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Abstract

As anthropogenic influences on climate change become more readily apparent, the role of behavioral science in understanding barriers to sustainable actions cannot be overstated. Environmental psychologists have proposed that a major barrier to sustainability is the delayed, socially distant, and probabilistic effects of public policy efforts aimed at preserving Earth's resources. This proposal places sustainability squarely within the research topic of delay, social, and probability discounting – processes well known to behavioral scientists. To date, there has been surprisingly little behavioral research examining the role of discounting processes in environmental decision making. In the present study, we examined the degree to which simple hyperbolic models of discounting can describe college students' ratings of concern and their willingness to act in the face of an environmental disaster. Findings suggest that hyperbolic models of delay, social, and probability discounting adequately describe these self-report data. Interestingly, but sadly unsurprisingly, ratings of willingness to act were discounted more steeply than concern across delay, social, and probability discounting tasks. A greater understanding of the behavioral processes associated with sustainability can inform better public policy efforts and may bridge the gap between environmental psychology and behavior analysis.

Keywords: behavioral economics, delay discounting, environmental psychology, probability discounting, social discounting, sustainability

Do Actions Speak Louder Than Words?:

Delay, Social, and Probability Discounting of an Environmental Disaster

Earth's climate has seen a dramatic change in weather patterns and conditions. Global climate hazards such as Hurricanes Irene and Isaac, record amounts of precipitation (and lack thereof), and record temperatures have affected not only the United States, but also many other countries around the world (http://www.ncdc.noaa.gov/oa/reports/weather-events.html). Notably, climatologists have observed the most drastic increase in average global temperature within the past 100 years (Kaufman et al., 2009; Mann, 2012; Mann, Bradley, & Hughes, 1998). When graphed, this sharp uptick in temperature resembles the end of a hockey stick; thus, this trend in temperature change has been coined the "hockey stick" phenomenon.

The increase in average air and ocean temperature as well as the increased melting of the ice caps has led the United Nations Intergovernmental Panel on Climate Change (IPCC) to conclude that global warming is an indisputable reality (Pachauri & Reisinger, 2007). Of special emphasis is that, "Global atmospheric conditions of CO_2, CH_4, and N_2O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years" (Pachauri & Reisinger, 2007, p. 37). As more evidence is collected from the examination of ice cores and other atmospheric dating means, it appears increasingly likely that anthropogenic activity is linked to global climate change (Rosenzweig et al., 2008). Such data underscore the importance of studying psychological factors that contribute to environmentally destructive behavior (Thompson, 2010).

There are a number of psychological components that may contribute to and sustain environmental inaction (Gifford, 2011). Of relevance to behavioral psychology are uncertainty and judgmental discounting factors. In fact, the report by the American Psychological

Association Task Force on the Interface Between Psychology and Climate Change (available at http://www.apa.org/science/about/publications/climate-change.aspx) emphasizes that humans are "discounting the future and the remote," a phenomenon behavioral scientists have examined extensively. The phenomenon of discounting refers to the tendency of individuals to devalue outcomes based on contextual factors such as (a) the time until the outcome's occurrence, (b) the likelihood of its occurrence, and (c) who the outcome affects (see Madden & Bickel, 2010; McKerchar & Renda, 2012). For example, humans often opt for a smaller, immediate reward at the expense of receiving a larger, delayed reward. In other words, commodities available now are often valued more highly than commodities available in the future; the subjective value of the larger outcomes is thereby discounted as a function of its delay. Rewards and other outcomes are differentially valued depending on the likelihood of their occurrence (Estle, Green, Myerson, & Holt, 2007; Green & Myerson, 2004). For example, desirable commodities that have a high likelihood of receipt are valued higher (i.e., discounted less) than commodities that have a low likelihood of receipt; therefore the subjective value of these outcomes is discounted as a function of the likelihood of occurring. Discounting is also observed when outcomes affect individuals other than the self (Jones & Rachlin, 2006; Rachlin & Jones, 2008). Outcomes that affect individuals who are closer to one socially (e.g., a relative, best friend) are valued higher than outcomes that affect individuals who are considered more distant socially (e.g., an acquaintance). Outcomes, then, are also discounted as a function of social distance. Given the robust discounting literature in behavioral economics (stemming from the field of behavior analysis), it is surprising that empirical studies on the discounting of environmental outcomes are relatively rare.

Other fields of study, such as environmental economics and environmental psychology, have proposed and examined models of environmentally destructive decision making in discounting contexts. For example, in a study by Gifford and colleagues (2009), participants answered questions from the Environmental Futures Scale, which was developed to measure spatial and temporal environmental perceptions. Using Likert scales, participants rated aspects of the environment as they are now and how they think those aspects would change 25 years in the future on the local, national, and global levels. They found significant levels of pessimism on all three levels 25 years in the future. Unfortunately, their methods did not allow the authors to determine at what point in the future participants would report significant levels of pessimism. In other words, would individuals begin to report pessimistic attitudes at 1 year, 10 years, or would individuals only report such attitudes at 25 years in the future? Examining such attitudes with more durations of time would be important in determining how sensitive individuals are to changes in the environment at differing delays.

Hardisty and Weber (2009) used a procedure that approximated a discounting framework by asking their participants to make hypothetical choices between a smaller immediate outcome and a larger outcome delayed by either 1 or 10 years. These hypothetical questions were related to different domains such as monetary gains/losses, air quality gains/losses, mass transit gains, and garbage pile-ups (considered an environmental loss). Across a series of studies, they found participants' mean discount rates were significantly higher for all gains scenarios as compared to the loss scenarios. In addition, the researchers found discounting rates to be higher for monetary and air quality gains than for losses. Unfortunately, Hardisty and Weber employed a much more restricted number of delays than what is typically assessed in behavioral studies of delay discounting. This limitation prohibits the study of discount rates associated with delays between

1 year and 10 years. Moreover, it would be difficult to predict to what degree individuals would discount the scenarios above at relatively immediate delays or those delayed longer than 10 years. Finally, the use of only two delays makes it difficult to identify whether a particular theoretical model characterizes the discounting function

Finally, Hendrickx and Nicolaij (2004) asked participants to use a 5-point scale to rate the seriousness of risk involved in four hypothetical vignettes. The scenarios in the vignettes included two environmental risks (soil and water pollution), one financial risk (unexpected house repair costs), and one health risk (a medical disease). The independent variable consisted of three delays: 1 month, 2 years, and 25 years. The participants reported relatively high ratings of perceived seriousness at each of the three delays, but interestingly, such ratings did not decrease in the expected fashion with longer delays; that is, although high ratings of seriousness of risk were observed at all three delays, the ratings did not differ across the three delays. Further, while Hendrickx and Nicolaij assessed reports of seriousness across a wider range of delays than Hardisty and Weber (2009), they did not address the ability of a theoretical discounting model to describe their data.

Although the aforementioned studies suggest that individuals tend to discount aspects of delayed environmental outcomes, limitations in methodology and data analysis make it difficult to quantify the degree to which such outcomes are devalued across numerous delays or the degree to which they can be described by prominent discounting models. Given the relatively sparse use of behavioral economic paradigms in the reviewed literature, a synthesis of economic and environmental psychology may benefit from a behavioral economic approach to understanding the discounting of environmental concerns. Although there are a number of contemporary discounting models, Mazur’s (1987) hyperbolic discounting equation is perhaps the most prominent in the behavioral literature (Koffernus, Jarmolowicz, Mueller, & Bickel, 2013; Madden & Bickel, 2010). It is conceptually systematic, as it describes the discounting of humans and nonhumans alike. Furthermore, Mazur's hyperbola not only adequately describes the devaluation of delayed and probabilistic outcomes, it also describes the devaluation of outcomes as a function of the social distance of the recipient (i.e., social discounting).

The purpose of the present studies was to evaluate judgments of concern and time devoted towards solving an environmental outcome that differed in (a) the delay until the event, (b) whom the event affected (measured in social distance from the individual , and (c) the likelihood of the event occurring. We applied a behavioral economic framework to evaluate individuals' rates of discounting of an environmentally related issue (i.e., discounting an environmental loss). Further, we analyzed discounting data using Mazur's (1987) hyperbolic discounting equation.

Methods

Participants and Setting

One hundred and sixty three undergraduates (ages ranged from 18.5 to 26.3 years, *M* = 20.8, *SD* = 1.3) enrolled in an introductory psychology course and 143 undergraduates (ages ranged from 18.0 to 53.8 years, *M* = 20.6, *SD* = 3.3) enrolled in an introductory child development course were recruited and received extra credit for participation. Consenting participants completed questionnaires at individual desks during the first 15 min of a class period. Participants in the introductory psychology course completed both the delay-discounting and social-discounting tasks; participants in the introductory child development course completed the probability-discounting task.

Procedures

At the beginning of the questionnaire, participants were told the vignettes that followed were hypothetical scenarios and that they would answer questions associated with each vignette in the form of a visual analogue scale. The visual analogue scale (VAS) is frequently used in research and clinical settings to measure subjective phenomena (Wewers & Lowe, 1990). Recent behavioral research has begun to incorporate the use of VASs in studies of discounting (e.g., Johnson & Bruner, 2012) and has indicated that this form of assessment has adequate test-retest reliability (Johnson & Bruner, 2013). In its most common form, a VAS is a 100 millimeter (mm) horizontal line with descriptive anchors at each end. Ratings on a standard VAS are most typically measured in distance by measuring from one end of the VAS to the participant's mark on the line. Scores are quantified such that every millimeter serves as one "unit." Thus, on a 100 mm VAS, scores can range from 0 to 100.

At the top of each page of the questionnaire was a vignette that differed slightly depending on the specific task (i.e., delay, social, or probability tasks). Below each vignette was a series of statements and questions. Additionally, below each statement and question was a VAS in which participants rated their answer. Two questions were associated with each statement and each was displayed on one page within each condition (see Appendix for examples). In other words, one page constituted the "concern" question and one page constituted the "time allocation" question. The first question asked participants, "How concerned are you about the effects of the pollution on your farm? Draw an X on the line below to indicate how concerned you are." Anchors on the left and right sides of the VAS for this question read, "Not concerned at all" and "Extremely concerned," respectively. The second question asked participants, "What percentage of your time will you spend to fix the problem? Draw an X on the line below to indicate what percentage of time you will spend to fix the problem." Anchors on the left and right sides of the VAS for this question read, "0%" and "100%," respectively.

Ratings on the VAS were quantified and measured using a micrometer that calculated distance to one-hundredth of a mm, although ratings were only scored and recorded to the tenth of a mm. For each value of delay and social distance, an agreement was scored if a measure by two independent observers were within ±2 mm. Interobserver agreement (IOA) was determined for 33% of the participants, and was calculated by dividing the number of agreements by the total number of agreements plus disagreements and multiplying by 100. IOA was 98.3%. Disagreements were primarily due to the ratings being 1-2 mm outside the range of acceptability.

Delay Discounting Task. For the delay discounting condition, participants were presented with the following vignette (adapted from Hendrickx & Nicolaij, 2004) at the top of the page:

> Imagine you own and operate a farm[1] on the outskirts of town where you grow and sell vegetables. One day disaster strikes! A strike of lightning causes a large wildfire near your farm. Uncontrolled fires produce a lot of air pollution. After a while, this pollution will settle down and also pollute the soil and groundwater. Your farm is also at risk.

Below the vignette were statements that read:

> Within **X Delay**, polluted groundwater will reach the farm. When that happens, no one will be able to buy or eat vegetables from your farm for a long time.

Associated with each statement were a question and VAS. As described earlier, the questions asked how concerned the participant was about the effects of the pollution, as well as what

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[1] Given the study was conducted at a large Midwestern university located in a town surrounded by rural land, and thus farms, we replaced Hendrickx & Nicolaij's (2004) original wording of "garden" with "farm."

percentage of their time they would devote to solving the issue. Specifically, on one page under each statement was a question regarding how concerned the participant was and on another page under each statement was a question regarding how much time they would allocate to fixing the issue. Delay values were presented in progression starting at 1 month and increasing to 6 months, 1 year, 3 years, 5 years, and 10 years.

Social Discounting Task. The social discounting task was similar to the delay-discounting task. However, before the vignette and at the top of the first page, participants were presented with the following instructions (adopted from Jones & Rachlin, 2006):

> The following questions ask you to imagine that you have made a list of the 100 people closest to you in the world ranging from your dearest friend or relative at position #1 to a mere acquaintance at #100. The person at number one would be someone you know well and is your closest friend or relative. The person at #100 might be someone you recognize and encounter but perhaps you may not even know their name. You do not have to physically create the list -- just imagine that you have done so.

Below the instructions, participants were presented with the following vignette:

> Imagine the #____ person on your list owns and operates a farm on the outskirts of town where he/she grows and sells vegetables. One day disaster strikes! A strike of lightning causes a large wildfire near his/her farm. Uncontrolled fires produce a lot of air pollution. This pollution has settled down and has polluted the soil and groundwater. His/her farm is also at risk as polluted groundwater has reached his/her farm. No one will be able to buy or eat vegetables from his/her farm for a long time.

Below the vignettes were statements that read:

> Imagine the **# [Social Value]** person on your list owns and operates this farm.

Associated with each statement were a question and VAS. Similar to the delay discounting portion, the questions asked how concerned the participant was about the effects of the pollution as well as what percentage of their time they would devote to solving the issue. However, in this scenario we varied the social distance of the farm owner and operator to the participant. Values of social distance were presented in progression starting at #1 and increasing to #5, #10, #20, #50, and #100.

Probability Discounting Task. Similar to the previous two tasks, participants were presented with the following vignette at the top of the page:

> Imagine you own and operate a farm on the outskirts of town where you grow and sell vegetables. One day disaster strikes! A strike of lightning causes a large wildfire near your farm. Uncontrolled fires produce a lot of air pollution. After a while, this pollution will settle down and also pollute the soil and groundwater. Your farm is also at risk.

Below the vignettes were statements that read:

> There is a **X%** chance that polluted groundwater will reach the farm. If that happens, no one will be able to buy or eat vegetables from your farm for a long time.

Associated with each statement were a question and VAS asking participants to rate how concerned they were about the effects and what percentage of time they would spend to fix the problem. Probability (i.e., likelihood) values began with 95% and progressively decreased to 90%, 50%, 30%, 10%, and 5% across consecutive questions.

Results

Mazur's (1987) hyperbolic discounting equation (Equation 1) was fit to all individuals' subjective ratings of concern and time allocation (action).

$$V = 100 / (1 + kX) \qquad \text{Equation (1)}$$

In this equation, V represents the participant's rating, or the discounted subjective valuation of concern or percent time to help, *100* represents the undiscounted maximum value of concern or percent time to help, and X represents the independent variable, in this case either delay, social distance, or odds against (discussed below) values. Finally, k is the derived parameter describing the discount rate. Because k describes the rate at which the subjective value of an outcome decreases as a function of the independent variable, k was the dependent measure of interest in the current study.

For probability discounting data, we converted the percent chance of the outcome's occurrence to the odds against its occurrence, and used this as X in Equation 1:

$$\Theta = (1 - p) / p \qquad \text{Equation (2)}$$

where Θ is the odds against and p is the percent chance. Expressed in this way, as the odds against receiving an outcome increases, we expect the subjective value of that outcome to decrease (Rachlin, Raineri, & Cross, 1991). Specific values of odds against the outcome's occurrence (i.e., X values) were: .053, .111, 1, 2.33, 9, and 19.

All 163 participants' data were retained for the delay and social discounting analyses. However, of the 143 participants who completed the probability discounting task, two were excluded from the analysis due to missing data sets. We plotted the median subjective ratings of concern and action in the delay, social, and probability discounting tasks (Figure 1). In the delay task, median k values (and R^2 and *RMSE* values) for the aggregated (i.e., group) data for social concern and action were .019 (R^2= .87; *RMSE* = 7.28) and .032 (R^2= .81; *RMSE* = 9.42), respectively. In the social task, median *k* values for the aggregated data for social concern and action were .026 (R^2= .87; *RMSE* = 7.9) and .066 (R^2 = .87; *RMSE* = 9.25), respectively. Finally, median *k* values for the aggregated data for the probability task were .431 (R^2 = .97; *RMSE* = 4.84) and .515 (R^2 = .93; *RMSE* = 7.80) for concern and action, respectively. As indicated in Figure 1, ratings of concern and action were negatively decelerated as the delay, social distance, and odds against values increased.

Analyses were conducted at the individual level as well by fitting Equation 1 to each participant's data. Then we identified the median *k* value from all of the individual participants in all three tasks.. For the delay task, the median *k* values were .019 (*M* = .082; *R* = 4.1×10^{-19} to 4.26; *SD* = .359) and .033 (*M* = .196; *R* = 3.68×10^{-4} to 9.39; *SD* = .86) for ratings of concern and action, respectively. For the social task, the median *k* values were .027 (*M* = .084; *R* = 4.9×10^{-4} to 1.94; *SD* = .222) and .069 (*M* = .439; *R* = 1.81×10^{-4} to 21.89; *SD* = 1.9) for ratings of concern and action, respectively. Finally, for the probability task the median *k* values were .41 (*M* = 1.25; *R* = -6.6×10^{-18} to 42.69; *SD* = 4.66) and .49 (*M* = 4.45; *R* = 3.01×10^{-3} to 177.9; *SD* = 20.03) for ratings of concern and action, respectively.

Interestingly, across all three discounting tasks, ratings for concern were reliably higher than for ratings of action. That is, at every delay, social distance, and odds against value, participants reported a higher rating of concern compared to ratings of action. A Wilcoxon signed-rank test revealed significant differences between concern and action for delay (W = 6904, $p < .0001$), social distance (W = 11776, $p < .0001$), and probability (W = 3836, $p < .0001$) conditions. Figure 2 depicts box and whisker plots (5-95th percentile) of individuals' discounting rate (*k*).

To further illustrate the difference between ratings of concern and action, we converted the aggregate *k* values into *ED50* values by taking the inverse of *k* (Yoon & Higgins, 2008). This value describes the point at which the discounted value is equal to 50% of the original value (100% for ratings of both concern and action). For the delay condition, ratings of concern and action decreased by 50% by 4.4 years (53.3 months) and 2.6 years (31.1 months), respectively. For the social condition, ratings of concern and action decreased by 50% by the 38^{th} person and 15^{th} person, respectively. Finally, for the probabilistic condition, ratings of concern and action decreased by 50% when the likelihood of the disaster was ≈30% (odds against: 2.32) and ≈34% (odds against: 1.94), respectively. At the aggregate level, participants' ratings of concern decreased by 50% at a later delay, at a higher social value (i.e., further in social distance), and at a lower likelihood of the event happening as compared to their reports of action demonstrating the more rapid discounting of action than of concern.

Discussion

Two major sets of findings emerged from the present study. First, both the concern for an environmental disaster and the amount of time participants were willing to spend towards fixing it was a hyperbolic function of (a) the delay until its occurrence, (b) the social distance of the person affected by the disaster, and (c) its likelihood of occurrence. Second, the discounting of one's concern for an environmental disaster was reliably less than their discounting of the amount of time they were willing to allocate toward fixing the problem. This was the case across the contextual factors of delayed, socially distant, and probabilistic environmental outcomes.

Although a few studies have assessed the discounting of environmental outcomes as a function of delay (Hardisty & Weber, 2009; Hendrickx & Nicolaij, 2004), to our knowledge, the present study is the first to assess the ability of a quantitative and theoretical model to describe the discounting of such outcomes within a behavioral economic framework. Mazur (1987) originally found that Equation 1 provided an excellent description of pigeons' discounting of delayed food reinforcers. Rachlin et al. (1991) found that Equation 1 also described humans' discounting of delayed and probabilistic monetary rewards. Since then, hundreds of studies have demonstrated the ability of Equation 1 to describe the discounting of various rewarding and aversive outcomes, including drug, health, and sexual outcomes (see Madden & Bickel, 2010). Furthermore, a number of studies have shown that a hyperbola also provides a very good description of the relation between the amount of money one is willing to forgo and the social distance of the recipient (i.e., social discounting, see Locey, Jones, & Rachlin, 2013). We extend this literature to the previously unexamined area of environmental discounting. Delay, social, and probability discounting functions were well described by the same simple hyperbola in the present study. This is important because a hyperbolic discounting model specifies that the rate at which the subjective value of an outcome declines is not constant—instead subjective value declines more rapidly across smaller values of the independent variable than across larger values. As applied to the present study, the decline in the subjective concern for an environmental disaster and one's willingness to act in the face of one was greater across smaller values than across the larger values of delay, social distance, and odds against the outcome. While 10 years was the longest delay assessed in the current study—also the longest delay assessed by Hardisty and Weber (2009)—we assessed discounting at numerous values of the independent variables, which allowed us to assess the ability of Equation 1 to describe environmental decision making. Such findings may be of importance to environmental interventionists and public policy officials so that they may optimize the effectiveness of their efforts.

Our finding that the temporal, social, and probability discounting of one's concern for an environmental disaster was significantly less than one's discounting of the amount of time they were willing to spend towards fixing the problem provides empirical support for Gifford's (2011) recent contention. The current study examined several of the barriers Gifford stipulates are hindering individuals' actions towards environmentally sustainable behavior change. Although the underlying mechanisms contributing to the disparity between reports of concern and action in the current study are unknown, future researchers may attempt to investigate these factors by integrating aspects of environmental psychology and behavioral economics. Such an approach may be fruitful in uncovering factors related to the observed differences and help inform possible interventions targeting environmental behavior change.

The present study and findings should be viewed as an early attempt to integrate environmental psychology and behavioral economics. As such, there are a number of dimensions on which the present study can be improved and extended upon. Following the lead of Hendrickx & Nicolaij (2004), our outcome was limited to an environmental "catastrophe" that produced pollution of the air, soil, and groundwater. For our participants (i.e., college students), this outcome may not mimic a scenario they will ever encounter. Future investigators could present other perhaps more relevant, less catastrophic outcomes or outcomes they will likely experience in their lifetime (e.g., high levels of CO_2 emissions, increase in global temperature).

Although we used a VAS to examine changes in concern for and willingness to act on environmental outcomes within a discounting framework, there are other possibilities for assessing the discounting of environmental outcomes. Hardisty and Weber (2009) had participants make repeated choices between smaller-sooner and larger-later improvements (gain) and decrements (loss) in air quality and other environmental outcomes (e.g., garbage pile-ups).

Unlike the VAS used in the present study, Hardisty and Weber used a titration procedure to identify the point at which participants were indifferent between two environmental outcomes. However, in their series of three studies they obtained indifference points at only two delays (i.e., 1 year and 10 years). An obvious extension of their work would be to assess the discounting of environmental outcomes with a titration procedure, but to do so at more than two delays. Having numerous delays would allow one to more confidently assess the shape of the environmental delay-discounting function. Furthermore, the extent to which the functions obtained using a VAS correspond to functions obtained using titration (psychophysical-like) procedures is unknown.

A number of empirical regularities have emerged from the human discounting literature, such as the sign effect and the magnitude effect (Madden & Bickel, 2010). The vast majority of these findings, however, have been demonstrated with monetary outcomes (Shead & Hodgins, 2009; Ohmura, Takahashi, & Kitamura, 2005). The extent to which the empirical regularities obtained with monetary outcomes extend to non-monetary outcomes (Odum, Madden, & Bickel, 2002)—and environmental outcomes in particular—has received much less attention. Using the current VAS paradigm, it is unknown to what extent discounting rates would differ in the context of a relatively large or small environmental loss or environmental gain.

Prior research has also shown that some subject characteristics are significant predictors of the rate of discounting particular outcomes. For example, Green, Fry, and Myerson (1994) as well as others (e.g., Olson, Hooper, Collins, St. Luciana, 2007; Scheres et al., 2006; Whelan & McHugh, 2010) have found an inverse relation between age and the rate of delay-discounting monetary rewards. The results of a recent meta-analysis indicated steep rates of delay discounting among those displaying addictive behavior and substance-abuse disorders when compared with matched controls (MacKillop, Amlung, Few, Ray, Sweet, & Munafò, 2011).

Other research has shown that the degree of delay discounting is also correlated with willingness to contribute in a public goods game (Jones & Rachlin, 2009) and demographic characteristics, such as education level, annual income, and cultural background (de Wit et al., 2007; Du, Green, & Myerson, 2002; Green, Myerson, Lichtman, Rosen, & Fry, 1996; for a review, see Odum & Baumann, 2010). As climate change is frequently described as a "tragedy of the commons" (Hardin, 1968) and thus can be conceptualized as a public goods game, the extent to which individuals' discount rates correlate with contributions in such games, as well as other certain subject variables, may represent an important area of research in the future. Such findings could contribute to targeted, and thus more effective, intervention and public policy strategies (for other examples of discounting related to social policy issues, see Weatherly, Plumm, & Derenne, 2011).

Although we evaluated the effects of delay, social distance, and outcome likelihood on environmental discounting each in isolation, a more face-valid task of environmental discounting would likely involve combining two or more of these (or other) factors. For example, future researchers might consider how concurrent changes in time and likelihood together affect environmental discounting. This seems particularly important because climate scientists frequently communicate to the public that although the worst of the anthropogenic impact on the environment will happen in the future, they also seem to acknowledge that the likelihood of the various outcomes is less than certain. Thus, an environmental discounting procedure that incorporates both delay and probability may go a long way toward increasing our understanding of environmental decision-making as it may more appropriately model real world scenarios.

We believe the current study and our recommendations for additional research lay the foundation needed for the future study of environmental discounting, choice, and decision making. The findings from such work may help bridge the gap between environmental psychology and behavioral economics, and more importantly, provide the information needed for public policy efforts aimed at addressing the issue of climate change and sustainability.

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Appendix

Example Environmental Discounting VAS Question

Imagine you own and operate a farm on the outskirts of town where you grow and sell vegetables. One day disaster strikes! A strike of lightning causes a large wildfire near your farm. Uncontrolled fires produce a lot of air pollution. After a while, this pollution will settle down and also pollute the soil and groundwater. Your farm is also at risk.

1. Within **1 month**, polluted groundwater will reach the farm. When that happens, no one will be able to buy or eat vegetables from your farm for a long time.

How concerned are you about the effects of the pollution on your farm? Draw an X on the line below to indicate how concerned you are.

Not concerned at all ——— *Extremely concerned*

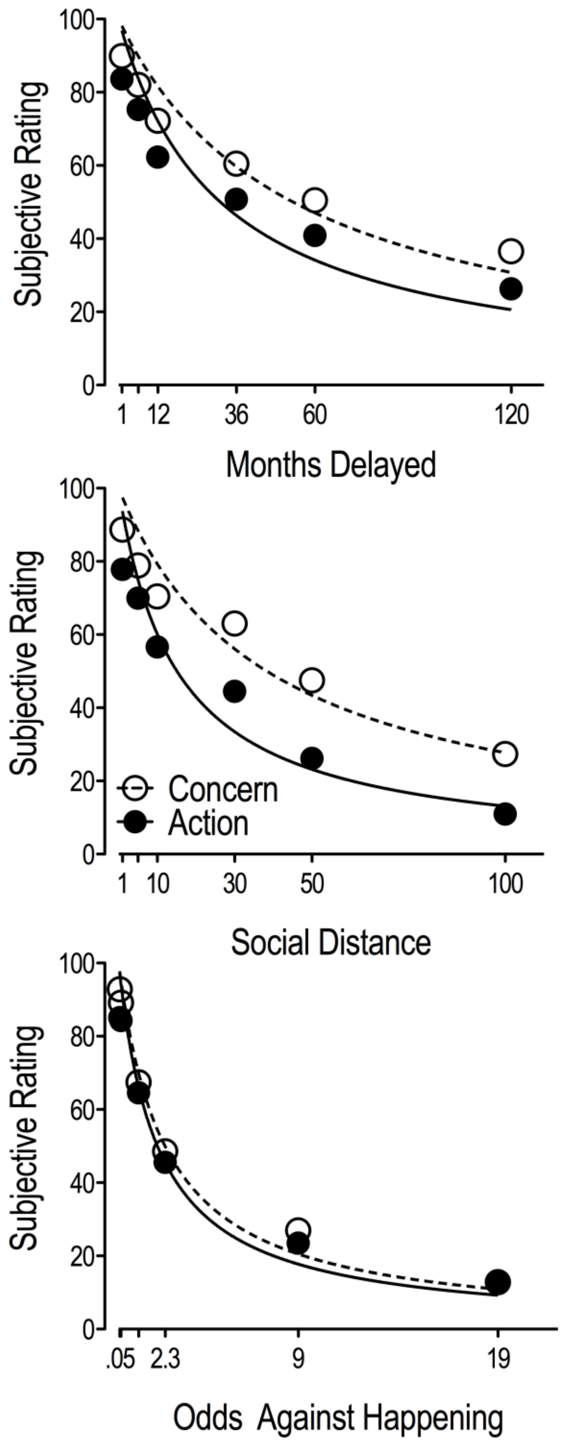

Figure 1. Discounting of an environmental disaster as a function of delay (top panel), social distance (middle panel), and probability (bottom panel). Open circles depict subjective ratings of concern while closed circle depict subjective willingness to act. Curves represent hyperbolic discounting fits according to Equation 1 using median VAS ratings.

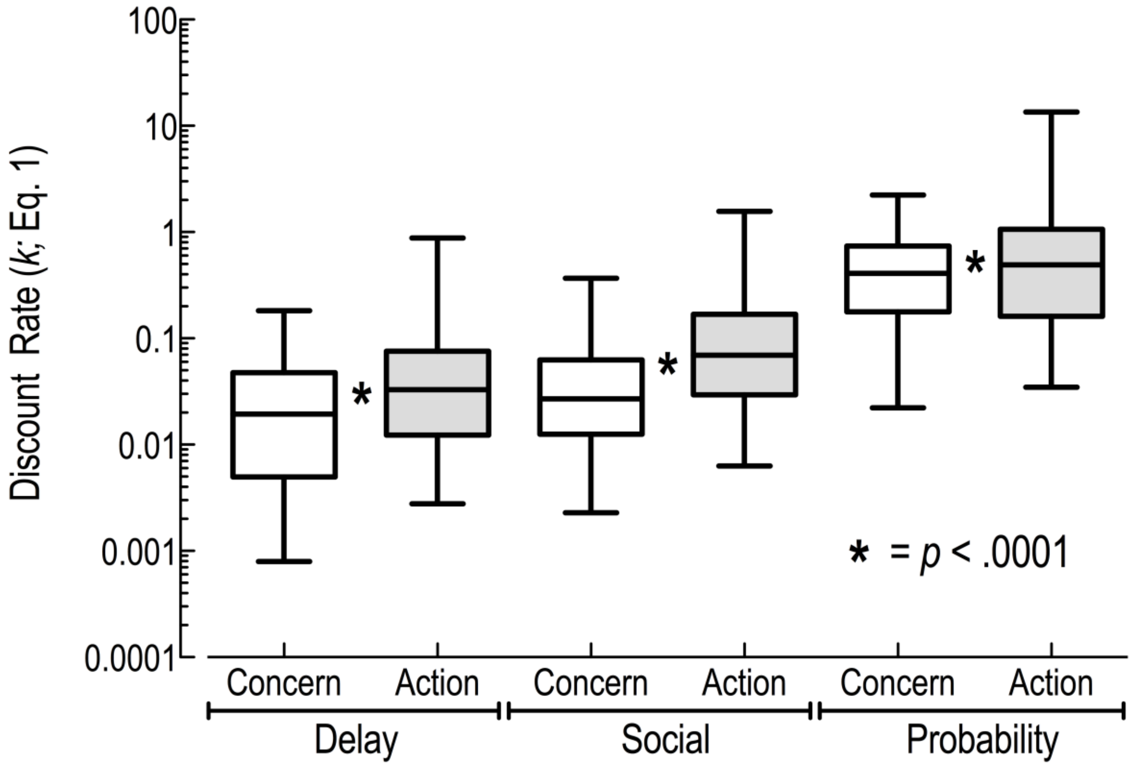

Figure 2. Box and whisker plots of individual discounting rates derived for both Concern and Action for delay, social, and probability discounting tasks (error bars represent 5-95th percentile). Note the log y-scale. Asterisks depict significant differences between discounting rates using Wilcoxon signed-rank test (alpha = .05; all p values < .0001).