and with certainty.

In addition to the tax payment in the risky option in different problems, participants earned an interest at a rate of 2% per year on a $5 balance (their salary) in their bank account for each year elapsed in both the experience and description conditions.

For an early timing of climate consequences, the balance in the bank increased to $6.09 and for a late timing of climate consequences, the balance increased to $16.41. The carbon tax ($18 or $36) that participants had to pay due to the early and late climate consequences at the end of the time elapsed was adjusted in the accumulated bank balance. The net amount of the carbon tax minus the accumulated bank balance was the cost of climate consequences to participants (see below for more details).

The Description Condition. One of the eight problems used in the description condition is shown in Figure 1 (other problems were identical in form to the example shown, but with different cost, timing, and probability values). The risky and safe options were randomly assigned to be shown on the left or right of the computer screen. A participant read and chose one of the two options in each of the eight problems, presented one-by-one in random order.

In the safe option (i.e., option 1 in Figure 1), a person had to pay a one-time carbon tax of $6 now for sure. Thus, upon selecting the safe option, a person started with a $5 balance in his bank account, did not get any interest on his $5 balance, and was to pay a $1 cost (i.e., $5 balance +$0 interest - $6 tax payment = $1). In contrast, in the risky option, a person had to pay a one-time cost of $X (=18 for a small tax or =36 for a large tax) with a probability P (=.20 for low or =.80 for high) Y years from now (=10 in the early timing or =60 in late timing), or $0 otherwise.

As previously mentioned, the value of time Y determined the interest that a participant got on his initial $5 bank balance. At 2% per annum when Y=10 years, the interest amount was $1.09, and at 2% per annum for Y=60 years, the interest amount was $11.41.

Therefore, participants paid a cost of $5 + $1.09 - $X (where, X = 18 for a small tax and X = 36 for a large tax with a probability P, and X=0 otherwise) for early timing, and participants paid a cost of $5 + $11.41 - $X (where, X = 18 for a small tax and X = 36 for a large tax with a probability P, and X=0 otherwise) for late timing.

As shown in Figure 1, participants in the description condition were shown a written description of their initial $5 bank balance, interest, tax, and the values of Y and P.

The Experience Condition. In the experience condition, participants clicked upon one of the two unlabeled buttons presented to them in each problem (see Figure 2 for an example of a problem given in the experience condition; other problems were presented similarly but with different cost, time, and probability values). Each button in a problem corresponded to one of the two options, safe or risky. Clicking on one of the buttons each time gave participants a carbon tax (=$6) if the button was assigned to the safe option.

Thus, upon clicking the safe button each time, a participant started with a $5 balance in his account, did not accrue any interest on his $5 balance, and was to pay a $1 cost (i.e., $5 balance +$0 interest - $6 tax payment = $1). In contrast, clicking on the other button gave participants another carbon tax ($X and $0). The value of $X could be either $18 if the cost was small, or $36 if the cost was large.

Furthermore, clicking the risky option delayed the presentation of the carbon tax by a certain number of years, depending on the timing (Y=10 years, if timing was early, or Y=60 years, if timing was late). One year corresponded to one second of real-time delay in the risky option. The one-second to one-year correspondence is motivated from previous time-preference studies with primates, where a similar magnitude of delay had been used (Dutt and Gonzalez, in press; McClure, Ericson, Laibson, Loewenstein, and Cohen, 2007).

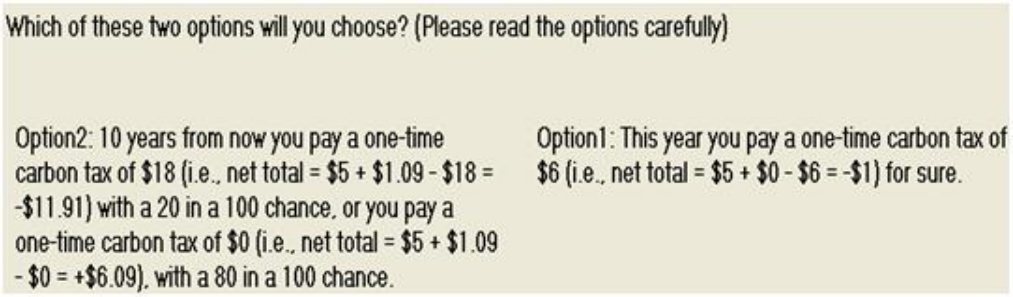

Figure 1. An example of a problem presented to each participant in the description condition. The problem has a small cost, early timing, and low probability of occurrence of climate consequences.

Just like in the description condition, the value of time Y determined the interest that a participant got on his initial $5 bank balance: when Y=10 years, at 2% per annum, the interest amount was $1.09, and for Y=60 years, at 2% per annum, the interest amount was $11.41. Thus, for the early timing, participants paid a cost of $5 + $1.09 - $X, and for the late timing, participants paid a cost of $5 + $11.41 - $X.

As shown in Figure 2, participants were presented with their initial $5 bank balance, interest, tax, and the values of Y and P as an experience based upon their choice for one of the two button options. Participants were first encouraged to sample both buttons as many times as they wanted (without any cost to them) to gain experience in a problem. Sampling essentially meant clicking on one of the two buttons to find the interest, carbon tax, and the cost that a participant would have to pay and to experience the corresponding time delay (without actually paying any cost for real). A participant was asked to make a final choice by clicking the "Make Final Decision" button after he was satisfied with his sampling. A final choice for the risky option in a problem allowed participants to earn money as interest in their bank account depending on the timing and to observe the cost at the end of time delay. A final choice for the safe option in a problem did not give participants any money as interest in their bank account while they observed the cost immediately.

Participants

Eighty-seven undergraduate and graduate students at Carnegie Mellon University participated in this experiment. Participants were recruited through a website advertisement that asked them to participate in a climate decision study. Forty-six participants were males.

Ages ranged from 18 years to 59 years (M = 26, S.D. = 8). All participants started with $5 base pay and depending upon their final choice in eight different problems they could win or lose money. In both conditions, only a participant's final choice affected his final payment (thus sampling the button options in experience did not cost participants). Participants were told about this fact in instructions before starting the experiment. Based upon different carbon taxes and interest amounts, the cost to participants could be $1 in the safe option in each of the eight problems and one of -$6.09, -$16.41, $11.91, $1.59, $29.91, or $19.59 in the risky option in a problem (a negative sign with a cost indicates a gain).

To pay participants, the amount obtained as a result of participants' final choices in each of the eight problems was added together to generate a total amount. Then, this total amount was scaled in a ratio of $10 in the experiment to $1 in real money and paid to participants. Participants were told that the final earnings in the experiment will be determined by the 10:1 ratio and their total amount across different problems depending upon their final choices. Participants were shown their total amount and the tax consequences of their final choices in each of the eight problems only at the end of the experiment (to avoid any learning effects).

Procedure

Participants were randomly assigned to one of the two conditions, experience or description. They read instructions that appeared on a computer terminal. The experimenter answered any questions about the instructions before participants could begin.

Figure 2. An example of a problem presented to each participant in the experience condition. The problem has a small cost, early timing, and low probability of occurrence of climate consequences. The two choice options in the problem were presented as two blank buttons that could be sampled many times by clicking in the buttons. Once a participant had sampled both buttons many times (without any cost to him), a final decision could be made by clicking the "Make Final Decision" button followed by the button the participant wanted to choose. Sampling a button showed the Net total, Initial Amount in Bank, Interest, and Tax Payment at the end of a time period. The participants had to wait for certain number of years (1 year simulated as 1 second of time delay) to get to know their carbon tax payment in the risky option. The Net total and Interest updated after the end of each year of wait in the risky option while the Tax Payment was updated and shown to participants at the end of their period of wait under the risky option. The Net Total, Initial Amount in Bank, Interest, and Tax Payment were displayed instantaneously (i.e., without any wait) in the safe option.

As part of instructions, participants were explained the breakup of different monetary amounts in each problem (e.g., initial amount in their bank account in each problem, interest earned in each problem under the risky option, and about the possibility of paying a carbon tax in each problem). Also, participants were told that they will get a base pay of $5. No participant took more than 15 minutes to complete the eight problems in each condition, description and experience.

RESULTS

To test H1, we compared the difference between the proportion of risky choices in the low probability problems (p=0.20) and the proportion of risky choices in the high probability problems (p=0.80) within the experience and description conditions, respectively. Figure 3 presents the proportion of risky choices according to the probability of occurrence of the tax consequences (low or high).

In experience, there was a significant difference in the proportion of risky choices when the probability was low (71%) compared to when the probability was high (34%), χ^2 (1) = 48.14, $p < .001$, $r = .37$. Similarly, in description, there was a significant difference in the proportion of risky choices when the probability was low (68%) compared to when the probability was high (40%), χ^2 (1) = 30.42, $p < .001$, $r = .29$.

Furthermore, according to our expectation in H1, the difference between the low and high probability (71%-34%=37%) in the experience condition was greater than the difference between the low and high probability in the description condition (68%-40%=28%) (due to the effect size, $r_{\text{experience}} (= .37) > r_{\text{description}} (= .29)$). Thus, these results are in the direction of our expectation in H1.

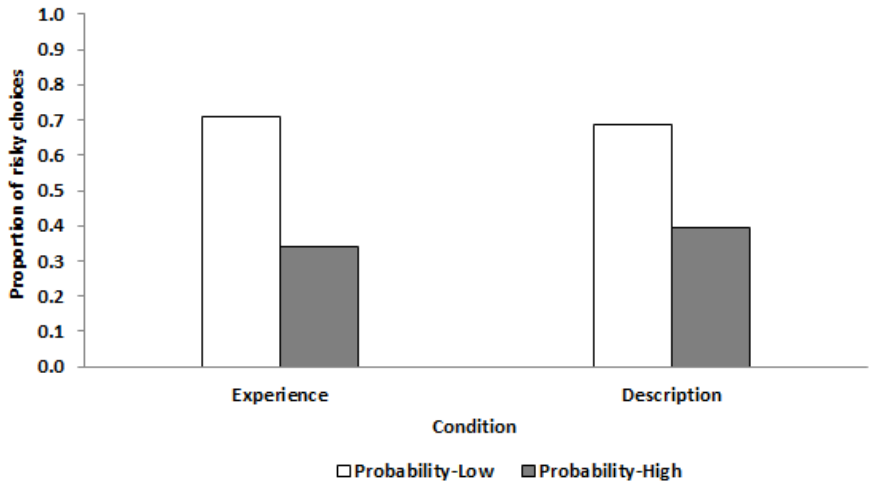

Figure 3. The proportion of final risky choices in the experience and description conditions according to the probability that future climate consequences (low or high) may occur.

To test H2, we compared the proportion of risky choices in problems where the timing was early (Y=10 years) or late (Y=60 years), within the experience and description conditions respectively. Figure 4 presents the proportion of risky choices according to the timing of the climate consequences (early or late).

In experience, the difference in the proportion choices when the timing of consequences was early (50%) than when late (56%) was not significant, χ^2 (1) = 1.38, *ns*, r = .06. However, in description, the difference in the proportion of risky choices when the timing of consequences was early (42%) than when late (67%) was significant, χ^2 (1) = 21.62, $p < .001$, r = .25. Therefore, a greater proportion of risky choices for later timing (H2) is supported in the description condition and not supported in the experience condition.

Finally, to test H3a and H3b, we compared the proportion of risky choices in problems where the carbon tax was small (X=$18) or large (X=$36), within the description and experience conditions respectively.

Figure 5 presents the proportion of risky choices according to the cost of the climate consequences (small or large). In experience, the difference in the proportion of choices when the cost of consequences was small (54%) than when large (51%) was not significant, χ^2 (1) = 0.29, *ns*, r = .03.

Therefore, this result in experience supports our expectation in H3b. However, in description, the difference in the proportion of risky choices when the cost of consequences was small (66%) than when large (42%) was significant, χ^2 (1) = 19.66, $p < .001$, r = .24. Therefore, this result in description also supports our expectation in H3a.

Although we did not have a prediction about the interaction between the cost, timing, and probability of future climate consequences, we present the joint effects in Figure 6. The figure shows the proportion of risky choices in each of the eight problems used in the experiment. Similarly, Table 1 shows the proportion of risky choices between experience and description conditions in the eight problems along with statistical differences. The proportion of risky choices was greater in the experience than in the description condition when the probability of consequences was low, cost was large, and timing was early.

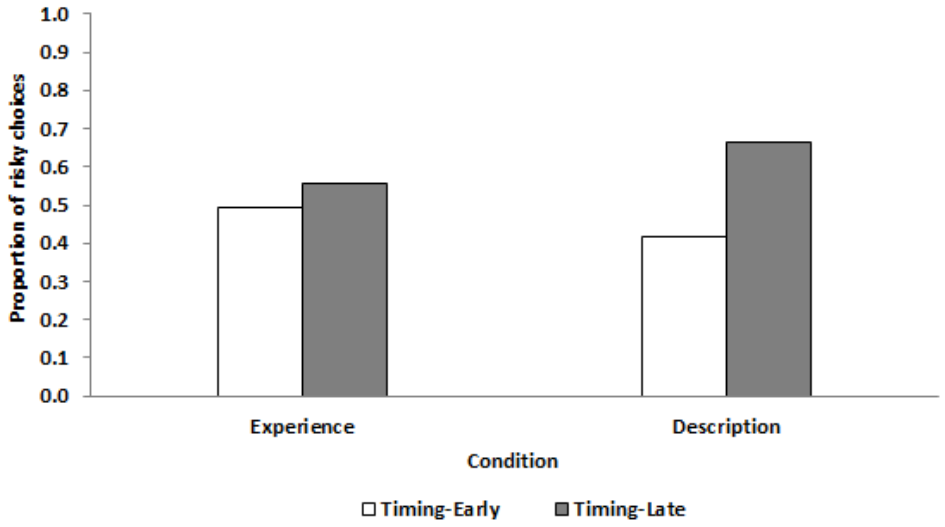

Figure 4. The proportion of final risky choices in the experience and description conditions according to the timing of the climate consequences (early or late).

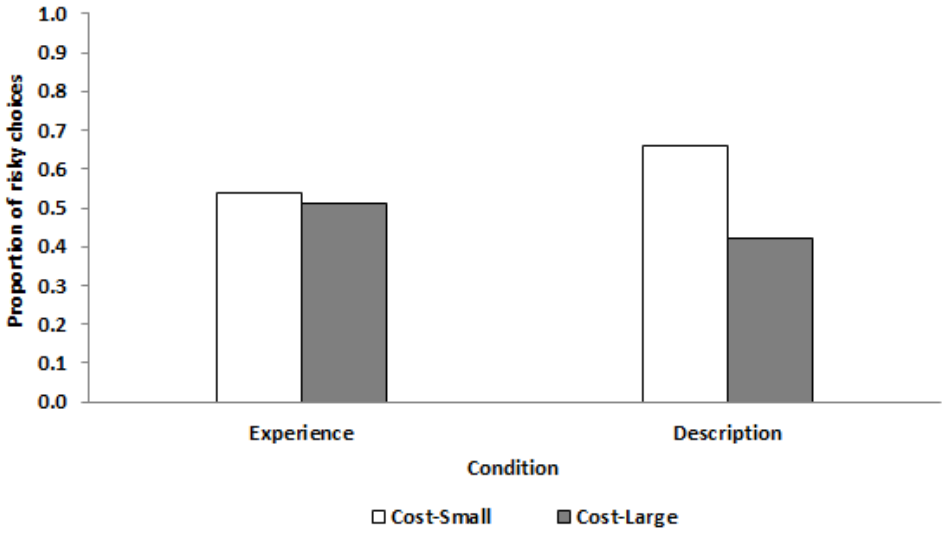

Figure 5. The proportion of final risky choices in the experience and description conditions according to the cost of the climate consequences (small or large).

In contrast, the proportion of risky choices was smaller in the experience than in the description condition when the probability of consequences was high, cost was small, and timing was late.

In all other combinations of probability, cost, and timing, the difference in the proportion between experience and description conditions was not significant.

These results suggest that if the cost, timing, and probability align together to support the proportion of risky choices in one of the experience or description conditions (based upon their individual effects in Figures 3, 4, and 5), the difference in the proportion of risky choices between description and experience conditions becomes significant.

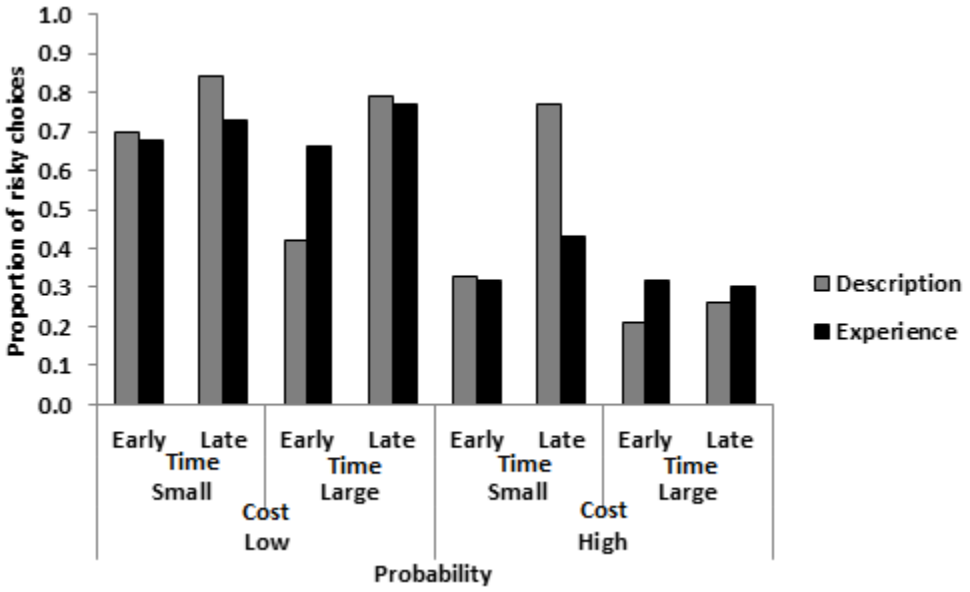

Figure 6. The proportion of final risky choices in the experience and description conditions as a function of the probability (low or high), time (early or late) and cost (small or large) of the occurrence of climate consequences.

Table 1. The proportion of risky choices between experience and description conditions in the eight problems

Values of Variables			Problems		Proportion of Risky (%)		Difference between Experience and Description
Probability	Cost	Timing	Risky Option[1]	Safe Option	Experience	Description	Statistics
Low	Small	Early	-11.91,0.2 and 6.09,0.8	-1,1.0	68	70	-02 (χ^2 (1) = 0.13, *ns*, r = .04)
Low	Small	Late	-1.59,0.2 and 16.41,0.8	-1,1.0	73	84	-11 (χ^2 (1) = 1.54, *ns*, r = .13)
Low	Large	Early	-29.91,0.2 and 6.09,0.8	-1,1.0	66	42	+24 (χ^2 (1) = 5.06, p < .050, r = .24)
Low	Large	Late	-19.59,0.2 and 16.41,0.8	-1,1.0	77	79	-02 (χ^2 (1) = 0.41, *ns*, r = .02)
High	Small	Early	-11.91,0.8 and 6.09,0.2	-1,1.0	32	33	-01 (χ^2 (1) = 0.01, *ns*, r = .01)
High	Small	Late	-1.59,0.8 and 16.41,0.2	-1,1.0	43	77	-34 (χ^2 (1) = 10.19, p < .001, r = .34)
High	Large	Early	-29.91,0.8 and 6.09,0.2	-1,1.0	32	21	+11 (χ^2 (1) = 1.33, *ns*, r = .12)
High	Large	Late	-19.59,0.8 and 16.41,0.2	-1,1.0	30	26	+04 (χ^2 (1) = 0.71, *ns*, r = .04)

Note: [1]The risky option where a cost occurred with a probability p and an interest amount occurred with a probability, 1- p, i.e., in the absence of a carbon tax (e.g., get -$1.59 with a 20% probability and get $16.41with an 80% probability in the second row of the table).

However, when one or two of the three factors opposes the effect of the remaining factors, the difference in the proportion of risky choices between experience and description conditions is not significant.

Sampling in Experience

Across all the eight problems in the experience condition, participants sampled both options less than five times on average. Although timing and cost did not affect how many times either options were sampled, the probability did affect the number of samples of the safe option. Consequently, the number of samples across both options was no different for early or late timing (for safe option: mean $_{early}$ (4.5) = mean $_{late}$ (1.9) with z = -1.90, *ns*, r = -.10; for risky option: mean $_{early}$ (2.0) = mean $_{late}$ (1.6) with z = -1.23, *ns*, r = -.07). As a delay was present on the risky option, this result for that option shows that participants did not perceive the timing as a cost, where a time-cost perception could have dithered them from sampling the risky option (like in Dutt and Gonzalez, 2012a, where time delay in the risky option did not provide any incentive to people). Similarly, the number of samples of both options was no different for a small or large cost (for safe option: mean $_{small}$ (4.2) = mean $_{large}$ (2.1) with z = -0.54, *ns*, r = -.03; for risky option: mean $_{small}$ (1.8) = mean $_{large}$ (1.7) with z = -0.06, *ns*, r = -.00, respectively). Furthermore, as mentioned above, the number of samples of the safe option was affected by the probability of consequences, low or high (mean $_{low}$ (4.7) >> mean $_{high}$ (1.7): z = -4.07, $p < .001$, r = -.22); whereas the number of samples of the risky option was unaffected by probability (mean $_{low}$ (1.8) = mean $_{high}$ (1.8): z = -0.39, *ns*, r = -.02). Therefore, when the probability of consequence was low on the risky option, participants sampled the safe option more often before making their final choices.

Hertwig et al. (2004) suggested that one main reason why probability of consequences affects participants' risk-seeking behavior is limited information search or limited samples of the two options. The smaller the number of samples from the risky (risk-seeking) option, the larger the chance that a participant will not come across the low probability consequence. Consequently, the participant will remain ignorant of the existence of the low probability consequence. Indeed, the small sample size in different problems made participants observe the low probability consequence at less than its expected probability.

Table 2 provides the proportion of risky choice in different problems as a function of the frequency of observing a low probability consequence as being less than, more than, or equal to its expected value (the median sample size for each option in each problem has been listed in brackets in Table 2 and depicts participants' small sample sizes).

The expected value is determined by the product of "n," the number of times the risky option is sampled by a participant in a problem, and "p," the true probability of observing a low probability consequence in the problem. The table shows these percentages for different problems, where the monetary consequences in the two options, the probability of the risky consequence, and the low probability consequence are clearly labeled. When the probability of a negative consequence was low, there was a clear evidence of people behaving as if the low probability negative consequence had less impact than it deserved according to its objective probability (irrespective of the timing and cost): The proportion of risky choices, where the low probability was encountered less frequently than expected, was greater than the

proportion of risky choices where the low probability was encountered as or more frequently than expected (76% > 53%, 76% > 67%, 73% > 29%, and 85% > 55%).

Similarly, the proportion of risky choices, where the low probability positive consequence was encountered less frequently than expected, was consistently smaller than the proportion of risky choices where the low probability positive consequence was encountered as or more frequently than expected (38% > 31%, 80% > 24%, 60% > 17%, and 53% > 17%).

These observations, which indicate participants' limited information search, is an explanation for the significantly greater proportion of risky choices in the experience condition when the probability of the negative consequence was low, and a significantly smaller proportion of risky choices in the experience condition when the probability of the negative consequence was high (see Figure 6).

DISCUSSION

This research contributes to a better understanding of people's risky choices in a climate problem according to what they rely to make their choices (a description or an experience).

We replicated the effects of the probability of future climate consequences in experience and description from Dutt and Gonzalez (2012a); and also demonstrated that cost and timing of future consequences have an effect on people's risky choices when decisions are made based upon a description, but not based upon an experience.

The amplification of the difference between low and high probability in experience is explained by people's risky choices in decisions from experience: People are risk-seeking and choose the risky option more for low probability consequences, and they are risk-averse and choose the safe option more for high probability consequences. While making decisions from experience, people behave as if the low probability consequences have less impact than they deserve according to their objective probabilities, and the high probability consequences have more impact than they deserve (Hertwig, in press). Similarly, the attenuation in description is explained by people's risky choices in decisions from description: People are risk-averse for low probability consequences and they are risk-seeking for high probability consequences (Hertwig, in press; Tversky and Kahneman, 1992).

As in the real world, there exists uncertainty about the true probability of future climate consequences (low or high). These results suggest that when descriptive methods like newspaper and institutional reports are used to communicate this future uncertainty, they might attenuate the impact of the uncertainty on people's current risky behavior. In contrast, experiential methods (like movies and video games) that communicate this uncertainty might have more impact on current risky policies for climate change compared to the descriptive methods.

Our results also indicate that the effect of timing is absent in experience, but present in description. In description, we found a greater proportion of risky choices when consequences occur later in the future compared to earlier. People's thinking seems to be largely driven by the greater gains they can gain as a consequence of the wait when the consequences occur late rather than early. Similarly, one possible explanation why timing lacked an effect in experience could be that people had to actually wait for the time to elapse, *unlike* people in the description condition.

Table 2. The proportion of risky choices with a low probability consequence as a function of the frequency of the low probability consequence occurring

Values of Variables			Problems		Low Probability Consequence	Proportion of risky choice (with low probability consequences)	
Probability	Cost	Timing	Risky Option	Safe Option		# < np[1] %	# ≥ np[2] %
Low	Small	Early	-11.91,0.2 and 6.09,0.8 (1)[4]	-1,1.0 (1)	-11.91,0.2	76 (22/29)[3]	53 (08/15)
Low	Small	Late	-1.59,0.2 and 16.41,0.8 (1)	-1,1.0 (1)	-1.59,0.2	76 (22/29)	67 (10/15)
Low	Large	Early	-29.91,0.2 and 6.09,0.8 (1)	-1,1.0 (1)	-29.91,0.2	73 (27/37)	29 (02/07)
Low	Large	Late	-19.59,0.2 and 16.41,0.8 (1)	-1,1.0 (1)	-19.59,0.2	85 (28/33)	55 (06/11)
High	Small	Early	-11.91,0.8 and 6.09,0.2 (1)	-1,1.0 (2)	6.09,0.2	31 (11/36)	38 (03/08)
High	Small	Late	-1.59,0.8 and 16.41,0.2 (1)	-1,1.0 (1)	16.41,0.2	24 (07/29)	80 (12/15)
High	Large	Early	-29.91,0.8 and 6.09,0.2 (2)	-1,1.0 (2)	6.09,0.2	17 (05/29)	60 (09/15)
High	Large	Late	-19.59,0.8 and 16.41,0.2 (1)	-1,1.0 (2)	16.41,0.2	17 (05/29)	53 (08/15)

Note: [1]Proportion of risky choices with a low probability consequence, where the low probability consequence was encountered less frequently than expected, i.e., n*p, where n is the number of samples of the risky choice performed by a participant and p is the probability of the occurrence of the low probability consequence. [2]Proportion of risky choices with a low probability consequence, where the low probability consequence was encountered as or more frequently than expected. [3]Numbers in brackets refer to the actual frequencies of different proportions. [4]This number indicates the median sample size for the option in the respective problem in the experiment.

In experience, people may have focused on the interest that grows in their account over time during their wait, rather than on the climate consequences that followed the wait. Not attending to or distinguishing the cost consequences after the early or late timing in experience could diminish the effects of timing. Another possible reason could be the experience of an increase in the interest amount with time in both early and late timing conditions. Participants sampled the risky option equally in both cases (which is indicated in our sampling results reported above) and later also chose the risky option with equal chances as their final choice. Thus, experiencing the timing seems to have a moderating effect on people's risky choices due to the actual delay present in the risky option under both timing conditions.

The effects of costs are present in the description condition and are absent in the experience condition. In description, a large cost reduced the proportion of risky choices; whereas, such a relationship is absent in the experience condition. People's discount rate fall sharply as the cost increases (Holcomb and Nelson, 1989; Thaler and Loewenstein, 1992). Thus, their disincentive due to a large cost in the risky option is greater than their disincentive due to a small cost in the same option.

The absence of a similar effect in the experience condition, however, could be because participants in experience needed to wait in order to pay a tax, while they accrued interest that seemed to moderate the effects of large and small taxes. This explanation is further supported by people's sampling of the risky option in our results: there was no difference in people's sampling behavior for small and large costs. Therefore, sampling was perceived as equally costly for both small and large costs, and thus failed to influence people's final choice for the different magnitudes of costs. Furthermore, our finding of the absence of effects of costs in experience support similar findings in literature involving humans (Green et al., 2004) and animals (Jimura et al., 2009).

Consequently, the descriptive methods seem to have more impact on people's risky policies for climate change compared to the experiential methods. Thus, reading descriptions about high and low cost alone, or an early and late timing alone carries more impact on people's risky behavior compared to when the same information about cost or timing is acquired through experiential methods.

Moreover, the joint effects of probability, cost, and timing are interesting because literature in JDM has considered the influence of probability presented as a description or as an experience on people's risky choices without also considering the influence of timing or cost (Hertwig et al., 2004; Kahneman and Tversky, 1979). Similarly, JDM research has considered the influence of timing alone or of timing and probability in decisions from description and experience without considering the influence of cost (Dutt and Gonzalez, in press; Hayden and Platt, 2007; Loewenstein and Elster, 1992; Luhmann et al., 2008; Madden, Begotka, Raiff, and Kastern, 2003; Mischel and Grusec, 1967; Thaler, 1981). Our results show that the proportion of risky choices is higher in experience compared to description when the probability is low, cost is large, and timing is early; however, this proportion is smaller in experience compared to description when the probability is high, cost is small, and timing is late. This result may be explained through the effect of the probability in both the experience and description conditions, and the strong and weak effects of timing and cost on both conditions, respectively. The differences in the proportion of risky choices are affected by all three factors.

Descriptive methods of climate risk communication might produce more risky behavior when uncertain climate information communicates a high probability, small cost, and late timing for future consequences; whereas, experiential methods of risk communication might produce more risky behavior when the information communicates a low probability, large cost, and early timing for future consequences. Future research that applies JDM principles to climate change would benefit by building upon the findings of this study.

ACKNOWLEDGMENTS

This research was partially supported by a Defense Threat Reduction Agency's grant to Cleotilde Gonzalez and Christian Lebiere (HDTRA1-09-1-0053). The authors are thankful to Hau-yu Wong, Dynamic Decision Making Laboratory, Carnegie Mellon University for providing experimental support.

The authors are also grateful to Lorrie Cranor, Michael Yu, Tomas Lejarraga, and Jolie Martin for reviewing this manuscript.

REFERENCES

Benzion, U., Rapoport, A. and Yagil, J. (1989). Discount rates inferred from decisions: An experimental study. *Management Science*, 35, 270-284. doi: 10.1287/mnsc.35.3.270

Cohen, M., Jaffray, J. Y. and Said, T. (1987). Experimental comparison of individual behavior under risk and under uncertainty for gains and for losses. *Organizational Behavior and Human Decision Processes,* 39, 1-22. doi: 10.1016/0749-5978(87)90043-4

CRED. (2009). The psychology of climate change communication (cred guide). Retrieved from http://guide.cred.columbia.edu/.

Dutt, V. and Gonzalez, C. (2012a). Why do we want to delay actions on climate change? effects of probability and timing of climate consequences. *Journal of Behavioral Decision Making*, 25, 154–164. doi:10.1002/bdm. 721

Dutt, V. and Gonzalez, C. (2012b). Human control of climate. *Climatic Change*, 111(3-4), 497-518.

Dutt, V. and Gonzalez, C. (2012c). Decisions from experience reduce misconceptions about climate change. *Journal of Environmental Psychology*, 32(1), 19-29.

Fishburn, P. C. and Kochenberger, G. A. (1979). Two- piece von Neumann- Morgenstern utility functions. *Decision Sciences,* 10, 503-518. doi: 10. 1111/j.1540-5915.1979.tb000 43.x

Green, L., Myerson, J., Holt, D. D., Slevin, J. R., and Estle, S. J. (2004). Discounting of delayed food rewards in pigeons and rats: Is there a magnitude effect? *Journal of the Experimental Analysis of Behavior*, 81, 39-50. doi: 10.1901/jeab.2004.81-39

Hayden, B. Y. and Platt, M. L. (2007). Temporal discounting predicts risk sensitivity in rhesus macaques. *Current Biology*, 17, 49-53. doi: 10.1016/j. cub.2006.10.055

Hau, R., Pleskac, T. J., Kiefer, J., and Hertwig, R. (2008). The description–experience gap in risky choice: The role of sample size and experienced probabilities. *Journal of Behavioral Decision Making*, 21, 493-518. doi: 10.1002/bdm.598

Hershey, J. C. and Schoemaker, P. J. H. (1980). Risk-taking and problem context in the domain of losses: An expected utility analysis. *Journal of Risk and Insurance*, 47(1), 111-132.

Hertwig, R. (in press). The psychology and rationality of decisions from experience. *Synthese*.

Hertwig, R., Barron, G., Weber, E. U., and Erev, I. (2004). Decisions from experience and the effect of rare events in risky choice. *Psychological Science*, 15(8), 534-539. doi:10.1111/ j.0956-7976.2004.00715.x

Hertwig, R. and Erev, I. (2009). The description-experience gap in risky choice. *Trends in Cognitive Sciences*, 13, 517-523. doi: 10.1016/j.tics. 2009.09.004

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change 2007: Synthesis report. In: R. K. Pachauri and A. Reisinger (Eds.), Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change (pp. 104). Geneva, Switzerland: IPCC.

Holcomb, J. and Nelson, P. (1992). Another experimental look at individual time preference. *Rationality and Society*, 4, 199-220. doi: 10.1177/1043 463192004002006

Jimura, K., Myerson, J., Hilgard, J., Braver, T. S., and Green, L. (2009). Are people really more patient than other animals? Evidence from human discounting of real liquid rewards. *Psychonomic Bulletin and Review*, 16, 1071-1075. doi: 10.3758/PBR.16.6.1071

Johnson, M. W. and Bickel, W. K. (2002). Within-subject comparison of real and hypothetical money rewards in delay discounting. *Journal of the Experimental Analysis of Behavior*, 77, 129-146. doi: 10.1901/jeab.2002. 77-129

Joint Science Academies (2007). Joint Science Academies' statement on growth and responsibility: sustainability, energy efficiency and climate protection (Prepared for the 2007 G8 Summit). Retrieved from http:// www.scj.go.jp/ja/info/kohyo/pdf/kohyo-20-s4. pdf.

Kahneman, D. and Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, 47, 263-291. doi: 10.1234/12345678

Loewenstein, G. and Elster, J. (1992). *Choice over time*. New York: Russell Sage.

Leiserowitz, A. (2007). International public opinion, perception, and understanding of global climate change. In: *Human Development Report 2007/2008.* United Nations Development Program.

Luhmann, C. C., Chun, M. M., Yi, D., Lee, D., and Wang, X. (2008). Neural dissociation of delay and uncertainty in inter-temporal choice. *Journal of Neuroscience*, 28, 14459-14466. doi: 10.1523/JNEUROSCI.5058-08.2008

Madden, G. J., Begotka, A. M., Raiff, B. R., and Kastern, L. L. (2003). Delay discounting of real and hypothetical rewards. *Experimental and Clinical Psychopharmacology*, 11(2), 139-145. doi: 10.1037/1064-1297.11.2.139

McClure, S. M., Ericson, K. A., Laibson, D. I., Loewenstein, G., and Cohen, J. D. (2007). Time discounting for primary rewards. *The Journal of Neuroscience*, 27, 5796-5804. doi: 10.1523/JNEUROSCI.4246-06.2007

Mischel, W., Grusec, J. (1967). Waiting for rewards and punishments: Effects of time and probability on choice. *Journal of Personality and Social Psychology*, 5, 24-31. doi:10. 1037/h0024180

Nordhaus, W. (1994). Expert opinion on climatic change. *American Scientist*, 82, 45-51.

Öncüler, A. (2010). How do we manage an uncertain future? Ambiguity today is not ambiguity tomorrow. In: E. Michel-Kerjan and P. Slovic (Eds.), *The irrational economist* (pp. 107-115). New-York, NY: PublicAffairs.

Prelec, D. and Loewenstein, G. (1991). Decision making over time and under uncertainty: A common approach. *Management Science*, 37, 770-786. doi: 10.1287/mnsc.37.7.770

Schoof, R. (2011). Ethics of climate change rise alongside economic concerns. Retrieved from: http://www.theolympian.com/2011/01/24/1517429/ethics-of-climate-change-rise. html#ixzz1D7qqPXsd

Sterman, J. D. (2008). Risk communication on climate change: Mental models and mass balance. *Science*, 322, 532-533. doi: 10.1126/science.1162574

Sterman, J. D. and Booth Sweeney, L. (2002). Cloudy skies: Assessing public understanding of global warming. *System Dynamics Review*, 18(2), 207-240. doi: 10.1002/sdr.242

Sterman, J. D. and Booth Sweeney, L. (2007). Understanding public complacency about climate change: Adults' mental models of climate change violate conservation of matter. *Climatic Change*, 80(3-4), 213-238. doi: 10.1007/s10584-006-9107-5

Stern, N. (2006). Stern review report in the economics of climate change. Retrieved from http://www.hm-treasury.gov.uk/sternreview_index.htm.

Thaler, R. H. (1981). Some empirical evidence on dynamic inconsistency. *Economics Letters*, 8, 201-207. doi: 10.1016/0165-1765(81)90067-7

Thaler, R. H. and Loewenstein, G. (1992). Intertemporal choice. In: R. H. Thaler (Ed.), *The winner's curse: Paradoxes and anomalies of economic life* (pp. 92-106). New York: Free Press.

The Economist. (2010). The clouds of unknowing. *The Economist.* Retrieved from http:// www.economist.com.

Tversky, A. and Fox, C. R. (1995). Weighing risk and uncertainty. *Psychological Review*, 102, 269-283. doi: 10.1037/0033-295X.102.2.269

Tversky, A. and Kahneman, D. (1992). Rational choice and the framing of decisions. *The Journal of Business*, 59(4), 251-278. doi: 10.1234/12345 678

Weber, E. U. (2006). Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Climatic Change*, 77(1-2), 103-120. doi: 10. 1007/s10584-006-9060-3

World Meteorological Organization (2006). Statement at the twelfth session of the conference of the parties to the United Nations Framework Convention on Climate Change. Retrieved from http://www.wmo.int/pages/mediacentre/statann/documents/SG21_2006_ E.pdf.

Wu, G. (1999). Anxiety and decision making with delayed resolution of uncertainty. *Theory and Decision*, 46, 159-199. doi: 10.1023/A:10049904 10083

Reviewed by:

Dr. Lorrie F. Cranor, Associate Professor of Computer Science and Engineering and Public Policy, Carnegie Mellon University, CIC 2207, 4720 Forbes Avenue, Pittsburgh, PA 15213. Phone: +1 412-268-7534; E-mail: lorrie @cs.cmu.edu.

Dr. Tomas Lejarraga, Visiting Professor of Business Organization, Jovellanos Building DB125. Tel: (+34) 971 172438; E-mail: tomas.lejarraga@ uib.eu.

Dr. Jolie M Martin, Assistant Professor of Journalism and Mass Communication, University of Minnesota, 111 MurH, 206 Church Street, Minneapolis, MN 55455. Phone: +1 617-851-6270; E-mail: jolie@umn.edu.

N.G.