Decision Architecture and Implicit Time Horizons

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Submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

in the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2014

ABSTRACT

Decision Architecture and Implicit Time Horizons

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Recent research on judgment and decision making emphasizes *decision architecture*, the task and contextual features of a decision setting that influence how preferences are constructed (Thaler & Sunstein, 2008). In a series of three papers, this dissertation considers architectural features related to the intertemporal structure of the decision setting that influence cognition, motivation, and emotion, and include modifications of (i) informational, (ii) experiential, (iii) procedural, and (iv) emotional environments. This research also identifies obstacles to decision making, whether that obstacle is an individual difference (e.g., age-related change in emotional processing) or a temporary state (e.g., a change in motivational focus, or sensitivity to irrelevant features of the decision setting). Papers 1 and 2 focus on decision architecture related to *environmentally-relevant* decisions, investigating how structural features of the decision task can trigger different choice processes and behavior. Paper 1 explores a potential mechanism behind constructed preferences relating to climate change belief and explores why these preferences are sensitive to normatively irrelevant features of the judgment context, such as transient outdoor temperature. Paper 2 examines new ways of emphasizing time and uncertainty with the aim of turning psychological obstacles into opportunities, accomplished by making legacy motives more salient to shift preferences from present-future and self-other trade-offs at the point of decision making. Paper 3 examines how the temporal horizon of a decision setting influences predicted future preferences within the domain of affective forecasting. In addition, Paper 3 explores how

individual and situational differences might affect the match (or mismatch) between predicted and experienced outcomes by examining differences in forecasting biases among older versus younger adults. Taken together, these three papers aim to encourage individuals to make decisions that are not overshadowed by short-term goals or other constraints, with the aim of producing actionable modifications for policy-makers in the presentation of information relevant to such decisions.

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ACKNOWLEDGMENTS

I would first like to acknowledge my gratitude towards my dissertation committee: Drs. Elke Weber, Eric. Johnson, E. Tory Higgins, Richard Gonzalez, and Kevin Ochsner. Exceptional thanks are due to my advisor Elke Weber, for the support and guidance she has given me throughout my graduate career. I would also like to thank my collaborators on the projects used for this dissertation: Eric Jonhson, Ye Li, Elizabeth Keenan, Ezra Markowitz and Elke Weber. I am additionally grateful for the help of a team of other collaborators. Special thanks are due to Kirstin Appelt, Seth Baum, Zeynep Enkavi, Jie Gao, David Hardisty, Jenn Logg, Jaime Madrigano, Nada Petrovic, Matthew Sisco, and Jon Westfall. I am also very thankful for the support of two great labs: The Center for Research on Environmental Decisions and the Center for Decision Sciences. Finally, I would like to thank the National Institute of Aging and the National Science Foundation for their generous support, including a dissertation improvement grant.

DEDICATION

To Jeff, Janet, Ed, Shara and PC

Thank you for the support, encouragement and inspiration

Introduction

Behavioral decision research has firmly established that people's preferences in response to a judgment task are often constructed in the immediate context of decision making (Lichtenstein & Slovic, 2006; Payne, Bettman, & Johnson, 1992; Slovic, 1995). People construct their preferences because decision settings are often complex, involving many alternatives, with uncertain outcomes. For example, attitudes towards climate change (a complex and presently contentious topic) appear to be malleable and constructed at the moment of elicitation, rather than simply retrieved from memory (Li, Johnson, & Zaval, 2011; Weber & Johnson, 2009). The concept of preference construction has led to an increased understanding of the contextual variables that influence preferences and attitudes, including the decision context (i.e., the level of uncertainty), the decision goal (i.e., accuracy versus minimal efforts) and various individual differences (i.e., level of experience).

Recent research on judgment and decision making emphasizes *decision architecture*, that is, the features of a decision setting that influence how preferences are constructed (Thaler & Sunstein, 2008). Decision settings have many structural features that potentially can be varied, and which serve as entry points for the design of decision environments. These structural features can influence the evidence and goals that the decision maker considers, as well as other features of the process of preference construction. Examples include how outcomes are framed and what intertemporal structure is implied in the setting.

Indeed, the implicit intertemporal structure of a decision task has important implications for decision architecture (Hardisty et al., 2012; Johnson et al., 2012). Many decisions involve future outcomes that take place over long time horizons, which may influence preference construction in several ways. First, future outcomes generally involve a high degree of uncertainty, which can cause the decision maker's preferences for future outcomes to become unclear. This can lead to an over-weighting or under-weighing of future outcomes. For example, the long time horizon and ambiguity associated with the consequences of climate change serve as obstacles to pro-environmental decisions, resulting in an underinvestment of present mitigation efforts (Gifford, 2011; Kunreuther & Weber, in press; Petrovic, Madrigano & Zaval, under review; Weber & Stern, 2011). Secondly, future uncertainty can cause the decision maker to become overly sensitive to certain highly salient future outcomes. For example, in the context of affective forecasting, people tend to overestimate affective reactions to future decisions by failing to consider the extent to which peripheral events may influence their emotional responses (Schkade & Kahneman, 1998; Wilson & Gilbert, 2003).

By examining how the temporal horizon of a decision-making setting affects observed (constructed) preferences, and understanding the cognitive and emotional processes involved, the decision architecture can create better tools to overcome intertemporal biases. With this in mind, this dissertation considers architectural features related to the intertemporal structure of the decision setting that influence cognition, motivation, and emotion, and include modifications of (i) informational, (ii) experiential, (iii) procedural, and (iv) emotional environments. This dissertation also considers and identifies various obstacles to decision making; including whether that obstacle is an individual difference (e.g., age-related changes in emotional processing) or a temporary state (e.g., a change in motivational focus, or sensitivity to irrelevant features of the environment). These research questions are examined in a series of three papers, which together report results from ten empirical studies and experiments involving over 2,500 participants.

The concept of decision architecture has implications for several consumer and public policy domains in which individuals regularly experience suboptimal decisions. However, relatively little is known about how decision architecture affects *environmental decisions*. Accordingly, Papers 1 and 2 of this dissertation focus on decision architecture that is related to environmentally-relevant decisions, and investigates how structural features of the decision setting can trigger different choice processes and behavior. Long time horizons and uncertainty pose major challenges for effective decision architecture for environmental decisions. Paper 1 explores a potential mechanism behind observed (constructed) preferences relating to climate change belief, as evidenced by the fact that these preferences are often sensitive to salient, but normally irrelevant features of the judgment context, including transient outdoor temperature. Paper 2 examines how the psychological barriers of time and uncertainty can be turned into opportunities, by making legacy motives more salient, resulting in shifting preferences for present-future and self-other trade-offs at the point of decision making.

Decisions involving long time horizons often involve making predictions about future outcomes and preferences, which in turn may or may not coincide with experienced outcomes (Loewenstein, O’Donoghue, & Rabin, 2003). However, relatively little is known about how individual and situational differences might affect the match or mismatch between the two. The third paper in this dissertation thus explores the interactions of temporal structure and *individual or situational differences in level of experience,* another important contextual variable that influences preference construction. This paper examines the processes involved in how the temporal horizon of a decision setting influences predicted future preferences within the domain of hedonic forecasting. Paper 3 also examines the role of individual differences in emotional experience, by examining potential differences in forecasting biases among older and younger participants. This work suggests that theories and policies involving decision architecture must distinguish between targeted decision makers, in order to accurately describe and predict people's preferences. Taken together, the three papers in this dissertation call upon policy-makers to actively adjust and monitor their presentation of information, so that individuals may make decisions that are not overshadowed by short-term goals or other constraints.

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Paper 1: How warm days increase belief in global warming

Lisa Zaval, Elizabeth A. Keenan, Eric J. Johnson, and Elke U. Weber

KEYWORDS: Attribute Substitution, Decision Making, Environmental Behavior, Constructed Preferences

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Abstract

Climate change judgments can depend on whether today seems warmer or colder than usual, termed the "local warming" effect. While previous research has demonstrated *that* this effect occurs, studies have yet to elucidate *why* or *how* temperature abnormalities influence global warming attitudes. A better understanding of the underlying psychology of this effect can help explain the public's reaction to climate change and inform approaches used to communicate the phenomenon. Across five studies, we find evidence of attribute substitution, whereby individuals use less relevant but available information (e.g., today's temperature) in place of more diagnostic but less accessible information (e.g., global climate change patterns) when making judgments. Moreover, we rule out alternative hypotheses involving climate change labeling and lay mental models. Ultimately, we show current temperature abnormalities are given undue weight and lead to an overestimation of the frequency of similar past events, thereby increasing belief in and concern for global warming.

How warm days increase belief in global warming

During a particularly hot summer in 1988, James Hansen testified before a congressional hearing on the dangers of global warming. The night before his testimony, committee members had opened the room's windows and turned off the air conditioning, hoping the sweltering heat would underscore Hansen's warnings and make the greenhouse effect concrete to anyone present (Pielke, 2000). This intuition, that today's temperature would affect climate change beliefs, anticipates a more recent finding that subjective temperature does, in reality, affect reported beliefs in climate change.

Given that the challenge of reducing carbon emissions depends, in part, on changes in individual behavior, it is important to understand the basis of global climate change perception and concern. Notably, individuals' beliefs about the phenomenon appear to be constructed at the moment of elicitation, rather than simply retrieved from memory (Weber & Johnson, 2009). This is demonstrated by the fact that individuals are sensitive to normatively irrelevant features of the judgment context, including transient temperature (Brody, Zahran, Vedlitz, & Grover, 2008; Egan & Mullin, 2009; Howe, Markowitz, Lee, Ko, & Leiserowitz, 2013; Joireman, Barnes Truelove, & Duell, 2010; Krosnick, Holbrook, Lowe, & Visser, 2006; Risen & Critcher, 2011; Ungar, 1992). Mounting evidence shows personal experience with the daily weather tends to dominate more diagnostic but paler statistical information provided by "experts" (Slovic, Finucane, Peters, & MacGregor, 2002; Tversky & Kahneman, 1973; Weber, Shafir, & Blais, 2004), because the former is more vivid and accessible. Importantly, perceived abnormalities in current temperature have been linked causally with changes in belief in global warming, an effect termed 'local warming' (Li, Johnson, & Zaval, 2011). Specifically, respondents who perceived today's temperature as being "warmer than usual" exhibited greater belief in and heightened concern for global warming and also donated more money to a climate change charity.

Despite accumulating evidence that global warming judgments are influenced by short-lived temperature variation and local weather, the underlying psychological processes regarding *how* or *why* this relationship occurs have not been fully explored in the literature (see Supplementary Table 1 for a review of existing literature). There are at least three mechanisms by which transient, local temperatures may influence individuals' judgments about global climate change. One mechanism suggests that choice option labels influence belief construction. For many issues, subtle changes in question terminology can result in pronounced differences in obtained answers (Schuman & Presser, 1996; Schwarz, 2001), a phenomenon supported by the literature on attribute framing effects in decision research (Hardisty, Johnson, & Weber, 2010; Petrovic, Madrigano, & Zaval, under review; Tversky & Kahneman, 1991). Specifically, the term "global warming", which has been used in previous studies, may prime heat-related cognitions, leading to biased judgments. Second, the local warming effect could be due to a knowledge deficit on the part of respondents, causing them to mistakenly believe that long-term climate and short-term temperature deviations are highly related. A third explanation, rooted in the cognitive heuristics literature (Gilovich, Griffin, & Kahneman, 2002), proposes that individuals use less relevant but salient and available information (e.g., today's temperature) in place of more diagnostic but less accessible information (e.g., global climate change patterns) in belief generation. While this process, known as *attribute substitution* (Kahneman & Frederick, 2002), may seem highly irrational if done consciously and explicitly, other psychological process implementations give it greater plausibility. In particular, we suggest that unusually warm or cold weather conditions may increase the availability of other unusual warm or cold temperature events in memory, changing estimates of the frequency of such events, and thereby affecting respondents' global warming attitudes. To preview our results, we find evidence for only the last of these three mechanisms**.**

STUDY 1

Study 1 explored whether the local warming effect is caused by the use of the term "global warming" in question wording. "Global warming" may prime associations of heat-related impacts and rising temperatures (Leiserowitz, 2005), whereas the term "climate change" is more readily associated with a wider range of weather events (Whitmarsh, 2009). To examine if the influence of perceived temperature depends on the phrasing of the survey question, we asked respondents about their belief in and concern for "Global Warming" or "Climate Change". Participants also reported whether the local temperature on the day they completed the survey was colder or warmer than usual for that time of year.

Methods

In Studies 1, 682 U.S. participants were recruited from the website Amazon Mechanical Turk, where participants can take short surveys online in exchange for small payments (Buhrmester, Kwang, & Gosling, 2011)[1]. See Supplementary Information for demographic details for all studies. These panels represent a wide range of

[1] These panels represent a wide range of socioeconomic factors not seen in university lab settings. Notably, the effect of temperature on global warming judgments has also been corroborated in nationally representative panels (Egan & Mullin, 2012; Howe, Markowitz, Lee, Ko, & Leiserowitz, 2012).

socioeconomic factors not seen in university lab settings. Notably, the effect of temperature on global warming judgments has also been corroborated in nationally representative panels (Egan & Mullin, 2012; Howe et al., 2012).

In Study 1, participants were randomly assigned to the global warming vs. climate change conditions and answered three standard questions, based on the methodology used by Li et al., 2011. Respondents reported how convinced they were "that '*global warming'* ['*climate change'*] is happening" and how much they "personally worried about '*global warming'* ['*climate change*']. Response options ranged from 1 (*not at all convinced/worried*) to 4 (*completely convinced/a great deal worried*). These questions and response scales were adapted from prior public-opinion studies about global warming (Leiserowitz, Shome, Marx, Hammer, & Broad, 2008). Belief and concern correlated significantly in this and all subsequent studies ($r = .59$, $p < .01$). Participants also reported whether the local temperature on the day they completed the survey was colder or warmer than usual for that time of year, using a 5-point scale that ranged from −2 (*much colder*) to 2 (*much warmer*). The belief question came before the concern question, in this and all subsequent studies; however, the presentation order of the belief/concern and temperature questions was counterbalanced. In addition to these questions in this and all other studies, respondents provided information about political affiliation and extensive demographic information. We also collected actual temperature and historical temperature deviation data for the day that participants completed the studies, using their ZIP code information (see Supplementary Information for actual temperature data collection methods).

Results

Results from Study 1 show that the overall effect of perceived temperature deviation on belief in and concern for global climate change persisted whether the phenomenon was described as *climate change* or *global warming.* A multiple regression testing the effect of perceived temperature, framing condition (Warming vs. Change), and their interaction on belief and concern revealed a main effect of perceived temperature on concern, $\beta = 0.16$, $t(683) = 3.03$, $p < .01$, and a marginally significant effect on belief, $\beta = 0.10$, $t(683) = 1.73$, $p = .08$. However, the interactions were not significant (concern, $p = .64$ and belief, $p = .47$), suggesting that there was no effect of phrasing (see Figure 1). We conducted a number of additional regressions that directly control for actual temperature, actual deviation from the historical average, gender, education, age, income, political affiliation, environmental attitude, and subjective knowledge of the phenomenon (see Supplementary Tables 3-A and 3-B). The effect of perceived temperature remained significant in the presence of these controls for both frames. Additionally, to control for reverse causality and omitted variable biases, we employed instrumental variable regression, an econometric tool used to help establish causality in observational data (Angrist & Krueger, 2001; Sargan, 1958). Using actual temperature deviation as an instrument for perceived deviation, we causally link perceived temperature abnormalities with changes in global warming attitude (see Supplementary Analyses). While attribute labels can produce pronounced differences in judgments and choices (Payne, 1951; Schuldt, Konrath, & Schwarz, 2011), termed attribute framing effects in decision research (Hardisty et al., 2010; Tversky & Kahneman, 1981), the idea that the local warming effect is simply caused by being primed with the term *global warming* was not supported by our results.

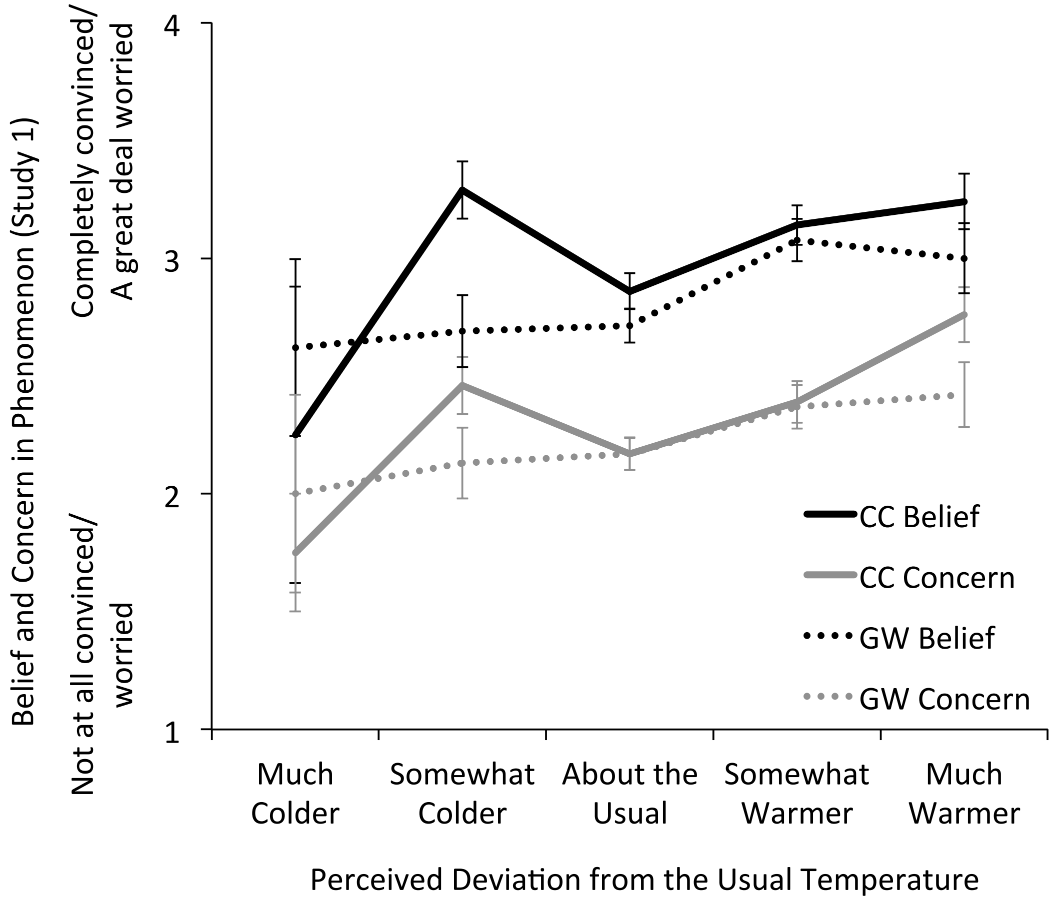

Fig. 1. Climate change labeling and local warming. Level of belief in and concern about climate change (CC) and global warming (GW) as a function of perceived temperature deviation (Study 1). Bars denote ±1 *SEM*.

STUDY 2

Study 2 tested the possibility that participants have limited understanding of climate science and incorrectly believe that today's local temperature *is* relevant information to use in global warming judgments. Local short-term and broad long-term temperature trends are related, but it is only when temperatures are averaged over space and time that climate change patterns emerge (Solomon et al., 2007). If the local warming effect is due to a lay understanding that local temperature is a useful metric for predicting long-term temperature trends, then information about the scientific distinction between local temperature and global climate change should reduce or eliminate the local warming effect.

Methods

In Studies 2, 330 U.S. participants were recruited via Columbia University's Center for Decision Sciences national panel, which consists of over 56,500 people who have agreed to participate in psychological and decision research for financial compensation. We randomly assigned participants to either an information or no-information (control) condition. Those in the information condition read a passage highlighting the differences between minor weather fluctuations and global climate change, which constituted our manipulation of knowledge, while those in the no-information condition read a passage on the science of sleep. (See Supplementary Information for Study 2 passages). Participants were told that the purpose of the research was to "determine the best way to present scientific information to the general public". Both passages were similar in length and educational in tone. To check our manipulation of knowledge, we examined whether participants in the information condition correctly answered an open-ended question about the difference between daily temperature and climate. Two coders independently categorized level of understanding (Cohen's Kappa measurement for agreement was .83, $p < .01$), and found that 82% of participants responded accurately. Only these participants were included in analyses. Participants were also asked to state what they thought the specific purpose of the study was. None of the participants correctly guessed the true purpose of the research. All participants then completed an unrelated filler task and answered the same temperature, belief, and concern questions used in Study 1.

Results

Results from Study 2 show that increased knowledge does not eliminate the local warming effect. A moderation analysis using hierarchical multiple regression revealed a main effect of perceived temperature deviation on belief ($\beta = 0.16$, $p = 0.02$), but there was no main effect of information ($\beta = 0.08$, $p = 0.76$). Importantly, the Information x Perceived Temperature interaction term was also non-significant ($\beta = 0.04$, $p = 0.67$). Similarly, for concern, we find a main effect of perceived temperature deviation ($\beta = 0.14$, $p = 0.04$), but neither a main nor an interaction effect for the information condition. Participants in the information condition were more likely to believe in and be concerned about global warming if they perceived today to be warmer than usual (belief, $\beta = 0.14$, $t(132) = 3.27$, $p < .01$ and concern, $\beta = 0.15$, $t(132) = 0.16$, $p = 0.03$), suggesting that the effect of perceived temperature on climate change perceptions cannot be attributed to a knowledge deficit or incorrect lay theory (see Figure 2).

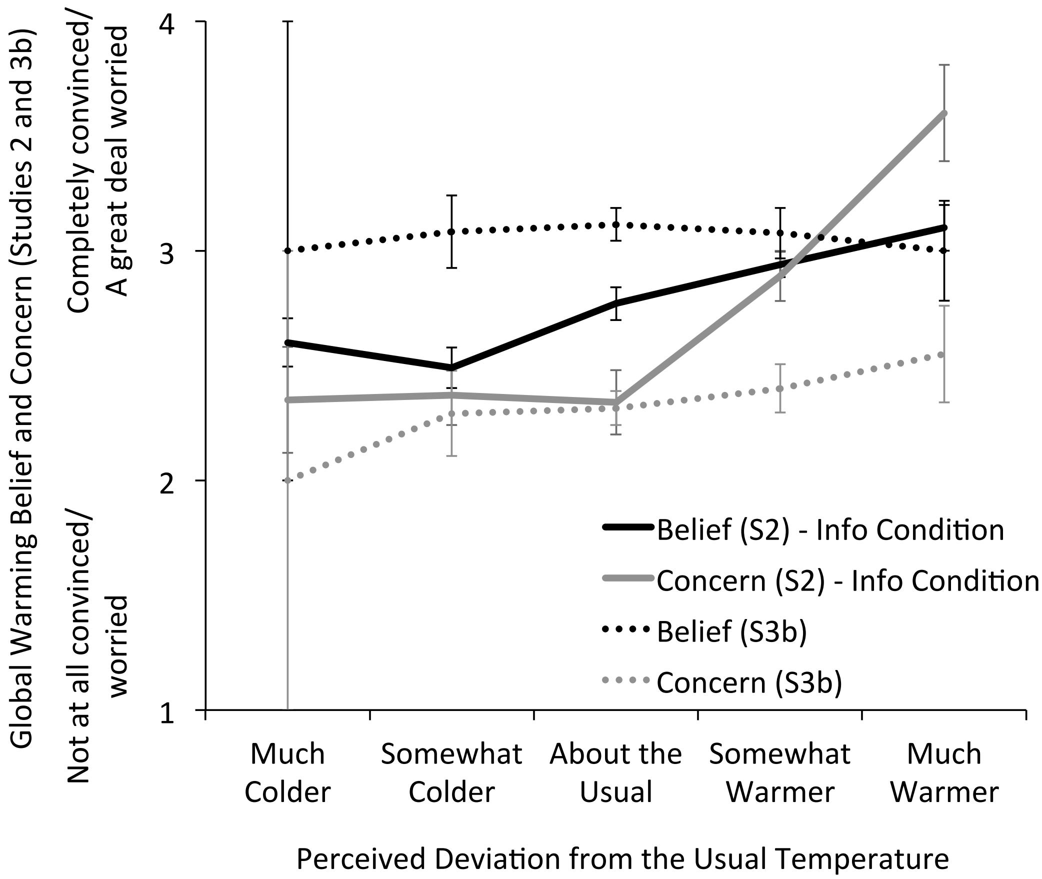

Fig. 2. Information, recency, and local warming. (1) Level of belief in and concern about global warming as a function of perceived temperature deviation, given information (Study 2). (2) Level of belief in and concern about global warming as a function of *yesterday's* perceived temperature deviation (Study 3b). Bars denote ±1 *SEM*.

STUDY 3A

Having eliminated the first two possible mechanisms, we turn to examining the details of attribute substitution. Specifically, we hypothesized that the *availability* of today's temperature deviation may make today's temperature observation disproportionately salient, changing estimates of the frequency of similar events (Tversky

& Kahneman, 1973; Williams & Bargh, 2008), and affecting respondents' global climate change judgments. This interpretation has several testable implications, which we examine in the following studies. Ultimately, we provide a process-level explanation for how *attribute substitution* leads to biased judgments about global warming.

Studies 3a and 3b examined the role of accessibility of temperature abnormalities. In Study 3a, we manipulated accessibility using a priming methodology. A body of research in psychology suggests that behaviors and social inferences can be subtly influenced through the use of temperature primes (Ijzerman & Semin, 2009; Joireman et al., 2010; Williams & Bargh, 2008). We hypothesized that when the concept of heat or cold is activated in one's mind (primed), that concept will more likely be used for subsequent evaluation of global warming.

Methods

In Study 3a, 300 participants, recruited from Mechanical Turk, answered the standard temperature perception question, and completed 10 minutes of unrelated filler material, and were then assigned to one of three experimental conditions: They completed one version (heat-prime, cold-prime, or control) of a scrambled-sentences priming task (Mauss, Cook, & Gross, 2007). (See Supplementary Methods for Study 3a scrambled-sentences text). Mean perceived temperature ratings did not differ by condition ($F(2, 288) = 0.07$, $p = .93$), supporting random assignment of participants to conditions. The scrambled-sentences priming task consisted of 13 sets of 5 scrambled words containing heat-related, cold-related, or neutral words (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001; Ijzerman & Semin, 2009). For each set of available words, participants chose four words to make a grammatically correct sentence (see

Supplementary Methods for scrambled-sentences text). Participants were told that the task was designed to "clear their minds" before other measures were taken. Twelve subjects did not complete the sentence task, and were removed from further analysis. After completing the scrambled-sentences task, all participants reported their belief in and concern about global warming.

Results

Supporting the role of immediate temperature perception in generating the local warming effect, we find that priming individuals with heat-related cognitions increases levels of belief and concern in global warming. The priming manipulation had a direct effect on average ratings of reported belief in and concern about global warming, as shown in Figure 3. There was a significant main effect of condition on global-warming belief, $F(2, 288) = 3.88$, $p = .02$, and concern, $F(2, 288) = 4.74$, $p = .01$. Post hoc comparisons showed that those in the Heat condition showed greater concern for global warming than those in the Control condition ($p = .02$) and Cold condition ($p = .03$). Similarly, those in the Heat condition showed greater belief in global warming than those in the Control condition ($p = .03$), and Cold condition ($p = .07$).

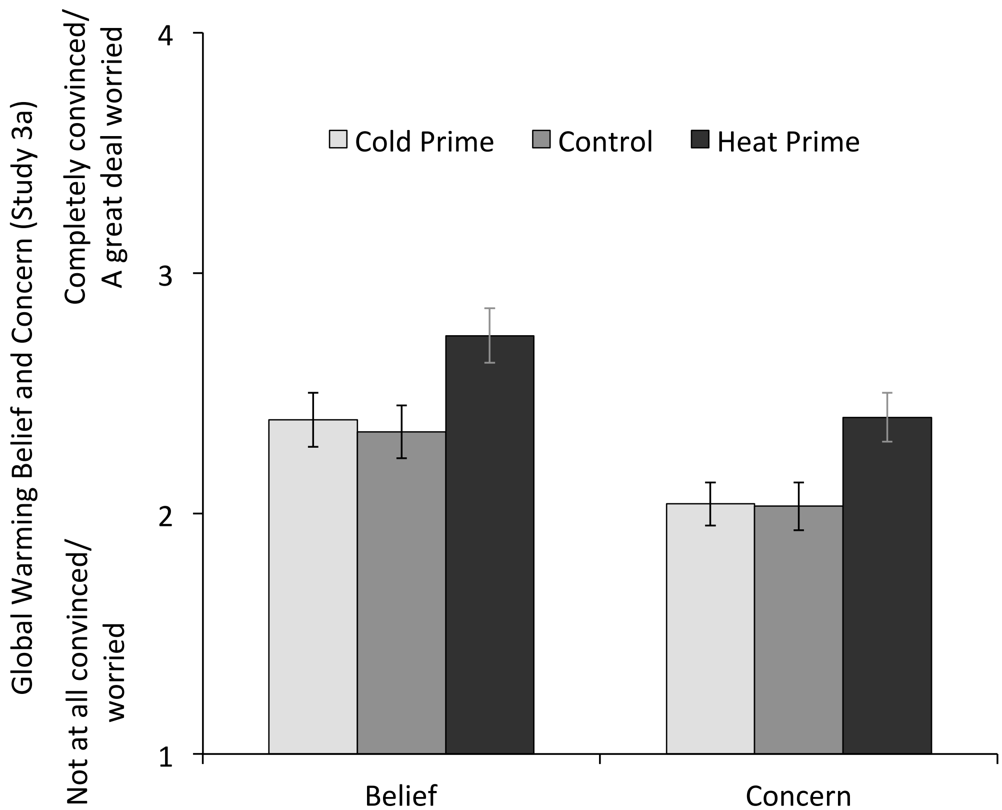

Fig. 3. Temperature priming and local warming. Effect of cold and heat temperature primes on global warming belief and concern (Study 3a). Bars denote ±1 *SEM*.

STUDY 3B

Study 3b examined the need for recency of temperature abnormalities by exploring whether prompting people to think about *yesterday's* perceived temperature deviation also affects their belief in or concern about global warming. We predicted that people rely on the most immediately available temperature (today's deviation), and that past temperature events, such as the previous day's temperature, will have less influence on global warming belief and concern.

Methods

In Study 3b, 251 participants were recruited from Mechanical Turk. Unlike previous studies, all participants were first asked about '*yesterday's*' temperature rather that the current day's temperature. Participants responded using a 5-point scale that ranged from 1 (*much colder*) to 5 (*much warmer*). Respondents then reported their belief in and concern about global warming. In addition to calculating the current day's objective temperature deviations, we used participants' ZIP code information to calculate objective temperature deviations for the day *before* subjects participated (yesterday). Note that Study 3b did not include a control condition in which participants were asked about today's temperature, and this prevents us from completely ruling out the possibility that we would not have found the local warming effect in this particular sample. This is unlikely, however, given the robust nature of the effect in previous studies drawn from the same subject pool.

Results

Asking respondents about *yesterday's* temperature eliminated the relationship between perceived temperature deviation and global warming judgments. This suggests that the *immediacy* of experience with temperature affects judgments of global climate change. Linear regressions revealed that perceived deviation of *yesterday's* temperature had no effect on belief, $\beta = -0.02$, $t(250) = -0.38$, $p = .70$ or concern, $\beta = 0.08$, $t(250) = 1.30$, $p = 0.20$ (see Figure 2). When controlling for political affiliation and other demographic variables, the results remain non-significant for belief, $\beta = -0.06$, $t(208) = -$

0.79, $p = .43$ and concern, $\beta = 0.03$, $t(208) = .43$, $p = .67$ (see Supplementary Tables 4-A and 4-B). To confirm that subjects were attending to *yesterday's* temperature deviation, and not *today's* temperature, we compared yesterday's perceived temperature ratings with actual objective temperature deviations from the historical average for both yesterday and today. Results show that yesterday's perceived temperature deviation correlated positively with yesterday's actual deviation from the historical average (r_s = .26, $p < .01$). However, yesterday's perceived temperature deviation did not correlate with today's actual temperature deviation ($r_s = .08$, $p = 0.23$); suggesting that participants were indeed attending to *yesterday's* temperature, and not *today's* temperature. Additional regressions controlled for actual temperature and demographic factors, including political affiliation (see Supplementary Tables 4-A and 4-B), and found that the effect of perceived deviation on belief and concern remained non-significant. These findings suggest that it is the *immediacy* of experience with temperature that affects judgments of global climate change. Although one difference between yesterday and today relates to recency of experience, another important distinction is that the former is a memory and the latter is currently experienced as sensory input. Thus, our results are also consistent with the hypothesis that beliefs are influenced by the use of the most salient sensory information available (e.g., perceived deviation of today's temperature).

STUDY 4

In Study 4, we further investigated our proposed mechanism for attribute substitution, namely construct-consistent recall from memory. We hypothesized that thinking about today's unusually warm weather will increase the availability of other unusually warm temperature events from memory, leading respondents to overestimate the frequency of such events. To test this hypothesis, we examined whether days that are perceived as being warmer than usual lead one to overestimate the frequency of unusually warm days throughout the year and whether this overestimation mediates the local warming effect.

Methods

In Study 4, 270 U.S Participants were recruited via Columbia University's Center for Decision Sciences national panel. In addition to answering the temperature, belief and concern questions as in the preceding studies, participants were asked, "Over the past year, what percentage of days seemed to be 'warmer than usual' for that time of year, compared to the historical average?" Participants indicated their answer by clicking their mouse anywhere on a 100-point slide scale anchored by 0%, 50%, and 100%. We refer to this variable as 'Percentage Days Warmer' (PDW).

Results

Results reveal that people who thought today was warmer than usual reported more days in the year as being warmer than usual compared to people who thought today was colder than usual (see Figure 4). PDW was positively correlated with perceived temperature deviation, $r = .41$, $p < .01$, today's actual temperature (F), $r = .15$, $p < .05$, and global warming belief and concern, $r = .35$, $p < .01$; $r = .33$, $p < .01$, respectively. A regression controlling for today's actual temperature and today's objective temperature deviation reveals perceived temperature deviation influenced PDW, $\beta = 0.39$, $t(269) = 7.4$, $p < .01$. This suggests that attention to and perception of today's temperature, and not actual temperature deviation, affects recall of past temperature events. Path analysis conducted to test our mediation hypotheses indicates that perceived PDW partially mediates the effect of perceived temperature deviation on belief in and concern about global warming. A Sobel *Z* test showed a similar effect on belief in global warming (perceived deviation, direct: $t(270) = 4.92$, perceived deviation, mediated: $t(268) = 2.74$, boot-strapped Sobel's $Z = 3.91$, $p < .01$) and concern about global warming (perceived deviation, direct: $t(270) = 3.84$, perceived deviation, mediated: $t(268) = 1.62$, boot-strapped Sobel's $Z = 4.02$, $p < .01$). Results from Study 4 suggest that those who perceive today to be warmer than usual are more likely to overestimate the frequency of unusually warm days throughout the year, which then mediates global warming judgments.

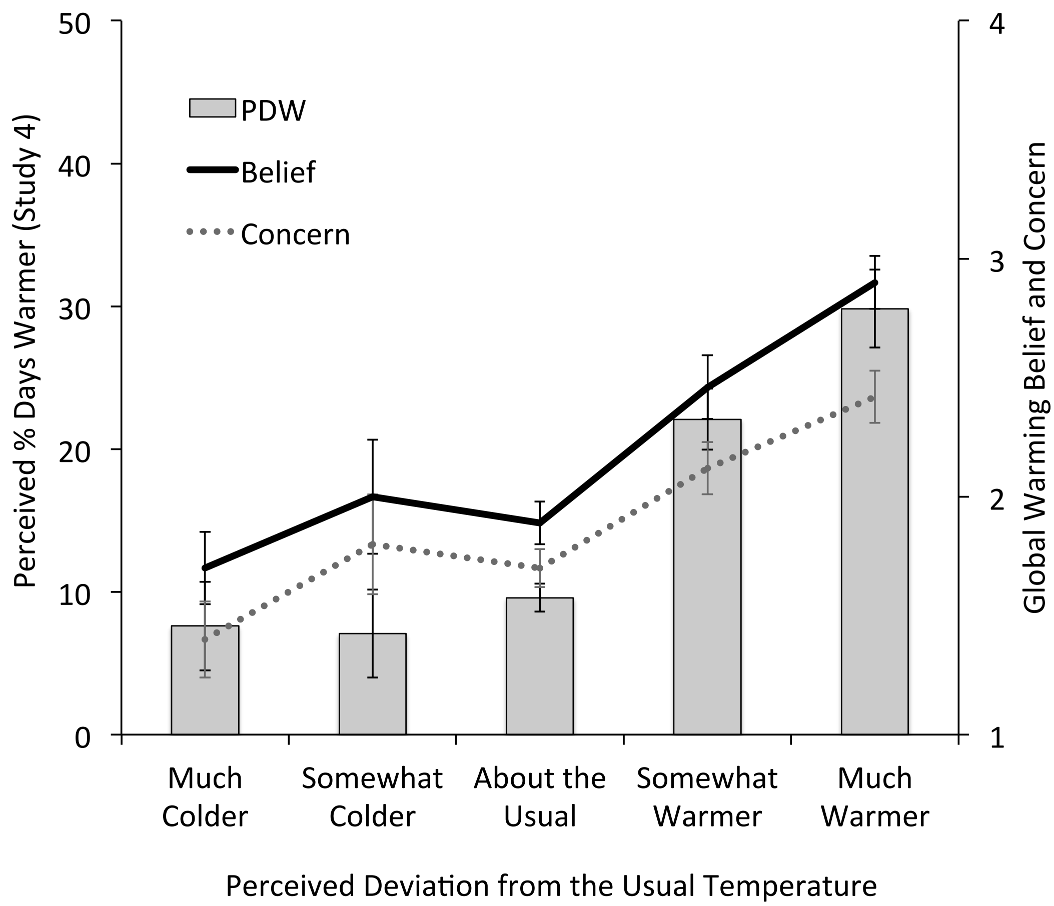

Fig. 4. Perceived percentage days warmer and local warming. Perceived Percentage Days Warmer (left y-axis) and belief in and concern about global warming (right y-axis) as a function of perceived deviation from the usual temperature (Study 4). Bars ±1 *SEM*.

Conclusions

A growing body of research shows that transient temperature variation influences the public's opinion of global climate change. We extend this research by examining several hypotheses regarding why this happens and exploring the mechanisms underlying the local warming effect. Our results suggest that an attempt to de-bias this robust effect will not be easy, as changes to survey terminology and enhanced scientific knowledge do not eliminate the effect of perceived temperature abnormalities. Further research is needed to determine how people's belief in global climate change can be encouraged to develop over time from constructed, experienced-based reactions to more stable conclusions. Additionally, although we find that attribute substitution is an important cause of the effect, rule out two alternative explanations, and show that temperature priming can influence global warming attitudes, there may well be other sources of biases and heuristics that lead to the very stable 'local warming effect.'

The local warming effect is an important real-word demonstration of how opinion on important issues can be constructed in response to a direct inquiry, rather than retrieved from memory. For climate change, a complex issue with contradictory coverage, individuals can draw weak conclusions and appear to reconsider their opinion each time they are asked a question. This characterization of climate change opinion, and the apparent difficulties individuals experience when dealing with uncertain climate-related decisions, have strong implications for public policy. For instance, these findings raise important questions regarding the potential role of the local warming bias in polling results. Our results suggest that recency and salience of warming constructs are promising ways of promoting heightened concern about climate change, at least among those who's beliefs or disbeliefs are not well established (Weber, 2013). However, the opposite can also occur: The "Snowpocalypse" of 2010 in Washington D.C. resulted in increased media coverage of climate skeptics denying the existence of climate change. As climate change continues to cause an increase in the intensity of extreme weather fluctuations (Francis & Vavrus, 2012), the local warming effect may lead to even greater confusion among the general public. Weather variability will need to become better associated with heightened belief in climate change, though this new association will need to be accomplished through education and analogies, and not personal experience. If the United States is to take a stronger stance against climate change, forecasters may be well advised to make increasing warming abnormalities more cognitively available to the general public.

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How warm days increase belief in global warming

Supplementary Information

Supplementary Tables

Supplementary Table 1. Temperature and public perception of global climate change in the literature.

Authors	Year	Journal	Effect
Ungar, S.	1992	Sociological Quarterly	Public anxiety over global warming peaks during hot, dry summers.
Krosnick, J., Holbrook, A., Lowe, L., & Visser, P.	2006	Climatic Change	Self-stated personal experience of recent increases in local temperatures exerts positive effects on the on the perceptions of global warming.
Semenza, J., Hall, D., Wilson, D., Bontempo, B., Sailor, D., & George, L.	2008	American Journal of Preventive Medicine	Concern about climate change is positively related to perceptions of how hot the temperature was on the previous day (mild, hot, or extremely hot).
Brody, S.D., Zahran, S., Vedlitz, A., & Grover, H.	2008	Environment and Behavior	Long-term temperature trends do not predict individual risk perceptions of climate change.
Hamilton, L., & Klein, B	2009	International Journal of Climatology	Regional winter warming trends are associated with an increased likelihood of perceiving major local effects of climate change.
Joireman, J., Barnes Truelove, H., & Duell, B.	2010	Journal of Environmental Psychology	Belief in global warming is positively correlated with actual outdoor temperature, but only on the low end of the temperature range.
Li, Y., Johnson, E. J., & Zaval, L.	2011	Psychological Science	Belief in and concern about global warming depends on whether today seems warmer or colder than the historical average, a bias termed 'the local warming effect'.

Risen, J.L., & Critcher, C.R.	2011	Attitudes and Social Cognition	Outdoor and indoor ambient temperature predicts belief in the validity of global warming, and this effect is not qualified by political ideology.
Egan, P. J., & Mullin, M.	2012	Journal of Politics	Americans more likely to agree there is “solid evidence” that the earth is getting warmer when local temperature rises above normal.
Howe, P. D., Markowitz, E. M., Lee, T. M., Ko, C., & Leiserowitz, A.	2012	Nature Climate Change	Perceptions of local temperature trends are most influenced by abnormal average temperatures in the most recent three months and perceptions of a long-term local warming trend are most associated with warmer recent average temperatures than with long-term local temperature trends.
Hamilton, L.C., & Stampone, M.D.	2013	Weather, Climate, and Society	In a statewide sample, among Independents, but not Democrats or Republicans, belief that humans are changing the climate is predicted by temperature abnormalities on the day of the interview and previous day.
Deryugina, T.	2013	Climatic Change	Among conservatives, longer-run temperature fluctuations (1 month – 1 year) are significant predictors of belief that the effects of global warming had begun to happen.

Supplementary Table 2. Demographic characteristics of the study samples.

Variable	**Study 1** (*N* = 686)	**Study 2** (*N* = 330)	**Study 3a** (*N* = 300)	**Study 3b** (*N* = 251)	**Study 4** (*N* = 270)
Sex, %					
Males	43	37	49	51	52
Females	57	63	51	49	48
Age, *M* (SD)	34 (12.7)	38 (13.1)	31 (14.46)	28 (13.5)	33 (14.9)
Education, %	45.1	51.4	40.6	38.2	43.9
Race/ethnicity, %					
African American	7	5	5	3	7
White	74	78	73	79	75
Polit. Affiliation, %					
Democrat	35	40	48	53	35
Republican	20	23	27	16	23
Independent/Other	45	37	25	28	40
U.S. Region, %					
Northeast	22.4	27.5	25.8	25.3	31.0
South	35.6	28.3	30.3	28.1	28.7
Central	19.8	20.8	19.0	21.0	19.1
West	22.1	22.6	24.1	24.5	19.8
Objective Temp Deviation, % (yesterday)	51.1	50.8	53.3	60.2 (63.1)	60.5

Due to some participants choosing not to answer, the race/ethnicity, political affiliation columns do not total to 100.
*Educational Attainment = *at least some college.*
*Actual Temperature Deviation = *Day of survey > 1° (F) warmer than the historical average temperature for each ZIP code.*

Supplementary Table 3-A. Linear regressions for *belief* for GW/CC in Study 1. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2	3
Perceived deviation	0.120***	0.107**	0.112***
	(0.123)	(0.114)	(0.116)
CC Frame		0.270	0.144 **
		(0.150)	(0.079)
Frame x perceived deviation		0.025	
		(0.026)	
Actual temperature		0.005	0.002
		(0.006)	(0.023)
Actual deviation		-0.002	0.015
			(0.091)
Female		0.022	0.026
		(0.012)	(0.014)
Education		0.032*	0.042**
		(0.054)	(0.078)
Age			-0.001
			(-0.011)
Income (thousands)			0.025
			(0.042)
Democrat (relative to Other)		.565***	0.549***
		(0.301)	(0.295)
Polit. x perceived deviation			-0.131
			(-.120)
Environmental attitude			0.160***
			(0.231)
Knowledge			0.020
			(0.014)
Constant	2.532***	2.45***	1.83***
Observations	685	628	577
R^2	0.015	0.124	0.191

Supplementary Table 3-B. Linear regressions for *concern* for GW/CC in Study 1. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2	3
Perceived deviation	0.137***	0.133**	0.132***
	(0.147)	(0.142)	(0.142)
CC Frame		0.027	0.063
		(0.006)	(0.036)
Frame x perceived deviation		0.038	
		(0.041)	
Actual temperature		0.006	0.012
		(0.070)	(0.089)
Actual deviation			0.020
			(0.101)
Female		0.118*	0.162**
		(0.070)	(0.091)
Education		0.008	0.032
		(0.016)	(0.061)
Age			-0.001
			(-0.013)
Income (thousands)			-0.037
			(-0.063)
Democrat (relative to Other)		0.437***	0.383***
		(0.241)	(0.210)
Polit. x perceived deviation			-0.688
			(-0.073)
Environmental attitude			0.199***
			(0.293)
Knowledge			0.132*
			(0.093)
Constant	1.84***	1.65***	0.845***
Observations	685	628	577
R^2	0.021	0.092	0.193

Supplementary Table 4-A. Linear regressions of *yesterday's* temperature on *belief* in global warming in Study 3b. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2
Perceived deviation	-0.026	-0.059
	(-0.024)	(-0.055)
Actual temperature (today)		0.088
		(0.886)
Actual deviation (today)		-0.092
		(-0.553)
Actual temperature (yesterday)		-0.101
		(-0.780)
Actual deviation (yesterday)		0.087
		(0.492)
Female		0.186
		(0.109)
Education		-0.025
		(-0.034)
Age		-0.004
		(-0.048)
Democrat (relative to Other)		0.511***
		(0.298)
Income (thousands)		-0.009
		(-0.022)
Constant	3.179***	4.071***
Observations	250	208
R^2	0.001	0.131

Supplementary Table 4-B. Linear regressions of *yesterday's* temperature on *concern* in global warming in Study 3b. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2
Perceived deviation	0.091	0.034
	(0.082)	(0.031)
Actual temperature (today)		0.042
		(0.415)
Actual deviation (today)		-0.057
		(-0.334)
Actual temperature (yesterday)		-0.045
		(-0.339)
Actual deviation (yesterday)		0.045
		(0.248)
Female		0.067
		(0.38)
Education		-0.096*
		(-0.123)
Age		-0.006
		(-0.065)
Democrat (relative to Other)		0.436***
		(0.246)
Income (thousands)		0.003
		(0.008)
Constant	2.049***	2.716***
Observations	250	208
R^2	0.007	0.098

Supplementary Methods

Study 2 Passages

Instructions. We are conducting a survey to determine the best way to present scientific information to the general public. Our goal is to explain terms simply and clearly so people can fully understand them. On the next page, we will ask you to carefully read several paragraphs, which describe some scientific terms. You will then be asked questions about what you have read.

Information Condition: What is the difference between weather and climate? In most places, weather can change from minute-to-minute, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space. An easy way to remember the difference is that climate is what you expect, like a hot summer, and weather is what you get, like a hot day with thunderstorms. We talk about climate change in terms of years, decades or even centuries. Weather is the combination of temperature, humidity, cloudiness, and wind in one day while climate is the weather of a location averaged over some period (usually 30 years). (http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html)

No-Information Condition: What is REM sleep? REM stands for rapid eye movement sleep, and is one stage of sleep that most people go through each night. When we switch into REM sleep, our breathing becomes more rapid, and our heart rate increases. Also during REM sleep, our eyes move quickly in various directions, which is what gave this stage its name. Interestingly, it is during REM sleep that a person will dream. The first REM sleep period usually occurs about 70 to 90 minutes after we first fall asleep.

(http://www.howstuffworks.com/environmental/life/inside-the-mind/human-brain/sleep1.htm)

Study 3a Scrambled-sentences Text

Heat Prime	Cold Prime	Neutral Prime
boils eggs she the of	freezes leftovers she the of	ball the sudden toss once
fleas ago cat had the	fleas ago cat had the	fleas ago cat had the
his was sunburn painful although	his was frostbite painful although	was letter she a wrote
walk for go path a	walk for go path a	walk for go path a
had hot felt water the	had cold felt water the	dinner were dog ate the
new was gave movie the	new was gave movie the	new was gave movie the
saw over train he the	saw over train he the	saw over train he the
should the burning was tree	lake the frozen was should	played there band music the
ball the sudden toss once	ball the sudden toss once	ball the sudden toss once
The sweats man old of	the shivers man old of	heard should the he phone
curtain green how was the	curtain green how was the	curtain green how was the
glove gone she a found	glove gone she a found	glove gone she a found
potatoes she the roasted it	meat she the defrosted it	a should wrote a he letter

Actual Temperature Data Collection Methods

Temperature data were accessed using the ASOS (Automated Surface Observing Systems) system, which includes approximately 2,000 weather stations located at airports across the country. The ASOS program is a joint effort of the National Weather Service, the Federal Aviation Administration, and the Department of Defense. The ASOS weather stations are the United State's primary surface weather observing network used by NOAA

(National Oceanic and Atmospheric Administration).
(http://www.nws.noaa.gov/ost/asostech.html).

Participants' ZIP codes were used to specify the location for each query in order to generate actual and historical temperatures for the day that participants participated in our study. The Weather API returned the temperature data from the National Weather Service ASOS weather station nearest to each zip code. Temperature data were accessed through the Weather API maintained by Weather Underground, Inc. (http://www.wunderground.com/weather/api). We used the Weather API to access the daily high and low temperatures for the date and location each participant took the survey (midpoints were calculated directly from these values). Average temperatures were calculated by taking the midpoint of the high and low temperatures, and objective deviations were calculated by taking the difference between that day's average and the historical average. To generate the historical averages, we queried the daily high and low temperatures for the same calendar day on each of the 15 years prior to the date the survey was taken. Ninety-five percent of the cases have two or less years of historical data missing. The mean number of years of historical data missing is .53. For cases where years of historical data missing totaled seven or more (1.5% of cases), we deemed the historical averages unusable and treated them as missing data.

U.S. temperatures during Study 1 averaged 75.8 degrees Fahrenheit (*sd* = 10.9) with a mean deviation of 1.1 degrees (*sd* = 5.2). During Study 2, temperatures averaged 51.2 degrees (*sd* = 9.1) with a mean deviation of -1.0 degrees (*sd* = 4.9). U.S temperatures during Study 3a averaged 65.6 degrees (*sd* = 14.4) with a mean deviation of 2.58 degrees (*sd* = 5.2), whereas Study 3b averaged 66.9 degrees Fahrenheit (*sd* = 8.82), with a mean deviation of 3.81 degrees (*sd* = 4.7). Finally, in Study 4, which was conducted over the summer, temperatures averaged 78.5 (*sd* = 11.6) degrees with a mean deviation of 4.11 degrees (*sd* = 5.1)

Supplementary Analyses

Instrumental Variable Regression

To control for reverse causation and omitted variable biases, we employ instrumental variable regressions, a technique widely used in economics to help establish causality in observational data when randomized experiments are not possible (Angrist & Krueger, 2001; Sargan, 1958). This was the analysis employed by Li, Johnson and Zaval (2011) to causally link perceived abnormalities in current temperature with changes in belief in global warming. The idea is to model the purported causal variable (global warming attitude) using a third variable that is related to but not possibly caused by it. In our case, we can use objective temperature measures as instrumental variables for the perceived deviation from usual temperature and perform two-stage least squares regressions. We reason that although actual temperature deviations can affect perceived deviations, the reverse case—that peoples' beliefs influence actual temperature—cannot be true.

Using data from the GW Frame in Study 1, and using actual temperature deviation from the historical average as an instrumental variable for perceived temperature deviation, we establish that perceived deviation has a direct causal link to global warming attitudes, and this analysis weakens the possibility of any 3rd omitted variable producing the result.

We used actual temperature deviation from the historical average (T) as an instrumental variable for perceived temperature deviation. Estimates for instrumental variables were calculated using two-stage least squares regression. The first-stage regression used actual temperature deviation to generate predicted values of perceived deviation ($\hat{Y}P$). These predicted values of perceived deviations, which were free of any effects of global warming attitude, were then used to estimate effects on global warming attitudes (A). In other words, P was regressed on T, which generated $\hat{Y}P$; we then ran regressions estimating A as a function of $\hat{Y}P$. We find that actual deviation was correlated with perceived deviation ($r = .24$, $p < .01$), as well as concern about global warming ($r = .14$, $p < .01$). The variance estimator used the original endogenous regressor to construct residuals and not the first-stage fitted values. The F statistic from the first-stage regression was 21.17 and was therefore strong enough to yield results that are substantially less biased than OLS. The second stage regression confirmed our central result: The predicted values of perceived deviation obtained from the first-stage regression had significant effects on concern for global warming ($\beta = .57$, $t(343) = 2.60$, $p = .02$). Because the predictor was a function of only objective temperature deviation, this analysis should eliminate the concern about reverse causality and omitted variable biases (Angrist & Krueger, 2001). We also conducted an analysis in which we interact $\hat{Y}P$ with framing condition (Warming vs. Change) to test this regression coefficient for statistical significance. As expected, there was no significant interaction between the predicted values of perceived deviation and framing condition. This result remained the same in the presence of demographic controls.

We ran similar analyses for Studies 2, 3b and 4.[2] For Study 3b, yesterday's deviation from the historical average was used as an instrument for yesterday's perceived temperature. The *F* statistic from the first-stage regression was 13.91. As expected, the predicted values of yesterday's perceived deviation obtained from the first-stage regression did not have significant effects on either belief or concern in global warming (p = .51, .45). In Study 4, the *F* statistic from the first-stage regression was 121.6. The predicted values of perceived deviation obtained from the first-stage regression had significant effects on belief in global warming (β = .21, $t(321)$ = 2.52, p = .01). We also used predicted values of perceived deviations to estimate effects on PDW (percentage days warmer) as the dependent variable. Consistent with our hypothesis, the predicted values of today's perceived deviation obtained from the first-stage regression also had highly significant effects on PDW (β = .36, $t(271)$ = 3.96, $p < .01$).

[2] We recognize that a reliable implementation of an IV must utilize a sufficient sample size to allow for reasonable estimation of the treatment effect. This assumption may not be satisfied in Study 2 (in the knowledge condition): The effect of the predicted values of perceived deviation obtained from the first-stage regression on belief in global warming did not reach significance, though the direction was similar (t = 1.2, p = *ns*). Though we expect direction in all of these studies, it is unlikely that reverse causality operates in some studies but not others, given that these are replicating the same paradigm.

Paper 2:

How will I be remembered? Conserving the environment for legacy's sake

Lisa Zaval, Ezra M. Markowitz and Elke U. Weber

KEYWORDS: Decision Making, Environmental Behavior, Constructed Preferences, Legacy

Author note: This research has been submitted for publication as a co-authored article (with Ezra Markowitz and Elke Weber). This research has been supported by the PIIRS Communicating Uncertainty research grant. Correspondence concerning this article should be addressed to Lisa Zaval, Columbia University, Department of Psychology, 419 Schermerhorn, 1190 Amsterdam Avenue MC: 5501, New York, NY, 10027, e-mail: lz2261@columbia.edu

Abstract

Long time horizons and social distance are often viewed as key barriers to pro-environmental action due to intertemporal and interpersonal discounting, particularly in the case of climate change. We suggest that these challenges can be turned into opportunities by making salient relevant long-term goals and motives, thus shifting preferences for present-future and self-other trade-offs at the point of decision-making. Here we test whether individuals' latent motivation to leave a positive legacy can be leveraged to increase engagement with climate change and other long-term environmental problems. In an initial study, we find that individual differences in legacy motivation are positively associated with pro-environmental behaviors and intentions. In a second study, we demonstrate that priming legacy motives prior to providing an opportunity to donate to an environmental charity increases donations, as well as self-reported pro-environmental intentions and beliefs. Using a new short-form scale designed to measure legacy motives, we confirm that changes in environmental behavior and belief induced by the legacy prime are mediated by increased concern for one's future legacy. This work provides the first experimental evidence that domain-general legacy motives can be exploited to support intergenerational environmental stewardship, and represents a previously under-studied and powerful strategy for increasing pro-environmental behavior.

How will I be remembered? Conserving the environment for legacy's sake

The U.S public consistently ranks climate change as a low national priority (Leiserowitz, 2006), resulting in mitigation and adaptation efforts that most climate scientists and environmental economists find woefully insufficient (Solomon et al., 2007; Stocker, 2013). This underinvestment in the future is due, in part, to a perceived sense of temporal and social distance from the most severe likely consequences of climate change (which will be felt by individuals living far away in time and space). This sense of distance can act as a psychological barrier to environmental action by promoting intertemporal and interpersonal discounting (Gifford, 2011; Markowitz & Shariff, 2012; Spence, Poortinga, & Pidgeon, 2012; Weber & Stern, 2011). Yet it is exactly the long time-frame and strong path dependencies inherent in climate change that makes taking action in the present so critical (Solomon et al., 2007).

Emerging research, however, indicates that people's latent motivation to extend themselves into the future via their personal legacies may provide a pathway to overcoming such psychological barriers to pro-social, intergenerational action (Fox, Tost, & Wade-Benzoni, 2010; Wade-Benzoni, Tost, Hernandez, & Larrick, 2012). Interest in passing along knowledge, skills and resources to future others may play a key role in motivating protective and preemptive action on long-term environmental threats, which involves making present sacrifices and investments in order to secure a stable, flourishing world for future. Such interest can take multiple forms, including the multidimensional aspiration to leave a positive legacy (Hunter & Rowles, 2005; McAdams & Logan, 2004). In economic terms, a commitment to legacy goals may be expressed as reduced discount rates, with lower discount rates implicitly putting greater value on current investments in sustainability for future generations.

We propose that legacy motivations may represent a previously under-studied and powerful mechanism by which to circumvent the otherwise detrimental psychological barriers (e.g., intertemporal distance and discounting) that inhibit preventive action on climate change. To date, no published work has systematically examined the link between legacy motives and climate change engagement, nor determined whether increasing the salience of such motives can increase action on climate change. Our predictions are grounded in existing correlational data, which show a positive relationship between concern for future generations and pro-environmental attitudes (Matsuba et al., 2012; Milfont, Harré, Sibley, & Duckitt, 2012; Van Winden, Van den Berg, & Pol, 2007). For example, Urien and Kilbourne (2011) reported that generative concern, a component of legacy motivation (Newton, Herr, Pollack, & McAdams, 2013), was positively related to environmentally friendly behaviors and purchasing eco-friendly products. Moreover, recent research has proposed the concept of *environmental generativity* to describe the positive relationship between concern for future generations and self reported ecological behavior (Milfont et al., 2012). However, in contrast to the concept of altruistic generativity (Erikson, 1963), legacy motives are grounded in processes through which both the individual and recipients of generative or legacy-building actions may benefit (Newton et al., 2013).

The present work builds on emerging decision-making research, which suggests that attitudes and behavioral responses towards climate change are malleable and influenced by psychological factors (Hershfield, Bang, & Weber, 2014; Li et al., 2011;

Weber & Johnson, 2009; Zaval, Keenan, Johnson, & Weber, 2014). Although there are multiple routes to increasing willingness to take action on behalf of future others, we predict that leveraging and making salient individuals' concern for their own legacy represents a potentially powerful strategy for increasing action on climate change. We conducted two internet-based studies to test this claim. In the first, we confirmed the relationship between domain-general legacy motives and pro-environmental behavior. In the second, we used a novel legacy prime to experimentally manipulate the salience of legacy motives, and examined subsequent effects on pro-environmental beliefs, intentions, and actual mitigation behavior.

STUDY 1

Method

In Study 1, a diverse sample of 245 U.S participants, recruited through Amazon's Mechanical Turk (Buhrmester et al., 2011), elected to participate in an online study advertised as a survey on how people make decisions. All participants had a 97% or higher approval rating according to the screening procedures of this site. These panels represent a wide range of socioeconomic factors not seen in university lab settings (see Table S1 in Supplementary Material available online for demographic details for both studies).

To test individual differences in legacy motives, we created a single composite measure of eight items ($\alpha = .90$), which were modified from the Loyola Generativity Scale (LGS; McAdams & de St. Aubin, 1992). The creation of this novel scale was explicitly focused on one's reputation in the eyes of future generations (Detailed information about the question items and scales are available in the Supplementary

Materials).

Participants next answered two sets of questions, one assessing their beliefs about climate change and the other their willingness to take pro-environmental action. Climate change beliefs were measured using the average score of five randomly ordered items (α = .88), including, "I feel a responsibility to reduce my personal contribution to climate change". Participants responded to each statement on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Similarly, pro-environmental behavioral intentions were measured using the average score of six items that asked participants how often they intend to perform a series of mitigation actions over the next month (α = .76), including, "Buy green products instead of regular products" (1= *never*, 6 = *all the time*). Following the legacy, belief and intention ratings, we gave participants the option of donating part of a $10 bonus, as determined by lottery, to make a real financial donation to a nonprofit environmental advocacy organization, Trees for the Future. Participants typed in the amount they would donate, from $0 to $10. Donations were actually given to the organization. All studies were approved by Columbia University's Institutional Review Board.

Results

Figure 1 plots the relationship between legacy scores and our three measures of environmental engagement. People who reported being highly motivated by legacy motives were more likely to show heightened levels of pro-environmental beliefs and behavioral intent compared to those who were not motivated by legacy goals. Simple linear regressions showed a significant positive relationship between legacy motives and both belief, $\beta = 0.13$, $t(238) = 2.08$, $p = .038$, and behavioral intention, $\beta = 0.29$, $t(239) =$

4.69, $p < .001$. Additional regressions revealed the robustness of these relations when controlling for demographics, including political affiliation and parental status (see the Supplemental Materials). Although party affiliation, income, and parental status had significant effects on climate change behavioral intentions, legacy motives remained highly significant in the presence of these controls. In fact, legacy motives alone accounted for a greater proportion of the variance in behavioral intention compared to whether or not someone identified politically as a Democrat versus Independent or Republican (8.1% vs. 2.8%).

Participants higher in Legacy motives also donated a larger amount of their bonus money to the environmental non-profit organization than those lower in legacy motives, $\beta = 0.23$, $t(241) = 3.73$, $p < .001$. Participants in the bottom quartile of legacy motives donated an average of \$1.75 (*SD* = \$2.21; 22% donated) whereas those in the top quartile donated an average of \$3.41 (*SD* = \$2.87; 31% donated). The role of legacy on donations remained robust after controlling for demographics, political affiliation and parental status (see Supplemental Materials).

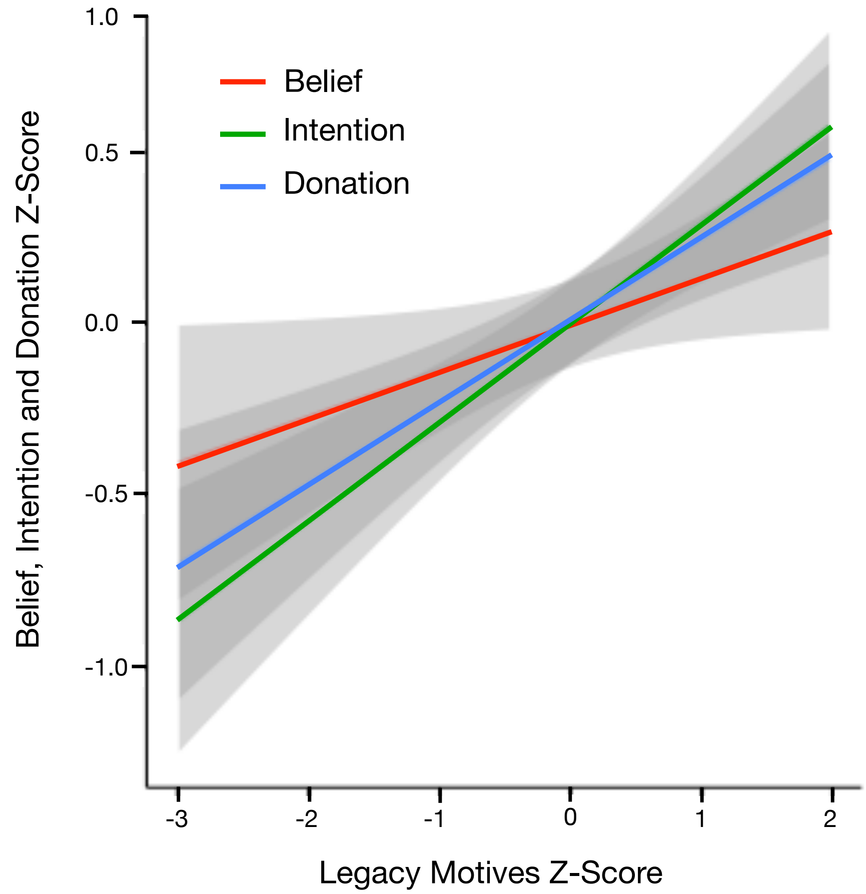

Fig. 1. Results from Study 1: regression plots (and 95% confidence bands) showing the relationship between climate change belief, behavioral intention and amount of donations to charity as a function of legacy motives. [COLOR FIGURE]

STUDY 2

Study 1 demonstrated a robust relationship between legacy motives and people's willingness to engage in behaviors aimed at combating climate change. To investigate whether legacy motives can be leveraged as a tool for promoting action on climate change, and to clarify the causal direction of this observed relationship, we tested whether priming legacy motives positively influences participants' level of environmental engagement. In Study 2, we add an experimental manipulation of the accessibility or salience of legacy motives prior to administering the scales described above. Specifically, we test whether priming legacy motives using an essay-writing task positively influences participants' pro-environmental beliefs, intentions and behavior. We hypothesized that participants exposed to a legacy motive-inducing prime would show enhanced environmental engagement compared to those in a control condition.

Methods

In Study 2, 312 U.S. participants who did not complete Study 1were recruited via Amazon's Mechanical Turk to participate in an online study advertised as a study on decision-making. Participants were randomly assigned to one of two conditions. In the Legacy condition, participants were asked to write a short essay describing what they want to be remembered for by future generations.[3] The instructions asked participants to think about ways in which they would have a positive impact on future generations, (e.g. "think about skills or knowledge you will teach others"). Essay completion took 6.5 minutes on average. The legacy essay was omitted in the Control condition. Next, all participants completed a battery of questions measuring climate change beliefs, behavioral intentions, and financial donation as in Study 1. (Detailed information about all question items and scales used in Study 2 are available in the Supplementary Materials).

Measure of mediator

To test the proposed underlying mechanism that increased concern for one's legacy mediates legacy prime-induced changes in climate change attitudes and actions,

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[3] We piloted the Legacy priming manipulation in a separate experiment confirming that the essay writing exercise significantly increased reported legacy motives. We determined sample size for Study 2 based on results of the pilot, which suggested a small to medium effect size.

we constructed a new short-form scale that uniquely taps into people's legacy motives. Using the Loyola Generativity Scale (McAdams & de St. Aubin, 1992) as a model, we constructed a measure of legacy motives that was explicitly focused on one's future legacy and reputation in the eyes of future generations, excluding generative motives (such as the desire to pass skills and knowledge to future generations). This measure consisted of the average score of three items relating to legacy ($\alpha = .82$): (1) "It is important to me to leave a positive legacy", (2) It is important for me to leave a positive mark on society", and "I care about what future generations think of me." Participants indicated the extent to which each statement described them (1= *not at all*, 6 = *a great amount*). This legacy motives scale was placed at the end of the survey, which was separated from the essay task by 8 minutes on average. We predicted that participants exposed to the prime would show higher agreement with these items, and further, that this measure would mediate the effect of the essay prime on the dependent variables. Additional items tapping into more generalized pro-social motives were also included at the end of the survey, but were not expected to mediate the effect of the prime on the environmental outcomes of interest.

Results

As expected, the essay manipulation worked successfully to enhance overall levels of legacy motives. Almost ten minutes after being exposed to the manipulation, participants who wrote the essay reported higher legacy motives ($M = 4.47$, $SD = 1.06$) compared with those in the control condition ($M = 4.19$, $SD = 1.05$), $F(1, 310) = 5.64$, $p = .018$; Cohen's $d = .27$. Moreover, as predicted, we found a significant effect of the legacy prime on willingness to engage in behaviors aimed at combating climate change.

Participants who were primed with legacy motives reported higher belief scores (*M* = 5.39, *SD* = 1.08) than those in a control condition (*M* = 5.11, *SD* = 1.27), $F(1, 309)$= 4.08, $p = .040$, $d = .23$. We also found a significant effect of the legacy prime on behavioral intentions. Participants who were primed reported higher levels of behavioral intention (*M* = 3.05, S*D* = .86) than those who were not primed (*M* = 2.73, *SD* = .85), $F(1, 309)$ = 10.07, $p = .002$, $d = .36$ (See Figure 2).

To confirm that the influence of the prime on climate change attitudes was driven by increases in legacy motives, we conducted a mediation analysis using the mean legacy motives score as a mediator. As shown in Figure 3, the effect of essay priming on individuals' climate change belief was fully mediated by increases in legacy motives: Priming condition, direct: $t(308) = 2.01$, priming condition, mediated: $t(308) = 1.29$, Sobel's $Z = 2.19$, $p = .028$. Mediation was also confirmed by a bias-corrected bootstrapping procedure (Preacher & Hayes, 2008; see Supplementary Materials). Based on 5000 bootstrapped samples, the indirect effect of the legacy induction on climate change beliefs through legacy concern was significant, with a 95% confidence interval excluding zero (β= .041, CI_{95} [0.01-0.09], $p = .029$). Behavioral intentions were also partially mediated by increases in legacy motives: Priming condition, direct: $t(311)$ = 3.17, priming condition, mediated: $t(311) = 2.65$, Sobel's $Z = 2.11$, $p = .034$; the indirect effect of the legacy induction on behavioral intent through legacy motives was significant ($\beta = .034$, CI_{95} [0.01-0.08], $p = .035$).

Results for our donation measure were consistent with the self-report results. As Figure 2 demonstrates, participants who were primed with legacy motives donated significantly more of their earnings to an environmental organization than those who were placed in the control condition $F(1, 310) = 8.79$, $p = .003$, $d = .34$. Those who were not primed donated an average of $2.31 (SD = $2.74; 61% donated), whereas those who were primed donated an average of $3.34 (SD = $3.29, 70% donated). The differences remained significant when we examined the square root transformed values of the donation amounts in order to account for the negatively skewed distribution, $\beta = 0.15$, $t(310) = 2.74$, $p = .007$. Based on 5000 bootstrapped samples, we found marginally significant evidence of partial mediation through legacy concern, $\beta = .015$, CI_{95} [0.001-0.045], Sobel's $Z = 1.52$, $p = .13$. As in Study 1, we conducted additional analyses that revealed the robustness of these effects when controlling for demographics, political affiliation and general environmental attitude.

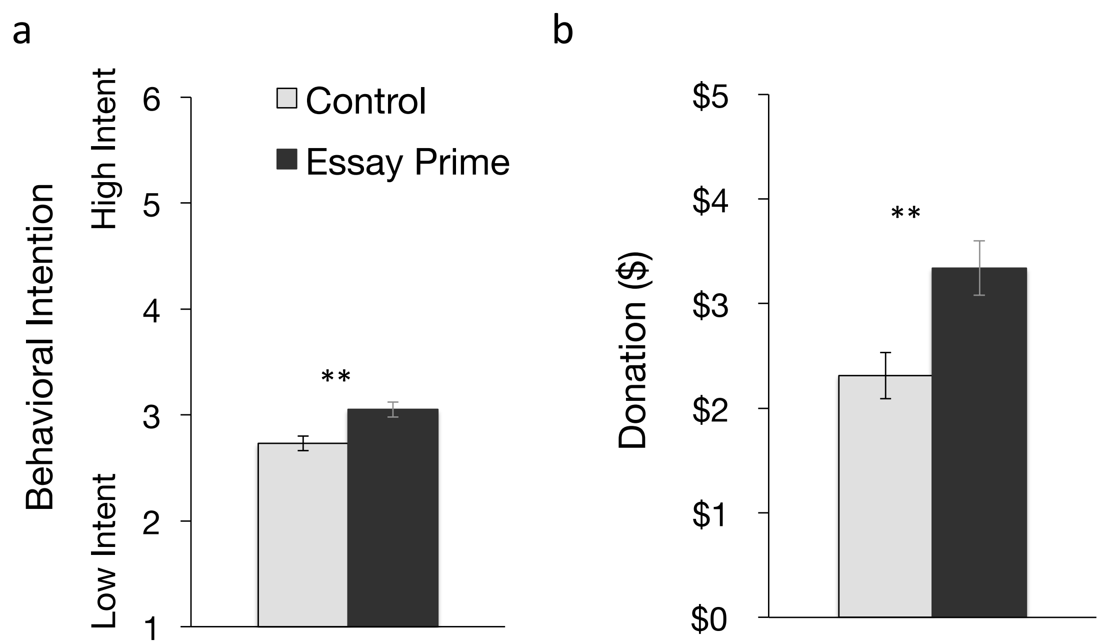

Fig. 2. Effect of legacy prime on climate change behavioral intention (panel a) and donation to charity (panel b). Error bars denote ±1 *SEM*. *< .05, **< .01

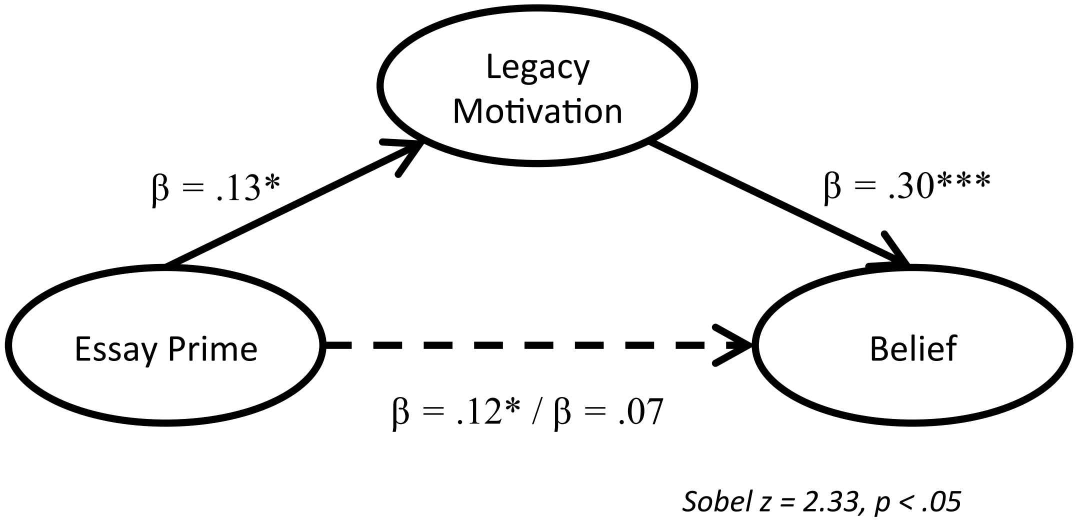

Fig. 3. Mediation Analysis (Study 2). Legacy prime-induced changes in climate change belief are mediated by increased legacy motives. β = standardized coefficients
*< .05, **< .01, ***< .001.

General Discussion

Over the past several years, researchers and policymakers have begun to recognize that psychological obstacles to climate change mitigation need to be addressed in order to foster progress on this important topic. In the studies reported here, we find that people's attitudes and mitigation behaviors towards climate change are related to their generalized motivation to leave behind a positive legacy for future generations, and that differences in legacy motives are related to consequential environmental charitable giving. The present results also provide the first experimental demonstration that increasing the salience of legacy motives can increase people's desire to engage in environmental sustainability.

Environmental protection requires individuals to consider time frames well beyond their own life spans. Often, the long time horizons involved in environmental conservation are viewed by issue advocates, policymakers and researchers as barriers to mitigation, due in part to intertemporal and interpersonal discounting (Gifford, 2011; Markowitz & Shariff, 2012; Moser & Ekstrom, 2010; Weber & Stern, 2011). In stark contrast with this view, we demonstrate that this fundamental feature of environmental problems can, under certain conditions, be leveraged to promote rather than inhibit environmental engagement. Specifically, when people's latent motivation to leave behind a positive legacy is made salient just prior to making a present-self versus future-other trade-off, behavior shifts towards favoring the well-being of future others, as predicted.

Our work demonstrates that legacy motives matter deeply for pro-environmental action, which often involves making trade-offs between current consumption and future well-being. Moreover, climate change mitigation and adaptation behaviors serve as potentially powerful outlets for expressing legacy motives. Importantly, our work has the potential to aid the development and implementation of effective strategies to support conservation efforts, particularly with respect to climate change mitigation and adaptation. This is critical, as policymakers and advocates continue to grapple with the question of how to increase citizen engagement with climate change (e.g., Moser & Dilling, 2011). For instance, the Alliance for Climate Protection, has spent $300 million in campaign efforts to change public perception (Revkin, 2008). To achieve meaningful global emissions reductions in time to avoid dangerous interference with the climate system (Solomon et al., 2007), new forms of discourse to support sustainability efforts will be required (Bandura, 2007). Our results suggest that public policies that make individuals' legacy motives salient may be effective in encouraging environmentally and ecologically sustainable behaviors. Prompts that encourage people to think about how they would want to be remembered (or perhaps what they *don't* want to be remembered for) may effectively promote environmental behavior by framing decisions as "win-win" for both present and future generations.

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How will I be remembered? Conserving the environment for legacy's sake

Supplementary Information

Supplementary Table 1. Demographic characteristics of the study samples.

Variable	**Study 1** (N = 245)	**Study 2** (N = 312)
Sex, %		
Males	52	54
Females	47	46
Age, *M* (*SD*)	35.9 (12.7)	34.3 (12.1)
Education, %	83	85
Race/ethnicity, %		
White	82	80
Parental Status %		
Parent	27	38
Non-Parent	73	62
Polit. Affiliation, %		
Democrat	38	39
Republican	15	13
Independent/Other	47	42

Due to some participants choosing not to answer, the race/ethnicity, political affiliation columns do not total to 100.

*Educational Attainment = *at least some college.*

Supplementary Table 2-A. Linear regressions of *Legacy Motivation* on *Behavioral Intent Score* in Study1. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2
Legacy Score	0.320 ***	0.275 ***
		(0.250)
Female		0.014
		(0.007)
Democrat (relative to Other)		0.362 ***
		(0.167)
Income (thousands)		-0.081*
		(-0.120)
Parent		-0.416 ***
		(-0.176)
Education		0.096
		(0.089)
Constant		2.46 ***
Observations	239	234
R^2	0.081	0.152

Supplementary Table 2-B. Linear regressions of *Legacy Motivation* on *Donation ($)* in Study 1. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2
Legacy Score	0.730 ***	0.441 **
	(0.234)	(0.141)

Female		0.458
		(0.084)
Democrat (relative to Other)		0.074
		(0.012)
Income (thousands)		0.072
		(0.038)
Parent		-1.880 ***
		(-0.281)
Education		0.428 **
		(0.141)
Constant	-0.332	2.20 *
Observations	241	236
R^2	0.050	0.140

Supplementary Table 3. Linear regressions of *Generative Prime* on *Behavioral Intention Score* in Study 2. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .10, ** < .05, *** < .01.

Model	1	2
Essay Prime	0.309 ***	0.271 ***
	(0.178)	(0.155)
Female		0.252 **
		(0.144)
Age		.007
		(0.103)
Republican (relative to Other)		-0.266 *
		(-0.101)
Income (thousands)		-0.019

		(-0.035)
Education		0.001
		(0.001)
Parent		-0.114
		(-0.063)
Constant	3.179 ***	2.51 ***
Observations	309	303
R^2	0.031	0.075

Test of Mediation

In addition to reporting results for normal theory tests, we also tested mediation using the Preacher and Hayes (2008) bootstrapping method, which generates a data driven sampling distribution that can be used to robustly estimate the significance of the indirect effect (macrocode available at http://www.quantpsy.org). In the present set of analyses, parameter estimates were based on a resample procedure of 5,000 bootstrap samples (bias corrected and accelerated estimates and 95% CI).

Preacher, K.J. & Hayes, A.F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavioral Research Methods*, 40(3), 879–891.

Supplementary Methods

Study 1 Legacy Motive Question Items:

Instructions: Please read each of the statements below carefully. Then select the answer choice indicating the extent to which each statement describes you. Please be as honest and accurate as you can be.

Scale: 1 (Not at all); 2 (Not very much); 3 (A little bit); 4 (Somewhat); 5 (A good deal); 6 (A great amount)

1. I care about what future generations think of me
2. I have important skills I can pass along to others
3. I am good at many things
4. I feel a connection to future generations
5. I am well liked by my friends
6. Others would say that I have made unique contributions to my community or society
7. It is important to me to leave a positive legacy
8. I feel a sense of responsibility to future generations

Study 2 Legacy Induction Essay Text:

> *What do you want to be remembered for?*
>
> For this writing task, we would like you to think about what you want **future generations** to remember you for when you're gone. In answering this question, you might think about ways in which you will have a positive **impact on other people**, skills or knowledge you will **teach others**, or aspects of your personality that you would like to be remembered for. In the space below, please *write a brief essay* describing your response to this question and try to be as honest as you can be.
>
> This essay should take you approximately 5-7 minutes to complete *(roughly half a page).*

Behavioral Intention Question Items:

Instructions: Please indicate how often you intend to perform the following behaviors over the next three months:

Scale: 1 (Never); 2 (Very Infrequently); 3 (Once in a while); 4 (Sometimes); 5 (Often); 6 (All the time)

1. Take showers that are 5 minutes or less
2. Use public transportation or carpool
3. Unplug appliances and chargers (e.g., TV, cell phone, computer) at night
4. Buy green products instead of regular products (e.g., dishwashing detergent), even

though they cost more

5. Attend rallies, public events or town hall meetings to voice my support for solving environmental problems
6. Write letters, email, phone or otherwise contact elected official to urge them to take action on environmental issues (e.g., habitat loss, air pollution)

Environmental Attitude Question Items:

Instructions: We'll next ask a few questions about your attitudes regarding environmental issues. There are no right or wrong answers--we just want to hear what you think.

Scale: 1 (Strongly Disagree) – 7 (Strongly Agree)

1. I feel a responsibility to reduce my personal contribution to climate change.
2. I feel that it is important to maintain the environment for future generations.
3. I am in favor of national policies and regulations that decrease fossil fuel burning, even if they increase energy and electricity costs today.
4. The so-called "global warming crisis" facing humankind has been greatly exaggerated. (reverse coded)

Donation Question Wording:

The organization you have an opportunity to donate to today is called Trees for the Future, whose motto is "Plant trees. Change Lives." Since 1989, Trees for the Future has helped communities in 19 countries around the world plant millions of trees. Their work has and will continue to improve the well-being of children and families for generations to come, by cleaning the air, reducing risks from landslides and reducing deforestation. If you'd like to learn more about the organization, their website is: http://www.treesforthefuture.org

Please note that the total amount must add up to exactly $10. Remember that you will be paid your MTurk compensation regardless of whether you win the lottery or not.

Donate ____

Keep for myself ____

Total ____

Paper 3:

Effects of Age on Affective Forecasting Ability

Lisa Zaval, Elke U. Weber, Eric J. Johnson, Ye Li

KEYWORDS: Affective Forecasting, Decision Making, Aging, Future Anhedonia

Author note: This research has been supported by NIA Grant R01AG044941.

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Abstract

Previous research on age differences in affective forecasting focused on identifying inaccuracies rather than the process in which forecasts are constructed. Based on a dual-system framework of decision-making, the present research examines under what situations age differences in affective forecasting emerge, and what underlying mechanism may account for these differences. Experiment 1 compared affective forecasting and experienced affect in younger and older adults under differential involvement of affective versus deliberative processes using the Columbia Card Task. Younger adults made more extreme forecasts than older adults, and exhibited greater forecasting accuracy for gain outcomes in the affective version of the task, but not for losses. Age did not affect accuracy of forecasting in the deliberative version of the task. Experiment 2 examined whether age differences in affective forecasting ability extend to long-term forecasting errors routed in temporal discounting behavior. In a continuous age sample, younger adults exhibited greater future anhedonia errors, mistakenly believing that they would experience less intense affect when an event happened in the future than when the same event happened in the present. These forecasting errors were also found to mediate the effect of age on time preference. Taken together, our findings suggest that affective forecasting is a skill that may improve across the lifespan, and thus may tap cognitive and affective abilities that increase with the experience that comes with age, including improved emotional regulation.

Effects of age on affective forecasting ability

1. INTRODUCTION

Decisions involving long time horizons often involve making predictions about future outcomes and preferences, which in turn may or may not coincide with experienced outcomes (Loewenstein, O'Donoghue, & Rabin, 2003). However, relatively little research has explored how individual and situational differences might affect the match or mismatch between the two. *Affective forecasting* examines the accuracy of people's expectations regarding their future emotional states (Loewenstein & Lerner, 2003; Wilson & Gilbert, 2003), and may depend on key contextual variables that influence preferences and attitudes, including the decision context (i.e., affective versus deliberative decision environments), and various individual differences (i.e., age and level of experience).

Indeed, affective forecasting ability may have particular practical relevance in advanced age. In the domain of financial decision-making, in particular, older adults must often make predictions about their future preferences and affective reactions to potential outcomes, including investment of savings and retirement income (Hershey, Jacobs-Lawson, McArdle, & Hamagami, 2007), health care planning (Anderson, 2007), insurance purchases (Frolik, 2009), and anticipating long-term care needs (Sörensen, Mak, & Pinquart, 2011). However, there has been relatively little empirical research on affective forecasting ability in older adults, and the few studies that have examined this topic lack consensus, compelling further investigation (Scheibe, Mata, & Carstensen, 2011). More importantly, the little research that has examined age differences in affective forecasting has focused on identifying forecasting inaccuracies, but neglected to study the *processes* by which forecasts are constructed.

The present research attempts to address this knowledge gap by examining under what situations age differences in affective forecasting emerge, and what underlying mechanism may account for these differences. First, based on a dual-system framework of decision-making (Weber & Johnson, 2009) and documented age differences in emotional processing (Scheibe & Carstensen, 2010), we consider the role of "hot processes" in decision-behavior by examining whether age differences in affective forecasts, made in a deliberative state, differ with those made during an emotionally charged state. We next consider whether age differences in long-term affective forecasts are related to time preference, another decision-making behavior governed by dual-systems (Laibson, 1997a). Overall, we predicted that advanced age, because it is associated with improved emotional regulation and reduced temporal discounting, would be associated with reduced affective forecasting errors, but only in tasks that drive affect-based strategy use. To provide the theoretical background for our predictions, we first review the literature on decision-making and emotional changes across adulthood, and then consider the possible implications for age-differences in affective forecasting.

1.1 Affective Forecasting

Everyday forecasting requires balancing hedonic impulses with deliberate long-term evaluations, in order to choose an option that will ultimately provide the greatest hedonic benefits (Loewenstein, 2007). To make these judgments, people must go beyond current experience and instead rely on semantic knowledge, including situation-specific beliefs about what emotions are typically elicited in particular situations and the levels and kinds of emotions generally experienced (Robinson & Clore, 2002).

Research on affective forecasting, however, has consistently demonstrated that individuals make inaccurate forecasts concerning the intensity and duration of their affective responses (Wilson & Gilbert, 2005). For example, people tend to overestimate affective reactions to future events and decisions, a source of error termed the "impact bias" (Wilson & Gilbert, 2005). When people generate forecasts regarding a future event, the target event becomes the focus of judgment, and consequently, people may fail to consider the extent to which other, peripheral events influence their emotional responses (Kermer, Driver, Wilson, & Gilbert, 2006; Schkade & Kahneman, 1998). To overcome these errors, people must correctly identify when they have experienced a comparable event in their past, (Wilson & Gilbert, 2003), an ability which may improve with accumulated life experience and greater emotional knowledge. Indeed, evidence suggests that people who have experience in a particular situation make more accurate forecasts concerning adaptation (Schkade & Kahneman, 1998).

A second type of forecasting error, consistent with research on temporal discounting, reveals that people falsely assume that they will experience less intense affect when an event happens in the future than when the same event happens in the present (Kassam, Gilbert, Boston, & Wilson, 2008); a bias termed "future anhedonia". It has been well documented that the temporal location of an event influences the way that event is mentally represented (i.e. Trope & Liberman, 2003; Zaval & Gureckis, 2010). As a result of these differences, representations of future events tend to evoke less intense affect than do representations of present events (McClure, Laibson, Loewenstein, &

Cohen, 2004). If people believe that their future emotions will be less intense than their present feelings, then time discounting may reflect their attempt to maximize benefits by enjoying them in the present. A body of work suggests that affective factors play a major role in temporal discounting behavior, and age differences in affective forecasting and future anhedonia would therefore seem to have important implications in this domain (Ifcher & Zarghamee, 2011; Lerner, Li, & Weber, 2013; Löckenhoff, O'Donoghue, & Dunning, 2011; Pyone & Isen, 2011).

1.2 Aging and Affective Forecasting

Although lifespan differences in affective forecasting have important practical implications, evidence regarding age differences in affective forecasting ability is scarce. Moreover, the handful of existing studies on this topic focus on identifying inaccuracies rather than the process in which forecasts are constructed. For example, in a monetary incentive delay task, younger, but not older adults overestimated increases in arousal in response to small monetary gain outcomes (Nielsen, Knutson, & Carstensen, 2008). Forecasting accuracy was also enhanced with age in a study in which participants predicted how they would feel if their preferred presidential candidate won or lost the 2008 election, particularly among supporters of the winning candidate (Scheibe et al., 2011). Contrastingly, no age differences in forecasting accuracy were found in a study in which old and young adults predicted how satisfied they would feel after choosing among everyday products (Kim, Healey, Goldstein, Hasher, & Wiprzycka, 2008). Thus, despite the preliminary evidence that older adults more accurately predict dynamic changes in affect, the mixed evidence and paucity of studies limit our confidence in these findings. Further, prior research failed to distinguish between the role of deliberative and affective decision environments on age differences in affective forecasting, which may account for previous mixed results, and which we next turn to in more detail.

1.3 Age, Decision Making, and Affect

Emerging interest in age-related changes in decision making focus on a dual-process model of decision making (Bruine de Bruin, Parker, & Fischhoff, 2012; Li, Baldassi, Johnson, & Weber, 2013), which distinguishes between affective "hot" processing abilities and deliberative "cold" processing (Epstein, 1994; Kahneman, 2003; Sloman, 1996). This work indicates that affective and deliberative processing abilities show differential age trajectories (Carstensen, 2006; Figner, Mackinlay, Wilkening, & Weber, 2009; Peters, Hess, Vaestfjaell, & Auman, 2007), with implicit forms of knowledge, such as affect, becoming more important inputs into decisions as deliberative processes decline with age (Mather, 2006; Peters, Finucane, MacGregor, & Slovic, 2000; Peters et al., 2007). Increased knowledge, life experience, and shifts in emotional goals may result in more efficient affective or experiential processing of decision information (Peters et al., 2007). Indeed, relying on affective cues has been shown to be beneficial in decision-making, as when seniors rely on simpler information search strategies, avoid the sunk cost bias, and resist the influence of irrelevant options on choices (Besedeš, Deck, Sarangi, & Shor, 2012; Kim & Hasher, 2005; Strough, Mehta, McFall, & Schuller, 2008). In these cases, accumulated emotional knowledge and experience may help older adults make appropriate decisions in situations of heightened emotional arousal.

One important way in which people incorporate emotions into their judgments is when constructing affective forecasts, and it seems likely that age differences in emotional processing would result in qualitative differences in young versus older adults' forecasting ability. For example, older adults' may exhibit an advantage in affective forecasting which stems from their ability to identify the specific emotions that arise from complex affective experiences (Carstensen et al., 2011; Scheibe & Carstensen, 2010). Further, age differences in dispositional emotions may reflect the ability to prevent emotional factors from intruding into everyday functioning (Löckenhoff et al., 2011). Indeed, evidence suggests that older adults' accumulated experience leads to improved emotion regulation and problem solving strategies (Blanchard-Fields, 2007; Grossmann et al., 2010; Kafetsios, 2004; Kessler & Staudinger, 2009; Scheibe & Blanchard-Fields, 2009), which may confer advantages in down regulating the "hot" system in favor of a more deliberative consideration of available trade-offs. These findings are in line with the hypothesis that age differences in affective forecasting may only occur under the influence of hot processes in decision behavior. If affect is critical to everyday choice processes and if older adults are better at effectively regulating affect, then they may make better choices in situations of heightened emotional arousal, despite analytic declines.

1.4 The Present Research

Our research is predicated on past work that distinguishes between deliberative and affective processes in age-related changes in decision-making. We first explore the hypothesis that older adults make better affective forecasts compared with younger adults, but only in affective versus deliberative decision environments. To examine this prediction, in Experiment 1, we examine the effect of age on short-term affective forecasting ability under differential involvement of affective versus deliberative processes using two versions a dynamic decision task. This study specifically focused on the prediction and actual experience of affective states elicited during the anticipation and realization of positive and negative outcomes, using a laboratory measure of decision making that closely mimics everyday life by the manner in which it factors in reward, punishment and risk. Experiment 2 builds upon these results by using a continuous age sample to explore the extent to which age-differences in affective forecasting extend to long-term affective forecasting biases routed in temporal discounting behavior. Specifically, we investigate whether people expect their affective reactions to an event to be less intense in the future than in the present, and examine the relationship between this bias and age differences in temporal discounting behavior.

2. EXPERIMENT 1

2.1 Overview

In Experiment 1, we considered the potential role of hot processes in decision-behavior by examining whether age differences in affective forecasts, made in a deliberative state, differ with those made during an emotionally charged state. Affective forecasting ability was compared in younger and older adults using two versions of the Columbia Card Task (CCT; Figner, Weber, Mackinlay, & Wilkening, 2009). This task was chosen because (1) it has previously proven useful in uncovering differences in risk preferences and emotional processing across the life span (Figner et al., 2007), and (2) because it exists in two versions that differentially trigger affective versus deliberative decision making, thus enabling our investigation of affective forecasting in both affect-based and deliberative risk-taking environments. Participants anticipated their emotional reactions to a range of hypothetical CCT outcome scenarios, and then reported experienced reactions while actually playing the CCT. We investigated forecasting errors among young and older participants by comparing both their predicted and experienced responses. Overall, we predicted that advanced age, because it is associated with improved emotional regulation, would be associated with reduced affective forecasting errors, but only in the affective versus deliberative version of the CCT.

2.2 Methods

2.2.1 Sample

A sample of 164 adults from the US was recruited in two age groups via the Columbia University Virtual Lab national panel, and were asked to participate in an online laboratory session. Participants were divided into roughly equal sized age groups: Eighty-one younger adults aged 18-25 years ($M = 21.5$, $SD = 1.48$) and 75 older adults aged 60-83 ($M = 67.8$, $SD = 5.0$). To ensure that any differences obtained between younger and older adults could not be attributed to age-related cognitive abnormalities, a separate sample ($n = 57\%$) of older adults from the CDS participant pool was screened using the Telephone Interview of Cognitive Status (TICS), finding 90% of the older adults completely non-impaired, 10% ambiguous, and none testing either mildly or severely impaired. Age was positively correlated with years of education ($r = .20$, $p < .01$) but was not related to level of household income ($r = .09$, $p = ns$). Seventy-nine percent of the sample was Caucasian, and sixty-eight percent were women (see Supplementary Table S1 for details of the breakdown of demographic distributions by age group).

2.2.2 Instrumentation

The CCT is a computer-based task in which participants play multiple trials of a card game. The Columbia Card Task exists in two versions: a “Hot” affective, and “Cold” deliberative version. In the Hot version, at the beginning of each trial, each participant encounters 32 cards presented face down (see Supplementary Figure S1-A for card presentation screen). Each card may be either a hidden gain or loss card. Each turned-over gain card adds a specified amount to the trial payoff, while each loss card subtracts a specified amount. In the present experiment, each CCT round involved 8 loss cards (out of 32), with gain cards worth +30 points and loss cards worth -90 points. Within each trial, cards can be continually turned over as long as gain cards are encountered, and the player can voluntarily end the trial at any point and claim the accumulated payoff. However, as soon as a loss card is encountered, the trial terminates, and a specified loss amount is deducted from the total payoff. The Hot version of the CCT triggers primarily affective processes because players make step-wise decisions about card selection and are provided with immediate feedback after each selected card. In contrast, in the Cold CCT, participants are only asked to indicate the total number of cards that they wish to turn over on a given trial. Decisions are not made incrementally and players do not receive feedback regarding their decision until the session is completed (See Supplementary Figure S1-B for Cold CCT presentation screen).

2.2.3 Procedure

Participants were paid $5 dollars for their participation via paypal upon completion of the experiment, plus any winnings obtained while playing the CCT. Bonuses were determined based on the scores of three randomly selected trials, such that individual round performance, and not cumulative performance, was consequential.

Participants first performed several CCT practice rounds with feedback, and answered a series of task comprehension questions (one-way ANOVAs revealed no difference in task comprehension between the two age groups, $p < .05$). After familiarizing themselves with the task contingencies, participants rated anticipatory affect by predicting their emotional reactions to hypothetical CCT trial outcomes. Participants were asked to imagine playing the CCT and to forecast how they would feel when anticipating six outcome types: (1) *high loss*: lose after selecting 1^{st} or 2^{nd} card; (2) *med loss*: lose after 3^{rd} or 4^{th} card; (3) *low loss*: lose after 5^{th} card or more; (4) *low win*: win after 1^{st} or 2^{nd} card; (5) *med win*: win after 3^{rd} or 4^{th} card; (6) *high win*: win after 5^{th} card or more. Ratings were made on 7-point scales (1=*very unhappy*, 7=*very happy*) (see Supplementary Methods for complete version of forecast rating questionnaire). Participants next played eight rounds of both CCT versions (Hot and Cold) in a randomized block design, and reported their experienced reactions while actually playing the game, after each trial. Draws were rigged such that participants experienced at least one of each of the six CCT trial outcome types, with order randomized.

CCT versions were separated by a set of unrelated questionnaires to minimize carryover effects. A manipulation check at the end of the experiment assessed whether the Hot and Cold CCT conditions differentially involved affective versus deliberative processes. Self–reported affect-based strategy was assessed with the item "I solved the task on a gut level," and deliberative strategy use via the item "I tried to solve the task mathematically." Emotional arousal was assessed with the self-report item, "At times when deciding what to do, I felt some excitement," on a scale from 1-5.

2.3 Results

2.3.1 Manipulation Check

The Hot/Cold manipulation check confirmed that the Hot and Cold CCT versions differentially involved affective versus deliberative processes. As predicted, we found greater affect-based strategy use and emotional arousal in the Hot than in the Cold CCT: Gut level, $t(324) = -2.79$, $p < .001$; excitement, $t(324) = -2.32$, $p < .001$. Deliberative strategy use was greater in the Cold than Hot CCT: mathematically, $t(324) = 1.85$, $p < .05$, all one-tailed (see Figure 1).

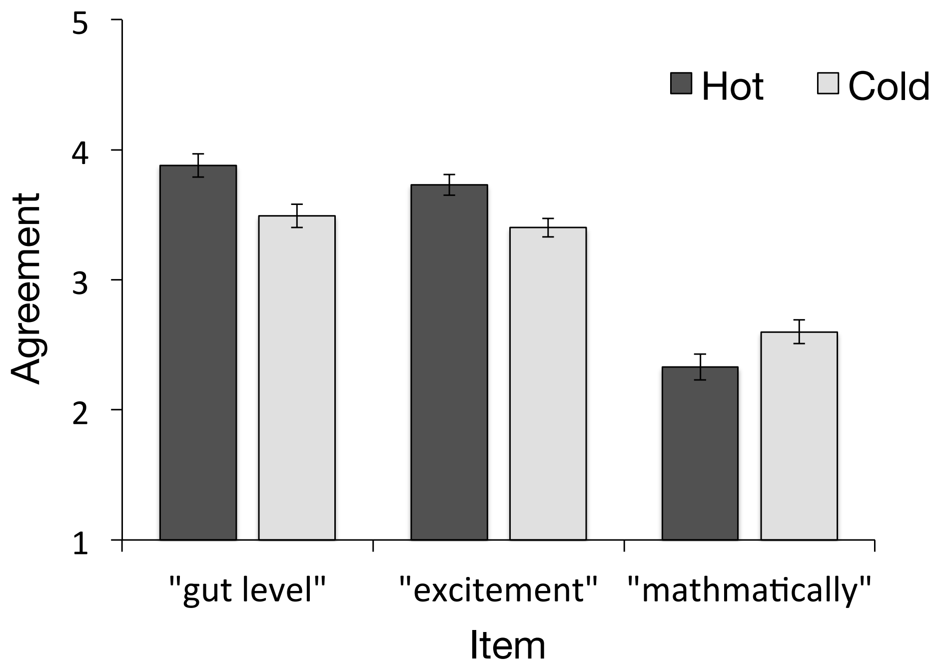

Fig. 1. Self-reported decision strategy items "gut level", "mathematically" and "excitement" differ by Columbia Card Task version (Hot and Cold CCT). Error bars denote ±1 *SEM*.

2.3.2 Forecasting Dynamics

With respect to anticipatory affect dynamics, we predicted that forecasted valence would be influenced by CCT version type (Hot versus Cold), and that any potential age differences in affective forecasting would be evident only in the Hot CCT version, which drives affect-based strategy use. We also assumed that expectations would be influenced by the type of CCT trial outcome (i.e., *low*, *medium* or *high* gain or loss), which drives anticipatory affect and predisposes expectations in the direction of the explicit stakes. By parsing forecasts into hot and cold dimensions, we endeavored to isolate the precise conditions of any age differences.

We first analyzed participants' predicted affect ratings, which were reported prior to playing the CCT. A 6 (trial outcome: low, medium or high loss or gain amount) x 2 (age: young versus old) mixed-effects ANOVA on forecast ratings for Hot CCT trials yielded a significant main effect of trial outcome, confirming that participants expected to feel larger increases in positive valence as the magnitude of reward increased, and larger increases in negative valence as the magnitude of reward decreased. This main effect was qualified by an age by trial outcome type interaction; $F(1, 906) = 448.67$, $p < .001$; $F(5, 906) = 5.951$, $p < .001$. Post-hoc analyses revealed that this interaction was driven by whether the trial outcome was in the loss or gain domain. A 2 (loss versus gain) x 2 (young versus old) mixed-effects ANOVA on affective forecast ratings yielded a significant interaction, with younger adults anticipating greater negative valence associated with hypothetical loss outcomes, and greater positive valence for gain outcomes $F(1, 914) = 21.17$, $p < .001$. Younger adults' loss and gain forecasts were thus significantly more distant from neutral (i.e., more polarized) than forecasts made by older adults (see Figure 2; Table 1 panel A). Controlling for baseline affect rating and demographic variables (i.e. gender, income) did not change the nature of this result.

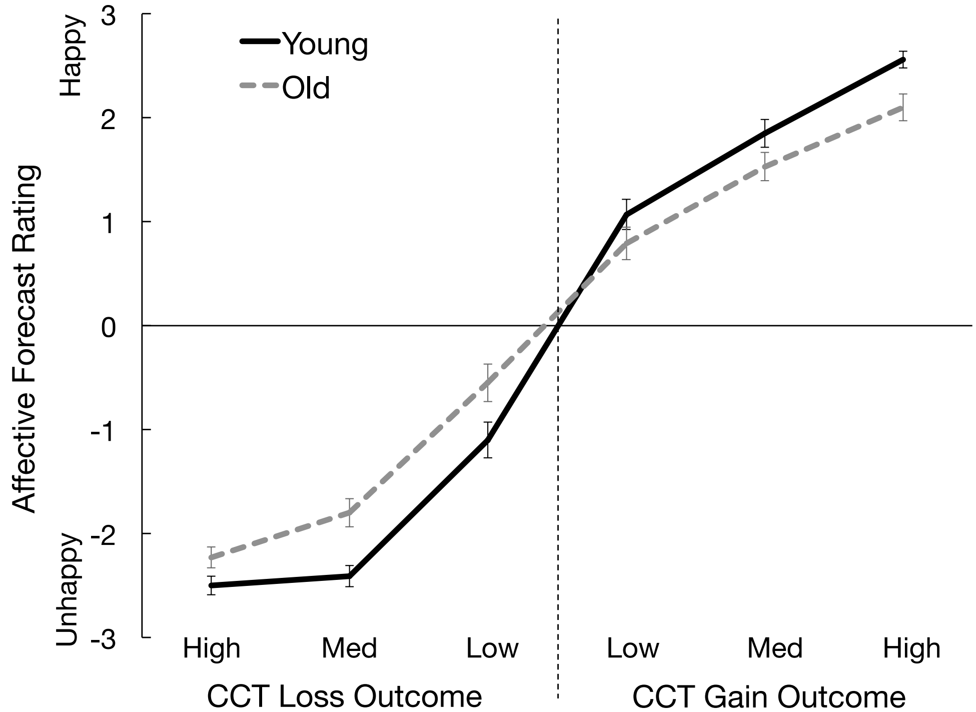

Fig. 2. Anticipatory affect ratings for Hot CCT trial outcomes among younger and older participants, derived from self-report ratings from the affective forecasting survey. Bars denote ±1 *SEM*.

For Cold CCT trials, we found no evidence of age differences in affective forecasting. A 6 (trial outcome) x 2 (age: young versus old) mixed-effects ANOVA on forecast ratings for Cold CCT trials yielded a significant main effect of trial outcome, $F(1, 906) = 375.3$, $p < .001$; but no other significant main or interaction effects. Most importantly, we did not find a main effect of age or an age × outcome interaction, indicating no age differences in absolute levels of affective forecasts for Cold CCT trial outcomes.

2.3.3 Experienced Affect and Forecasting Errors

Next, we examined the experienced affect responses that participants reported while actually playing the CCT. A 6 (trial outcome type) x 2 (age group: young versus old) mixed-effects ANOVA for Hot CCT trials on experienced affect rating yielded a significant age by trial outcome type interaction; $F(5, 906) = 2.63$, $p = .023$. A one-way ANOVA of Hot CCT *loss* outcomes by age revealed a significant main effect of age; $F(1, 453) = 4.12$, $p = .042$, such that younger adults experienced greater negative affect associated with CCT loss outcome trials relative to older adults. However, a significant main effect of age did not emerge in the gain domain as in the loss domain; $F(1,453) = 1.28$, $p = ns$. No age differences in experienced affect were found in the Cold CCT. A 6 (trial outcome) x 2 (age) mixed model ANOVA on experienced affect rating yielded no main effect of age or significant age by outcome interaction ($p = ns$).[4]

Aggregate affective forecasting errors among young and older participants were computed by comparing their predicted and experienced affect ratings, parsed into anticipatory (forecast ratings) and outcome (experienced ratings) phases. As expected and consistent with past literature, data revealed that participants experienced affective forecasting errors: A 2 (study phase: forecast vs. experience) x 6 (CCT trial outcome)

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[4]Because individual performance on the task might influence one's experienced emotional response to trial outcomes, we also explored whether CCT score correlated with experienced affective response. We found that higher trial scores were associated with greater increases in valence in response to the highest gain outcome type; $r = .32$, $p < .05$, $n = 40$. Thus, people who performed better on the CCT also perceived the best outcome as being more positive. However, overall CCT scores did not correlate with forecast ratings, suggesting that people who were more successful in the CCT did not forecast that they would feel better or worse than those who performed more poorly. Winnings (overall or by trial type) were not correlated with age, income, or any other demographic measure.

mixed-effects ANOVA on affect ratings yielded a significant trial type by phase interaction, $F(5, 912) = 7.07$, $p < .001$. In line with research on the impact bias, participants erred in anticipating greater positive outcomes in response to gains than was actually experienced (See Supplementary Figure S2).

To examine individual differences in affective forecasting, for each participant and trial outcome type, we calculated an affective forecasting error score, which was defined as the difference between participants' predicted and experienced affective response. As predicted, young and old adults differed in their ability to predict affective reactions to monetary outcomes in the Hot CCT version. A 6 (trial outcome) x 2 (age group: young versus old) ANOVA for Hot CCT trials on forecasting errors yielded a significant main effect of age, qualified by an age by trial outcome type interaction; $F(1, 906) = 13.05$, $p < .001$; $F(5, 906) = 3.62$, $p = .002$. Post-hoc analyses revealed that the age by CCT trial outcome interaction was driven by whether the outcome was a loss or gain. A 2 (trial outcome: loss versus gain) x 2 (age group) ANOVA yielded a main effect of outcome and age, qualified by an age by outcome type interaction; $F(1, 918) = 20.21$, $p < .001$; $F(1, 918) = 5.29$, $p = .022$; $F(1, 918) = 8.03$, $p = .004$. As predicted, younger adults made larger forecasting errors compared with their older counterparts. Paired contrasts revealed that older adults made reduced affective forecasting errors compared with young adults for all gain outcomes. However, age differences in forecasting accuracy were not observed in the loss domain as in the gain domain (Table 1 Panel B). The effect of age remained highly significant after controlling for baseline affect and demographic variables.

Trial Outcome	(A) Forecasting			(B) Forecasting Errors		
	Young	Old	*F*	Young	Old	*F*
CCT Loss						
Low	-1.10 (.17)	-0.55 (.18)	6.49*	1.12 (.13)	0.74 (.13)	0.74
Med	-2.41 (.10)	-1.82 (.13)	14.46**	0.52 (.12)	0.42 (.11)	0.41
High	-2.25 (.09)	-2.23 (.10)	1.98	0.38 (.09)	0.33 (.12)	2.12
CCT Gain						
Low	1.07 (.15)	0.79 (.16)	1.80	1.13 (.13)	0.73 (.13)	4.67 *
Med	1.85 (.13)	1.53 (.14)	3.69*	0.86 (.12)	0.50 (.11)	4.68 *
High	2.56 (.09)	2.10 (.13)	8.94**	1.19 (.15)	0.82 (.13)	3.90 *

Table 1. Age differences in (A) affective forecast ratings and (B) affective forecast errors for Hot CCT Trials: Means (and Standard Errors). Statistical comparisons represent post-hoc pairwise contrasts for individual CCT outcome types between age groups. * < .05, ** < .01

In contrast, and as predicted, age differences in affective forecasting error size were not observed in Cold CCT trials. A trial outcome type by age mixed-effects ANOVA on forecasting errors yielded only a significant main effect for outcome type, but no main effect of age, $F(1, 912) = 0.03$, *ns*, or age by outcome type interaction; $F(5, 912) = 0.87$, *ns*. Age differences in forecasting accuracy were not observed for any loss or gain outcomes types in the Cold CCT (see Supplementary Information).

2.4 Discussion

Young and old adults differed in their ability to predict affective reactions to monetary outcomes in the affective version of a dynamic decision making task, but not in the deliberative version. These results are consistent with the hypothesis that age differences in affective forecasting may depend on the influence of hot processes in decision behavior; a finding that may account for the previous mixed results regarding age differences in affective forecasting. Importantly, forecasting accuracy was enhanced with age for gain outcomes, such that seniors were less likely than younger adults to make the typical errors of overestimating positive affect. However, age differences in forecasting accuracy were not observed for loss outcomes, a result consistent with past research, which found older adults to be better than younger adults at forecasting their emotional experience only after a positive event (Scheibe et al., 2011). The absence of forecasting benefits for negative events coheres with research on the positivity bias in older adults, which suggests that older adults avoid negative information and show lower neural activation of losses (Mather & Carstensen, 2005; Samanez-Larkin, et al., 2007). Our results suggest that in situations of heightened emotional arousal, a positivity effect may occur for judgments about future events, such that older adults are more accurate than younger adults about forecasting responses to positive events, but not negative events.

Our results are also in line with the contention that affective forecasts, and to a lesser extent actual emotional reactions, reflect general age-related shifts toward reduced intensity of self-reported emotional experience (Hogarth & Einhorn, 1992; Schuman & Presser, 1981): In response to a loss, older adults both forecasted *and* experienced less of an increase in negative emotion than younger adults. In response to gains, older adults forecasted *and* experienced less of an increase in positive emotion. It is possible that reduced negative anticipatory affect in older adults may aid in decision making outside of the lab by allowing for more dispassionate, less affect-based processing. This hypothesis was corroborated by Figner et al. (2007), who found that adolescents, but not older adults, displayed increased risk-taking and simplified information use in the Hot, but not Cold version of the CCT.

Importantly, and consistent with Scheibe et al. (2011), age differences in *forecasted* affect were more apparent than age differences in *experienced* affect. Younger adults anticipated greater increases in positive emotion, yet their actual emotional reactions did not reflect these expectations. It has been suggested that exaggerated forecasts are advantageous in that they encourage an individual to work eagerly towards achieving states that are predicted to produce strong emotional reactions (Schwarz & Clore, 1983). If affective forecasts are influenced by one's representations of future rewards, then reduced intensity and more accurate forecasts may be associated with delay of gratification, improved emotion regulation, and increased patience in older adults.

Indeed, some results from the temporal discounting literature suggest that as people age, they discount the value of delayed rewards less steeply and are thus more patient relative to young adults (Green, Fry, & Myerson, 1994; Li et al., 2013; Reips, 2002). If one component of temporal discounting is governed by a hot system responding primarily to immediate rewards (Loewenstein & O'Donoghue, 2007), then age-related improvements in affective forecasting ability may confer advantages in down-regulating the hot system in favor of a more deliberate consideration of future rewards. Drawing on recent work that highlights the important roles of hot processes in temporal discounting behavior (Ifcher & Zarghamee, 2011; Löckenhoff, O'Donoghue, & Dunning, 2011; McClure, Laibson, Loewenstein, & Cohen, 2004; Lerner, Li, & Weber, 2013; Pyone & Isen 2011), we next turn to the question of whether age differences in affective forecasting extend to long term affective forecasts and hedonic forecasting biases routed in temporal discounting.

3. EXPERIMENTS 2A and 2B

3.1 Overview

Drawing on Experiment 1 results, we examine whether age differences in affective forecasting accuracy extend to a bias known as future anhedonia, which suggests that representations of future events evoke *less* intense affect than do representations of present events (Kassam et al., 2008). In the context of temporal discounting, greater accuracy in affective forecasting should include the recognition that an event should produce similar affective responses at the time of the event occurring, regardless of whether the event occurs immediately or at some point in the future. Based on Experiment 1 results, we hypothesized that age-related improvements in affective forecasting ability would extend to older adults having more accurate interpretations of trade-offs among present and future rewards. Specifically, we predicted that future anhedonia errors would decrease across the lifespan, such that younger adults would be more likely to mistakenly believe that they would experience less intense affect when an event happened in the future than when the same event happened in the present. Relatedly, we also predicted that age differences in future anhedonia errors would mediate age differences in temporal discounting behavior and greater patience among older adults.

3.2 Methods

3.2.1 Sample and Procedure

In Experiment 2a, a continuous age sample of 618 US participants, ranging in age from 18 to 86 years of age (*M* = 45.6, *SD* = 16.3), were recruited from the Columbia University's Virtual Lab Panel to participate in a web-based survey consisting of cognitive, decision-making, and demographic measures. Age was positively correlated with years of education ($r = .14$, $p < .001$) but not related to level of household incomes ($r = .04$, $p = ns$). Eighty percent of the sample was Caucasian and 60 percent were women (see Supplementary Table S1 for further details on subject recruitment and a breakdown of demographic details).

To assess affective state at baseline, participants were first asked to rate their current affect immediately before the beginning of the trial. Participants were then given an intertemporal choice forecasting scenario in which they were asked to estimate their present reaction to a present financial event, and their future reaction to a future financial outcome at the time of its occurrence in a between-subject design (based on the methodology used by Kassam et al., 2008). To measure future anhedonia for financial gains, participants were asked, "If you were given $100 dollars *right now,* how happy would you be?" and "If you were given 100 dollars *three months from now,* how happy would you be at that time? They made estimates on a 9-point scale anchored from *not at all happy* to *extremely happy*. We also explored future anhedonia errors for temporal gains by asking participants how happy they would be today [*in 3 months*]*,* upon discovering that they had an unexpected hour of free time (See Supplementary Information for full question text for Experiment 2). Finally, we assessed future anhedonia for financial losses using the questions, "If you lost $100 dollars right now [*3* *months from now*], how sad would you be [*at that time*]?" (1= not at all sad; 9 = extremely sad).

In Experiment 2b (*N* = 478), we examined whether a standard economic measure of value—willingness to pay—revealed age differences in future anhedonia when the focal event involved receipt of a consumer good. Study 2b was run three months after Study 2a, and a subset of participants from Study 2a were asked to read two scenarios. The *present* scenario asked participants to predict their reactions to a present event on the same scale used in Experiment 2a ("Imagine that as a promotion today, Amazon® gave you a boxset of DVDs of your favorite TV show, worth $100.00…How happy would you feel today if you were given this gift today?") and to estimate their willingness to pay ("Now imagine that Amazon® is considering selling the boxset at a discounted price instead…What is the maximum amount of dollars you would be willing to pay today to receive this gift?"). In the *future* scenario, participants were asked to imagine receiving the boxset in 3 months, to rate how happy they would be when they received the gift at that time, and also to estimate their willingness to pay in 3 months.

Across experiments, we measured individual time preference, which is the degree to which people discount future gains and losses. Participants completed the adaptive DEEP Time task (Toubia, Johnson, Evgeniou, & Delquié, 2013), a tool that presents 20 adaptive binary choices between smaller, sooner amounts and larger, later amounts, and estimates participants' discount rates using Bayesian Markov chain Monte Carlo methods. Importantly, the DEEP Time task estimates the quasi-hyperbolic discounting function, which includes both standard, exponential discounting of future consequences and "present bias" (Laibson, 1997b), or how much a decision maker discounts all future rewards regardless of delay length. For a full discussion of this adaptive, method and its Bayesian estimation procedure, including validity checks of the estimation of discounting and Prospect-theory parameters, see Toubia et al. (2012).

3.3 Results

3.3.1 Study 1a

Consistent with Kassam et al (2008), Study 2a aggregate data showed that participants demonstrated future anhedonia for financial gains. They predicted that they would be happier upon receiving $100 in the present (M = 8.57, *SD* = .81) than upon receiving $100 in the future (*M* = 8.26, *SD* = 1.08), *t*(618) = 9.03, $p < .0001$.[5] Participants also demonstrated future anhedonia when the variable of interest was an hour of free time. They predicted that they would be happier upon receiving one hour of free time in the present (*M* = 7.86, *SD* = 1.29) than upon receiving one hour of free time in the future (*M* = 7.52, *SD* = 1.49), *t*(618) = 7.23, $p < .0001$. However, future anhedonia did not extend to the realm of financial losses. Participants did not predict that they would be sadder upon losing $100 in the present (*M* = 7.44, *SD* = 2.33) than upon losing $100 in the future (*M* = 7.43, *SD* = 2.25), *t*(618) = -0.03, *p* = *ns*.

We next explore individual-level results to determine whether younger adults exhibited greater future anhedonia errors relative to older adults. Participants who indicated that they would be happier in the present than the future were considered to have made a future anhedonia error. Consistent with our hypotheses, older adults were

[5] To verify that future anhedonia errors would also persist in a between-subject web-based design (and were not the influence of carry-over effects), half of participants in another study were asked how happy they would be to receive $20 *right now*, while the other half were asked how happy they would be if they received $20 in *3 months time*. Participants exhibited future anhedonia: Those who were asked how they would feel if they received $20 *now* predicted that they would be happier (*M* = 8.0, *SD* = 1.25) compared with those subjects asked about receiving $20 *in 3 months* (*M* = 7.78, *SD* = 1.3), *t*(612) = 2.23, *p* = .01.

less likely than younger adults to commit future anhedonia errors for the $100 gain, temporal scenario, and loss scenario; $\beta = -1.18$, $z = -4.41$, $p < .001$, $\beta = -1.03$, $z = -4.19$, $p < .001$, $\beta = -2.23$, $z = -3.36$, $p < .001$.

For each forecasting scenario, we calculated for each participant a *future anhedonia index* which was defined as the difference between participants' predictions of their present reaction to a present event and their future reaction to a future event. For the $100 scenario, participants who felt that they would be happier in the future than the present were excluded from further analysis (2%). The mean future anhedonia index was 0.31 for $100 gain (*SD* = 0.85) and 0.34 for one hour of time (*SD* = 1.15).

A regression analysis with future anhedonia index for the $100 gain scenario as the dependent measure yielded a negative effect of the age, $\beta = -0.18$, $t(601) = -4.56$, $p < .001$, such that younger adults made greater errors compared to older adults, as shown in Figure 2. We also observe an age effect when the reward was an hour of free time: Participants who were most likely to believe that they would be happier upon receiving one hour of free time in the present than upon receiving one hour of time in the future were the younger participants $\beta = -0.08$, $t(600) = -1.87$, $p = .06$. The effect of age remained highly significant after controlling for time preference, baseline affect and demographic variables (see Supplementary Information). However, we did not find a significant effect of age for the $100 loss scenario future anhedonia index, $\beta = 0.05$, $t(600) = 1.21$, $p = ns$.

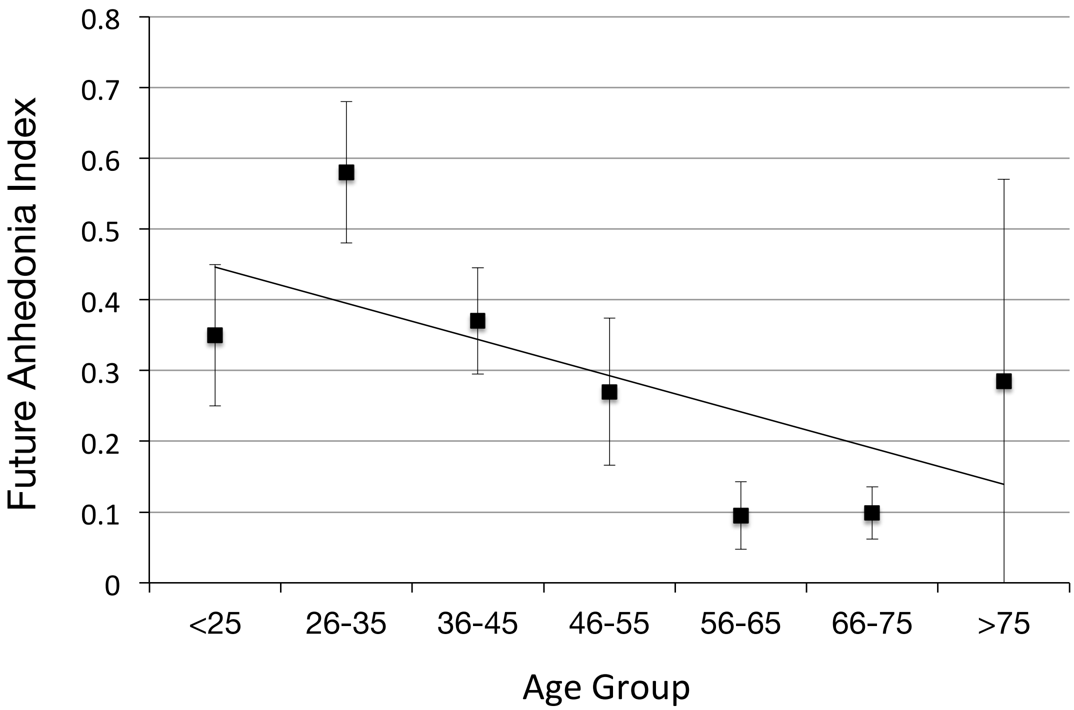

Fig. 3. Mean Future Anhedonia Index by Age Group for \$100 scenario in Study 2a. Error bars denote ±1 *SEM*.

3.3.2 Time preference and future anhedonia

We next examined whether future anhedonia errors, a forecasting bias predicated on temporal discounting behavior (Kassam et al., 2008), were related to components of an individual's time preference. As expected, exponential discount rate (*δ*) was correlated with future anhedonia index for an \$100 $r(607) = 0.20$, $p < .001$, and for an extra hour of time, $r(606) = .09$, $p < .05$, indicating that the participants who were most likely to believe that they would be happier upon receiving \$100 or an hour of time in the present than in the future were the participants who were least patient. Future anhedonia was also associated with higher present bias (the overvaluation of immediate outcomes). People with higher future anhedonia indices for the \$100 gain and 1 hour of free time displayed more present bias (a value β <1 indicates present bias), money: $r(607) = -.23$, $p < .001$; time: $r(606) = -.13$, $p < .001$.[6] Age was also a significant predictor of time preference. Older adults displayed less present bias and lower exponential discount rates compared to younger adults, β: $r(608) = .10$, $p < .05$; δ: $r(608) = -.09$, $p < .05$.

Importantly, future anhedonia error can be considered as fully mediating the effect of age on time preference: Exponential discount rate: age, direct: $t(609) = -2.31$, age, mediated: $t(609) = -1.59$, boot-strapped Sobel's $Z = -2.99$, $p = .002$. Present bias: age, direct: $t(609) = 2.53$, age, mediated: $t(609) = 1.71$, boot-strapped Sobel's $Z = 3.16$, $p < .001$. Thus, age differences in future anhedonia errors may partially explain why aspects of time discounting behavior improve with advanced age.

3.3.3 Study 2b

Results from Experiment 2b confirmed that age differences in future anhedonia extend to the receipt of consumer goods and willingness to pay. Overall, participants predicted that they would be happier upon receiving a DVD box-set today (M = 7.53, $SD = 1.63$) than upon receiving it in 3 months ($M = 7.02$, $SD = 1.84$), $t(472) = 8.60$, $p < .0001$, $M_{\text{FA Index}} = 0.5$, $SD = 1.28$). Participants were moderately more willing to pay for goods in the present ($M = \$29.63$, $SD = \$27.86$) than in 3 months ($M = \$26.63$, $SD = \$25.70$), $t(472) = 1.72$, $p = .08$, $M_{\text{FA Index}} = \$3.0$). Importantly, and consistent with Experiment 2a results, there was a negative relationship between age and future anhedonia index regarding receipt of the gift. A regression with future anhedonia index as the dependent measure yielded a significant effect of age, $\beta = -0.10$, $t(471) = -2.07$, $p < .05$. Similarly, younger adults showed greater discrepancies in willingness to pay for the

[6] Beta and delta were not related to future anhedonia of losses; β: $r(454) = .064$, $p = .17$; δ: $r(464) = -.05$, $p = .27$.

box-set at a discounted price: β = -0.12, $t(471) = -2.65$, $p < .01$. This effect of age on future anhedonia index remained significant after controlling for demographic factors and exponential discount rate.

3.4 Discussion

Consistent with our predictions and Study 1 results, we found a negative relationship between age and future anhedonia errors. These findings suggest that with advanced age comes the awareness that events will likely feel the same, regardless of whether they occur in the immediate present or at some delay in the future. Although all participants mistakenly believed that a receipt of a monetary gain, an hour of free time, or a consumer good would bring them less happiness when it happened in the future than when it happened in the present, younger adults were even more likely to believe that their future feelings would be less intense than their present feelings. As in Experiment 1, age differences in affective forecasting were observed for gains, but not observed for loss outcomes.

It has been speculated that future anhedonia occurs because representations of future events evoke less intense affect than representations of present events. With increased age and experience, seniors may hold more accurate beliefs about the value of future rewards, as emotional knowledge becomes a more important input in decision making (Mather, 2006; Peters et al., 2000; Peters et al., 2007). Accumulated experiences with more affect-based feedback may be needed to reduce the tendency towards future anhedonia.

Notably, these findings offer an interesting extension of age differences in affective forecasting into the realm of temporal discounting research. Our results indicate that lifespan changes in affective forecasting may be linked to age differences in temporal discounting. We found that future anhedonia index mediated the effect of age on time preference. Youthful short-sightedness has been implicated as a cause of poor judgment in risky decision-making. Increased future anhedonia in younger adults may be related to their tendency to maximize immediate gains, and to overweight consequences in the present relative to those that they expect to occur later.

4. CONCLUSION

The literature on affective forecasting is broad and wide-ranging, but has largely neglected a thorough investigation of individual differences. There is abundant evidence that individuals make systematic errors when predicting future emotional states, which can lead to suboptimal decisions (Gilbert & Ebert, 2002; Kermer et al., 2006). There is not, however, a great deal of research specifically examining whether older adults share these deficits in properly predicting affective responses to decision outcomes. The present set of findings suggest that older adults may be better at predicting their responses to outcomes and that these predictions may accurately influence and guide their decision making processes. Results from Experiment 1 demonstrated that older adults display distinct patterns of gain-related affective reactions for both predicted affect, specifically in situations of heightened emotional arousal. Forecasting accuracy improved with age for gain outcomes in an affective version of a dynamic decision making task, but not in the deliberative version, such that older adults were less likely to make the typical errors of overestimating positive affect. Results from Experiment 2 revealed that age-related improvements in affective forecasting extend to long-term forecasts routed in temporal discounting behavior. Future anhedonia errors decreased with age, with seniors being less likely to mistakenly believe that they would experience less intense affect when a reward happened in the future than in the present. These results also provide support for the hypothesized influence of affective forecasting ability on time preference and greater patience in older adults.

Given age-related cognitive losses and declines in physical health, it is critical to investigate whether other forms of knowledge, such as affect, may help to compensate for and mitigate declines in decision-making. Taken together, our findings add to the literature on age-related differences in decision-making by suggesting that affective forecasting is a skill that does not decrease across the lifespan, and thus may tap cognitive and affective abilities that increase with the experience that comes with age. Despite a body of research that suggests that older adults are impaired on simple judgment tasks, results from the present experiments are consistent with literature demonstrating that emotion-related abilities, such as recognizing emotion states (Labouvie-Vief, DeVoe, & Bulka, 1989), emotion regulation (Carstensen, Fung, & Charles, 2003) and ignoring interpersonal stressors (Neupert, Almeida, & Charles, 2007) are relatively spared or even enhanced in advancing age. Our findings are also consistent with an emerging body of research which suggests that experience and accumulated knowledge may help compensate for declining cognitive function in decision-making among older adults (for a review on this literature, see Zaval, Weber, Li, & Johnson, forethcoming), and that emotional knowledge, in particular, may help to compensate for the declines in decision-making that come with advanced age.

Our research further highlights the importance of distinguishing between the deliberative and affective processes of decision behavior when studying age-related changes in decision-making skills. If affect is critical to everyday choice processes and if older adults are better at effectively forecasting affect, then they may make better choices in situations of heightened emotional arousal, despite analytic declines. Future research should not ignore the widespread evidence for age-related preservation and enhancement in social cognitive function, and should instead build upon previous research to focus efforts on discovering the practical implications of potential age differences. Additional work is therefore needed to examine whether superior affective forecasting abilities contribute to older adults' practical problem-solving skills or planning for the future. Such work could provide preliminary insight into understanding how older adults make long-term decisions regarding their emotional well-being (including financial or medical decisions), and how they might plan to optimize these decisions.

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Effects of Age on Affective Forecasting Ability

Supplementary Information

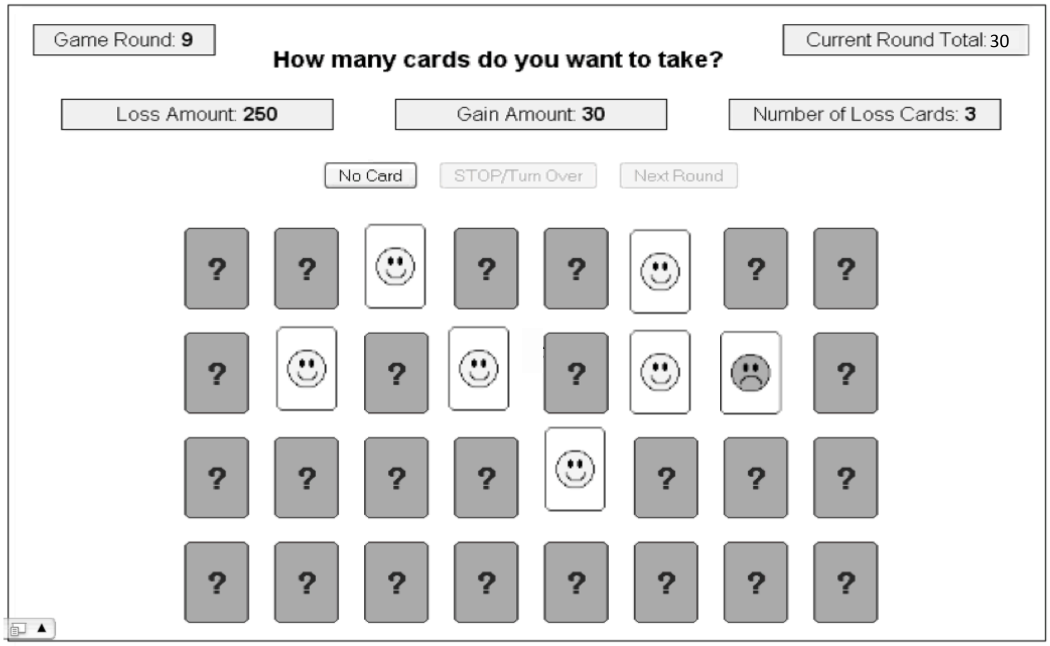
Supplementary Table 1. Demographic characteristics of the study samples as a whole and by age group.

Study 1 Variable	Total	Young	Old
N	156	81	75
Gender, % female	67.9	75.3	60
Age, *M* (*SD*)	47.2	22.5 (1.48)	67.6 (5.0)
Race/ethnicity %			
African American	7.1	8.6	5.3
Asian	13	23.5	1.3
White	79	64.2	92
Education	56.1	35.6	59.7
Income	46	38	60

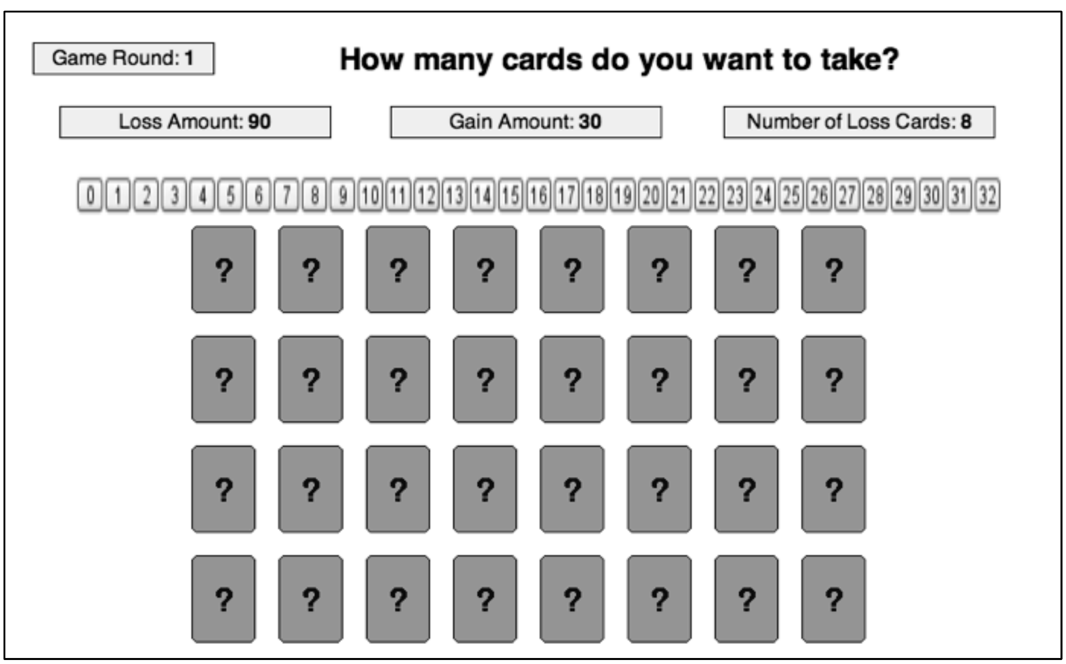
Study 2a Variable	Ages 18-30	Ages 30-45	Ages 45-60	Ages +60
N	146	181	151	141
Age, *M*	24.5	38.3	54.0	67.5
Gender, % female	68	50	70	56
Race/ethnicity % white	66	77	87	93
Income	45	75	65	55
Education	83	88	84	91
Study 2b				
N	96	147	121	114
Sex, % female	66	48	70	57
Age, *M*	24.3	38.55	53.9	67.9
Race/ethnicity % white	58	80	87	95
Income	35	75	65	55
Education	83	88	83	89

Due to some participants choosing not to answer, the race/ethnicity, political affiliation columns do not total to 100.
*Education = *some college or higher*; Income = *median in thousands*

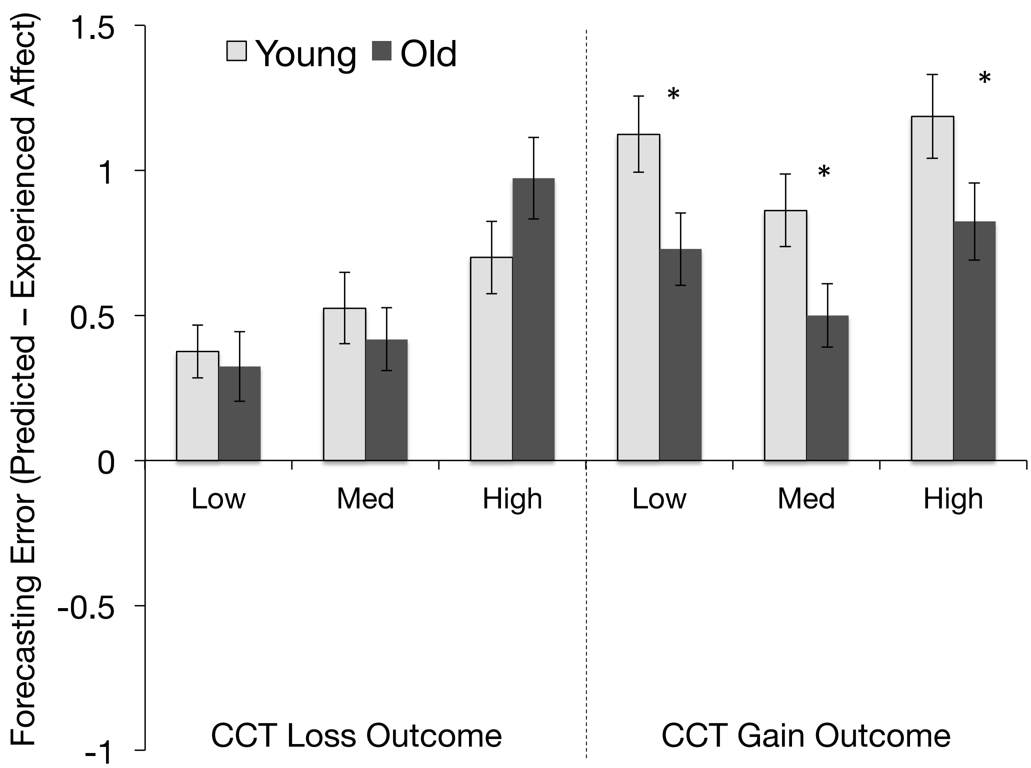
Supplementary Figure 1-A. Hot CCT card presentation screen.



Supplementary Figure 1-B. Cold CCT card presentation screen.



Supplementary Figure 2. Affective forecasting accuracy by age group for Hot CCT trials. Error bars denote ±1 *SEM*. * $p < .05$.



Supplementary Table 2. Linear regressions for *future anhedonia $100* in Study 2a. Note: Standardized regression coefficients in parentheses. Sample size is smaller for some regressions due to incomplete responses. * < .05, ** < .01, *** < .001.

Model	1	2	3
Age	-0.009***	-0.008***	-0.008***
	(-0.18)	(-0.15)	(-0.16)
Present bias (β)		-1.11***	-1.08***
		(-0.24)	(-0.23)
Education			0.004
			(0.009)
Income (thousands)			0.002*
			(0.10)
Male			0.145*
			(0.09)
Constant	0.762***	1.76***	1.56***
Observations	602	592	584
R^2	0.03	0.09	.10

Supplementary Methods

Study 1 Affective Forecasting Survey (Hot trials example)

The questions below ask you to imagine that you are playing the Columbia Card Task. Use the scales below to predict how *happy* you would feel in the following hypothetical cases. Please be as accurate and honest as you can be. For all of the questions below, specifically *imagine* that you are playing in a round where there are 8 loss cards, with gain cards worth +30 points, and loss cards worth -90 points.

1. How do you predict you would feel if the first or second card you turned over was a *loss card* and ended the game (score of -90 or -60)?
2. How do you predict you would you feel if the third or fourth card you turned over was a *loss card* and ended the game (score of -30 or 0)?
3. How do you predict you would feel if the fifth card or greater that you turned over was a *loss card* and ended the game (score of +30 or greater)?

Again imagine that you are playing the Columbia Card Task in a round with 8 loss cards, with gain cards worth +30 points and loss cards worth -90 points. Now imagine that you chose to end the round yourself, and never encountered a loss card.

1. How do you predict you would feel if you chose to end the round after selecting *one or two gain cards* (score of +30 or +60)?
2. How do you predict you would feel if you chose to end the round after selecting *three or four gain cards* (score of +90 or +120)?

3. How do you predict you would feel if you chose to end the round after selecting *five or more gain cards* (score of +150 or greater)?

Supplementary Text 2. Study 2b Question Text

1. Imagine that as a promotion today, Amazon ® gave you a boxset of DVDs of your favorite TV show, worth $100.00. Imagine yourself receiving the boxset today, and watching some of your favorite episodes. How happy would you feel if you were given this gift today?
2. Now imagine that Amazon ® is considering selling the DVD boxset at a discounted price instead. What is the maximum of dollars you would be willing to pay today to receive this gift today? (*Please enter an amount between 0 - 100*)
3. Now imagine that you were given the DVD boxset <u>three months from now</u>. How happy do you think you would be when you received the gift <u>at that time</u>?
4. Now imagine that, in three months, Amazon ® is considering selling the DVD boxset at a discounted price instead. <u>Three months from now</u>, what is the maximum amount of dollars you would be willing to pay for the boxset? (*Please enter an amount between 0 - 100*)

Study 2a and 2b Participants

Participants from Studies 2a and 2b were recruited from the Columbia University's Center for Decision Sciences' Virtual Lab Panel ($N = 469$) and from a private survey sampling company ($N = 150$). Participants completed four waves of a web-based survey consisting of cognitive, decision-making, and demographic measures. Participants were aged between 18 and 86 and were recruited in four age groups: *young* from ages 18 to 30 (*M* = 24.46, Median = 24, *SD* = 3.36), *middle-younger* from 31 to 45 (*M* = 38.32, Median = 38, *SD* = 4.47), *middle-older* from 46 to 60 (M = 54.01, Median = 55, *SD* = 3.88), and *old* from 61 to 86 (*M* = 67.47, Median = 67, *SD* = 4.91). All participants were U.S. residents and indicated English as their native language. Participants were emailed invitations to complete the Study 2a between January and April 2013. Study 2b participants completed the study in July 2013.

Table S1 shows demographic information by age group. Older participants were somewhat more educated than younger participants, with a higher percentage attaining post-graduate degrees (from old to young, 42.8% vs. 15.9% vs. 14% vs. 5.5.0%, $\chi^2(3)$ = 71.4, $p < .01$) and more years of education on average (from old to young, 15.8 vs. 14.5 vs. 15.1 vs. 14.6,, $F(1, 612) = 9.02$, $p < .01$). However, they had similar levels of household income (medians, Med_{old} = \$58.6K and Med_{young} = \$61.1K, $t = .58$, *ns*), somewhat higher than the U.S. median of $49,445 in 2010 (U.S. Census). Household income was positively correlated with years of education ($r = .12$, $p < .01$).