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Neural valuation of environmental resources

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ABSTRACT

How do people value environmental resources? To estimate public valuation of natural resources, researchers often conduct surveys that ask people how much they would be willing to pay to preserve or restore threatened natural resources. However, these survey responses often elicit complex affective responses, including negative reactions toward proposed destructive land uses of those resources. To better characterize processes that underlie the valuation of environmental resources, we conducted behavioral and neuroimaging experiments in which subjects chose whether or not to donate money to protect natural park lands (iconic versus non-iconic) from proposed land uses (destructive versus non-destructive). In both studies, land use destructiveness motivated subjects' donations more powerfully than did the iconic qualities of the parks themselves. Consistent with an anticipatory affect account, nucleus accumbens (NAcc) activity increased in response to more iconic parks, while anterior insula activity increased in response to more destructive uses, and the interaction of these considerations altered activity in the medial prefrontal cortex (MPFC). Further, anterior insula activity predicted increased donations to preserve parks threatened by destructive uses, but MPFC activity predicted reduced donations. Finally, individuals with stronger pro-environmental attitudes showed greater anterior insula activity in response to proposed destructive uses. These results imply that negative responses to destructive land uses may play a prominent role in environmental valuation, potentially overshadowing positive responses to the environmental resources themselves. The findings also suggest that neuroimaging methods might eventually complement traditional survey methods by allowing researchers to disentangle distinct affective responses that influence environmental valuation.

Introduction

How do people value environmental resources? Policymakers and researchers have long debated how to best assess the value of environmental goods (Carson et al., 2001; Diamond and Hausman, 1994; Portney, 1994; Sen, 1995). Much of the value that individuals derive from natural resources may lie outside the traditional bounds of the economic market. For instance, people often assign "existence value" to the preservation of a rare species or distant national park, even when they may never directly encounter that animal or place (Carson et al., 2003). Though assessing these nonmarket values can prove challenging, these additional considerations can significantly influence policy and legal decisions, such as compensation for environmental damages.

Since most individuals do not personally purchase or manage environmental resources, researchers have traditionally used surveys to estimate the value that the public places on those resources (Diamond and Hausman, 1994). For instance, widely used contingent valuation surveys (such as those conducted in response to the *Exxon Valdez* oil spill) ask people how much they would be willing to pay to prevent the loss of environmental resources or to repair existing damages (Sen, 1995). Responses to these contingent valuation surveys, however, may reflect affective reactions to specific situational details (Kahneman et al., 1999), overshadowing valuation of the resources themselves (Diamond and Hausman, 1994).

Extensive research has demonstrated specific and seemingly irrational biases that can occur during contingent valuation, including "protest zeroes" in which respondents refuse to put any price on a threatened resource (Mitchell and Carson, 1989), and "scope insensitivity" in which scaling the quantity of the resource has no impact on its valuation (Hausman, 2012). Environmental economists have noted that individuals often seem to base their willingness to pay for a natural resource on the severity of threats to the resource (such as an oil spill), rather than the value of the resource itself (such as the threatened coastline) (Diamond and Hausman, 1994). Thus, negative reactions associated with a desire to punish offenders who have damaged a resource may increase willingness to pay in contingent valuation surveys, while potentially obscuring positive responses to the natural resource itself. A better

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understanding of these responses might eventually improve assessments of environmental value.

Recent advances in neuroeconomics provide new options for measuring both the process and outcomes of valuation. Neuroimaging methods can confer advantages over more traditional measures of choice by allowing investigators to visualize the dynamic contributions of multiple decision components prior to choice, and also to verify whether those components then influence choice (even on a trial-to-trial basis). Mounting neuroimaging evidence suggests that affect (or emotional processes involving arousal and valence) contributes to valuation to a greater extent than previously suspected — not just with respect to concrete outcomes (e.g., eating, drinking), but also abstract outcomes (e.g., shopping and investing (Knutson and Greer, 2008; Loewenstein et al., 2008)). While excessive affect can suboptimally bias choice, some affect is required to inform even optimal choices (Bechara et al., 1997; Kuhnen and Knutson, 2005). Moreover, rather than acting through a single channel, multiple affective mechanisms (e.g., positive versus negative) may influence valuation (Knutson et al., 2014). Thus, neuroeconomic theories and techniques might allow researchers to deconstruct the different affective components that promote valuation of environmental resources, as well as to assess their relative impacts.

Accordingly, this research aimed to use behavioral and neuroimaging techniques to identify and distinguish different affective processes that influence environmental valuation. In behavioral and neuroimaging experiments, we specifically sought to test not only whether positive affective responses to natural resources would influence willingness to pay to protect those resources, but also whether negative affective responses toward proposed destructive land uses would increase willingness to pay. Further, we sought to explore whether value integration responses would reflect tradeoffs between positive responses to iconic natural resources and negative responses to destructive uses. To test these predictions in a behavioral experiment, we independently manipulated the perceived iconicness of state and national parks (environmental public goods) and the destructiveness of proposed uses of those sites and examined the impact of these variables on affect and willingness to donate to preserve parks from proposed uses.

In a subsequent neuroimaging experiment, based on an anticipatory affect model (Knutson and Greer, 2008), we predicted that the iconicness of the parks would increase self-reported positive arousal and associated nucleus accumbens (NAcc) activity and increase donations, while the destructiveness of proposed land uses would instead increase self-reported negative arousal and associated anterior insula activity – but would also increase donations. We further predicted that subjects might integrate these affective responses, weighing them against the personal "cost" of donating, as reflected by medial prefrontal cortex (MPFC) activity (Bartra et al., 2013; Clithero and Rangel, 2014; Knutson and Greer, 2008). We also sought to determine which of these responses would most powerfully influence willingness to donate. Finally, we examined whether individuals with stronger pro-environmental attitudes (assessed with the revised New Ecological Paradigm (NEP) scale (Dunlap et al., 2000)) would donate more – either due to increased positive affective responses toward iconic natural resources or increased negative affective responses toward destructive proposed land uses.

Materials and methods

Stimulus selection

To preselect affectively compelling stimuli for the donation task, we conducted two pilot surveys of park lands ($n = 36$) and land uses ($n = 29$). In the first survey, subjects rated photographs of national and state parks' elicited affect (valence and arousal) and perceived iconicness using seven-point (Likert) scales (Knutson et al., 2005). In a second survey, subjects similarly rated proposed uses' elicited affect (valence and arousal) and perceived destructiveness. Based on these ratings, and with the goal of selecting iconic parks that elicited positive arousal and destructive uses that elicited negative arousal, we selected 24 places (i.e., the 12 most iconic and the 12 least iconic) and 24 uses (i.e., the 12 most destructive and the 12 least destructive) to use as stimuli in the donation tasks.

Behavioral study

Subjects

Thirty-four healthy English-speaking adults who were United States residents participated in the behavioral study. Subjects had no history of neurological or psychiatric disorders and gave informed consent for a protocol approved by the Institutional Review Board of the Stanford University School of Medicine. Two subjects were excluded for not completing all trials and ratings, leaving a total of 32 subjects for analysis (21 females, mean age 22 ± 6 years). Subjects received an initial endowment of $24.00 minus their donation to state or national parks (see below) as well as $20.00 per hour for their time. The study was approved by the Institutional Review Board of the Stanford University School of Medicine.

Donation task

Subjects were first briefed on examples of current land use concerns in state and national park lands (e.g., mining pressures around Yosemite and the Grand Canyon, threatened closure of over a quarter of California's state parks due to budget crises in 2012). They were informed that while many of the scenarios they would see were constructed, they were representative of real concerns, and their donations would actually aid state or national park lands (see below). Subjects were asked to assume that the parks they saw were potentially under threat of closure, but that closure could be averted either by: 1) sufficient donations or 2) selling 25% of the park to a third-party buyer who would put the land toward a new use. They were also asked to assume that the requested donation amount, in concert with expected similar donations of others, should be sufficient to avert the sale and proposed land use. They then received a $24 cash endowment from which they could choose to donate on each experimental trial. They were notified that one of the trials would be randomly selected at the end of the experiment to count "for real." If they had decided to donate on that trial, that requested amount would be subtracted from their endowment and sent to their choice of the California State Parks Foundation or National Park Foundation — otherwise they would retain their entire endowment. Subjects were further instructed that since only one decision would be enforced, they should treat each choice as independent of the others, and not attempt to parcel out their endowment across multiple trials. Thus, subjects made incentive compatible decisions and no deception was necessary.

During the experiment, subjects were presented with 72 trials in one of two pseudorandomized orders ($n = 16$ subjects per stimulus order; statistical comparison revealed no significant differences between these orders in resulting donations). In each trial, subjects first saw a park (e.g., Yosemite, picture plus name; 4 s), then a proposed use for a quarter of the park (e.g., mining, picture plus name; 4 s), and then a request for a specific donation amount (e.g., $15) to help avert the proposed use (by indicating "yes" or "no" in a laterally counterbalanced position; 6 s; Fig. 1). The requested donation varied between $1 and $18 to yield low ($1–6), medium ($7–12), and high ($13–18) donation request amount categories for subsequent analysis. At the end of each trial, subjects focused on a fixation cross for a variable length of time (2–6 s) until the onset of the next trial (see Fig. 1). The timing of events within trials remained constant in order to ensure that peak neural activity in response to presentation of each variable of interest (e.g., park iconicness, land use destructiveness, requested donation amount) could be identified, extracted, and averaged or used for trial-to-trial

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