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Behavioral Economics and Neuroeconomics of Environmental Values

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Abstract

Identifying mechanisms of real-life human decision-making is central to inform effective, human-centric public policy. Here, we report larger trends and synthesize preliminary lessons from behavioral economic and neuroeconomic investigations focusing on environmental values. We review the currently available evidence at different levels of granularity, from insights into how individuals value natural resources (individual level), evidence from work on group externalities, common pool resources, and social norms (social group level) to the study of incentives, policies, and their impact (institutional level). At each level, we identify viable directions for future scientific research and actionable items for policy-makers. Coupled with new technological and methodological advances, we suggest that behavioral economic and neuroeconomic insights may inform an effective strategy to optimize environmental resources. We conclude that the time is ripe for action to enrich policies with scientifically grounded insights, making an impact in the interest of current and future generations.



Homo economicus:

humans modeled as rational maximizers of self-interest, who possess perfect knowledge of costs, benefits, and constraints of all actions

Ambiguity: uncertain situation with unknown probabilities of potential outcomes

Risk: uncertain situation with known probabilities of potential outcomes

Public good: a commodity available to all

Green action: any action aiming to minimize an otherwise negative footprint on the environment

1. INTRODUCTION

Human decision-making “in the wild” (i.e., in daily life) falls short of the economically rational *Homo economicus* (Persky 1995). Rather, it depends on the way we deal with gains, losses, uncertainty (Alpizar et al. 2011, Jang et al. 2020), and the temporal distance of prospective gains (Shamosh et al. 2008, Ballard & Knutson 2009). Further, emotions (Bechara & Damasio 2005) and even context (Weber et al. 2002, Dolnicar & Grün 2009) impact decision-making. This realization sparked novel interdisciplinary research, commonly subsumed under behavioral economics and neuroeconomics. These emerging fields benefit from interactions between behavioral studies, psychology, and neuroscience, enriching economic theory to accurately reflect human decision-making in daily life (Kahneman & Tversky 2013).

For instance, behavioral studies highlight the importance of simple heuristics, rather than accurate calculations of various probabilities (Deryugina 2013). Neuroscience reveals how complementary processes in distinct brain regions interact, supporting decision-making (Ballard & Knutson 2009). Moreover, different disciplines offer new insights into economic drivers and motivations (Sawe & Knutson 2015, Moser 2016), ambiguity (Hsu et al. 2005), risk processing (Weber et al. 2002, Hsu et al. 2005, Mohr et al. 2010, Charness et al. 2013), and temporal discounting (Ballard & Knutson 2009). Consequently, a broader, multidisciplinary approach may help to not only explain individual differences (Gifford & Nilsson 2014) for predicting human decision-making, but also inform effective policy (Ostrom 2008, Hepburn et al. 2010, Fischhoff 2021, Ranney & Velautham 2021). Considering this vast potential for societal impact by translating behavioral economic and neuroeconomic findings into policy may help to answer one of the ultimate pressing questions of our time: How can we build a sustainable future, and how can we engage the public effectively to achieve this end?

This review gives an overview of state-of-the-art findings of relevant cognitive processes underlying human economic decision-making, with a special focus on environmental valuation. While behavioral research increasingly focuses on protecting natural resources (Fischhoff 2021), neuroeconomic investigations with explicit environmental focus remain sparse (see, for example, Khaw et al. 2015, Sawe & Knutson 2015, Vedder et al. 2015, Vezich et al. 2017, Brevers et al. 2021). Consequently, where suitable, we discuss complementary neuroeconomic insights derived from more general research on decision-making. Further, we offer an enriched view of how individuals reach economic decisions regarding common pool resources, public goods, and institutional incentives. Finally, in the face of growing environmental crises, we highlight the exciting opportunity for effective green action informed by research and advanced technological innovation, steering the world toward more sustainable development.

2. METHODOLOGICAL FRAMEWORK

2.1. Behavioral Economics

Behavioral economics combines psychological insights with economic models to explain and predict human behavior. Specifically, behavioral theory departs from standard axioms of economics in three major ways (Mullainathan & Thaler 2000):

- Bounded rationality: deviations from rational solution due to cognitive errors,
- Bounded willpower: self-control failures, and
- Bounded self-interest: concerns for others’ welfare (as opposed to purely selfish motives).

These adjustments to the baseline assumptions of rationality form the foundations of theoretical predictions of behavioral economic models. Putting predictions of models to empirical tests allows researchers to evaluate the theory. Empirical studies in behavioral economics strongly draw

on methods from experimental economics (Loewenstein 1999). **Table 1** illustrates prominent empirical designs, from laboratory to field settings (Harrison & List 2004). Laboratory studies provide controlled settings, keeping potential confounding variables fixed between groups under consideration. Varying only the aspect of interest, one may attribute differences in participant's behavior to this aspect. This approach grants causal conclusions [internal validity (Lonati et al. 2018)].

Extensive control, however, comes at the cost of reduced external validity. The gap separating controlled designs and real life likely explains systematic differences between laboratory settings and natural environments (Galizzi & Navarro-Martinez 2019), questioning whether laboratory studies may truly provide quantitative conclusions (Loewenstein 1999). However, the linchpin of empirical findings is their applicability in real life, as economics aims to inform about the best course of action. Consequently, field experiments alleviate this issue by moving investigations from the lab to more realistic contexts (see **Table 1** and Harrison & List 2004). However, the distinction between laboratory and field is not necessarily synonymous with a trade-off between internal and external validity (Lonati et al. 2018): Experimenters applying scientific rigor and careful designs may succeed to preserve both also in field settings (Harrison & List 2004).

Ensuring incentive compatibility is a challenge in behavioral economics (Chen 2008). In fact, contingent valuation—the established way to assess environment valuation (**Table 1**) (Hanemann 1994)—has drawbacks commonly associated with methods that are not incentive compatible (Rakotonarivo et al. 2016). Recorded responses reflect true preferences only if participants may maximize their outcome by acting solely according to them. In experimental reality, true incentive compatibility is difficult, if not impossible, to achieve. First, participant biases (e.g., aligning behavior with assumed expectations, noncompliance) impede conclusions from observed behavior to true preferences (Lonati et al. 2018). Therefore, studies relying purely on self-reported preference are typically weaker in terms of internal and external validity. To remedy bias, we may extend self-reported preference measures with observational data reflecting true behavior. Second, practical reasons often hinder incentive compatibility. For example, policy outcomes can only be considered as hypothetical alternatives: One may ask people whether they prefer an increase in taxation to ameliorate the risk of flooding, but one cannot enforce these outcomes in real life.

Finally, discrete choice experiments (DCEs) are increasingly used to evaluate environmental policy options (Rakotonarivo et al. 2016, Boeri & Longo 2017, Mao et al. 2020). A DCE elicits a participant's preferences over complex goods through presenting them with a sequence of choices that differ on multiple dimensions along attributes of interest [e.g., different policies for renewable energy, described by the respective reduction in greenhouse gas emissions, number of power outages, jobs lost/created, and cost increase (Boeri & Longo 2017)]. Given the multifaceted nature of many environmental outcomes, DCEs reveal the most important attributes determining people's preferences and their respective trade-offs, even enabling forecasts of demands and behavior. However, a systematic meta-analysis of DCEs found low consistency between valuations and low reliability of hypothetical valuation when compared to factual cases (Rakotonarivo et al. 2016).

2.2. Neuroeconomics

Neuroeconomics complements behavioral economics by revealing the biological basis of economic decision-making: Researchers investigate the properties and interactions of brain activity during economic tasks using appropriate tools (**Table 2**).

Most established methods in neuroscience focus on patients with focal brain lesions (Vaidya et al. 2019) or electrodes implanted in animal models at sites of interest [local field potentials (LFPs) or single unit recordings (Herreras 2016)]. Modern neuroscience predominantly relies

Confounding

variable: unobserved variable introducing spurious associations by influencing both the supposed cause and the supposed effect

Internal validity:

the level of confidence for drawing causal conclusions from a study's results

External validity:

the level of generalizability of findings in a research setting to the environment approximated by the study

Field experiments:

studies taking place in the real-life context of interest

Incentive

compatibility:

the state reached if an individual achieves the best outcome just by acting according to their true preferences

Table 1 Overview of behavioral experimental designs

Description	Example ^a	IV	EV	Comment	Key studies with environmental focus
Incentive compatible					
Laboratory experiment (LAB)					
Laboratory setting, typically with student samples and abstract framing of task	Students decide how much money to donate to an anonymous peer and how much to keep themselves	↑	↓	Pro: highest experimental control Con: GOF from lab to field/student to other unclear	Harbaugh et al. (2007) ^b
Artifactual field experiment (AFE)					
LAB with specific target population	Coffee farmers in Costa Rica decide how much money to donate to an anonymous peer and how much to keep themselves	↑	→	Pro: improved GOF to target group Con: hard to recruit representative sample	Menges et al. (2005)
Framed field experiment (FFE)					
AFE extended by field setting (i.e., realistic commodities, outcomes, information, and stakes)	Coffee farmers in Costa Rica make investment decisions for adapting their farms to extreme weather events, with decisions determining monetary payoff	→	↑	Pro: improved GOF to target group and setting Con: hard to recruit representative sample	Alpizar et al. (2011), Anderson et al. (2017), Galizzi & Navarro-Martinez (2019), Werthschulte & Löschel (2021)
Natural field experiment (NFE)					
FFE within natural task environment; participants kept unaware of experiment	Crop insurance provider analyzes numbers and worth of insurance contracts of coffee farmers in Costa Rica before and after extreme weather events	↓	↑	Pros: most naturalistic setting, reduced Hawthorn effect ^c Con: little control of confounds	Clot & Stanton (2014)
Not incentive compatible					
LAB/AFE/FFE/NFE with hypothetical stakes					
Respective designs with hypothetical outcomes	Coffee farmers in Costa Rica make hypothetical investment decisions for scenarios such as adapting their farms to extreme weather events	→	↓	Pro: easy and cheap Con: low consistency/ reliability of hypothetical valuation	Hardisty & Weber (2009), Deryugina (2013)
Discrete choice experiment					
Participants choose hypothetical alternatives differing on multiple dimensions along attributes of interest	Coffee farmers in Costa Rica choose potential plans for extreme weather adaptation, described by respective cost increase, reduced risk of crop failure, and expected change in crop yield	→	↓	Pro: captures multidimensionality of environmental outcomes Con: low consistency/ reliability of hypothetical valuation	Boeri & Longo (2017), Mao et al. (2020)

(Continued)

Table 1 (Continued)

Description	Example ^a	IV	EV	Comment	Key studies with environmental focus
Contingent valuation study					
Participants answer surveys assessing valuation of nonmarket commodities such as environmental resources	Survey respondents state their maximum WTP for a change in the provision of the goods or service or their minimum compensation (WTA) if the change is not carried out	→	→	Pro: grants value estimates for nonmonetary resources Con: response bias/protest answers	Khaw et al. (2015) ^b , López-Mosquera & Sánchez (2011)

^aExamples constructed around the FFE by Alpizar et al. (2011).

^bStudies using behavioral design, combined with neuroscience methodology.

^cHawthorn effect: participants changing their behavior due to the fact of being observed.

Symbols: ↑, high; →, medium; ↓, low.

Abbreviations: EV, external validity; GOF, generalizability of findings; IV, internal validity; WTA, willingness to accept; WTP, willingness to pay.

on minimally or noninvasive neuroimaging techniques, combined with sophisticated experimental designs and appropriate data analyses. These methods reveal brain activation during task performance, like positron emission tomography (PET), functional near-infrared spectroscopy (fNIRS), and magnetoencephalography (MEG). Most prominently used, however, are electroencephalography (EEG) and functional magnetic resonance imaging (fMRI).

During an EEG recording, electrodes placed on the scalp measure electric potentials originating from the underlying brain tissue (Michel & Murray 2012). Thus, EEG signals serve as a direct estimate of collective neuronal activity, providing an excellent temporal resolution in the millisecond range (Michel & Murray 2012). An fMRI assessment requires participants to lie in a long, tubular MRI scanner that detects small changes in the brain's regional blood flow. These are taken to reflect the increased oxygen consumption by active neurons (Logothetis et al. 2001). With their three-dimensional images, fMRI measurements offer an excellent spatial scale. However, the temporal resolution is inferior to that of electrophysiological tools, as activity is only indirectly inferred (Bolton et al. 2020).

Final critical additions to the neuroscientific toolbox are noninvasive neuromodulation techniques. Transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) induce electrical currents in the brain, thus facilitating or inhibiting neural activity in target regions (Priori et al. 1998, Zhengwu et al. 2018). Modulating neural activity, these methods show great promise to help researchers generate causal inferences about the relationships between brain regions and their respective functions.

Although neuroeconomics promises a window into the human mind, some issues may spark justified skepticism. For instance, neuroeconomic data are often sparse, and conclusions are drawn from few participants in very specific settings (Harrison 2008). More fundamental methodological criticism points to poor test-retest reliability of fMRI (Elliott et al. 2020), inappropriate statistical handling of the data (Eklund et al. 2016), and limited capacity to establish causal links between observed brain activity and psychological processes under study (Poldrack & Farah 2015). Moreover, technical requirements of the equipment often dictate the scope of investigations: There is only so much a person can do while lying motionless in a stationary MRI scanner. However, it is often difficult to increase realism in neuroimaging studies, calling into question the generalizability of results. Thus, more flexible psychophysiological measures like electrodermal

Table 2 Overview of neuroscience methods

Explanation	Signal	Spatial resolution	Temporal resolution	Comment	Key studies with environmental focus
Lesion studies					
Studying behavioral/ cognitive deficits of patients with focal brain damage	Behavioral	Variable	Not applicable	Pro: allows directly relating dysfunction to the brain region Cons: small, heterogeneous samples; large variability lesion size/extent	None
Electroencephalography (EEG)					
Electrodes placed on scalp	Electric	40 mm	0.001–0.01 s	Pros: mobile, noninvasive, cheap Cons: poor spatial resolution, noisy data	Lee et al. (2014)
Local field potentials (LFPs), single unit recordings					
Implanted microelectrodes	Electric	0.4 mm	0.01 s	Pro: excellent temporal and spatial resolution Con: invasive	None
Functional magnetic resonance imaging (fMRI)					
Recording of magnetic signal variations of (de)oxygenated blood within the brain	Hemodynamic	1 mm	1 s	Pro: excellent spatial resolution Cons: expensive, stationary	Linder et al. (2010), Khaw et al. (2015), Sawe & Knutson (2015), Vedder et al. (2015), Vezich et al. (2017), Brevers et al. (2021)
Positron emission tomography (PET)					
Visualization of metabolic processes after injection of radioactive tracers	Metabolic ^a	5 mm	100 s	Pro: focus on specific processes Cons: invasive, expensive; participants subjected to radiation	None
Functional near-infrared spectroscopy (fNIRS)					
Near-infrared light projected through the scalp to record intensity of refracted light	Hemodynamic	5–10 mm	0.001–0.01 s	Pro: mobile Con: poor spatial resolution	None
Magnetoencephalography (MEG)					
Highly sensitive magnetometers record magnetic fields on scalp, generated by underlying neural activation	Electromagnetic	2–3 mm	0.001–0.01 s	Pro: excellent temporal resolution Con: effortful to eliminate environmental magnetic interference	None
Transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS)					
A magnetic field/electric current applied on the scalp targets specific brain regions, stimulating/ interfering with processing	Stimulation/ interference	25 mm ² –2,500 mm ²	0.001–1 s ^b	Pro: noninvasive Cons: poor spatial resolution, stimulation/ interference nonspecific, (low) risk of seizures	Langenbach et al. (2022)

^aUse of tracer determines targeted metabolic process (e.g., regional tissue composition, absorption, blood flow).

^bTiming largely depends on the TMS/tDCS protocol/method (e.g., single pulse is quick, but repeated TMS rather slow).

activity, electromyographic data, or respiration rate may complement contemporary neuroimaging methods, contributing insight into somatic states of cognitive processing (Bechara & Damasio 2005). Finally, next-generation neuroscientific technology promises mobile and wireless options for studies in more naturalistic settings outside the laboratory (Chi et al. 2013), making these tools particularly interesting in the domain of environmental valuation.

3. EMPIRICAL EVIDENCE ON ENVIRONMENTAL VALUATION

Given this diverse repertoire of methodologies, emerging literature highlights the behavioral and neural aspects of environmental valuation.

First, behavioral evidence reveals a striking disconnect between willingness to pay (WTP) and willingness to accept (WTA). Consumers likely name a much higher price for giving up existing access to clean water (WTA) than for gaining access (WTP). Research shows that the WTP–WTA disparity is greatest for environmental goods, compared to health, safety, or ordinary private goods (e.g., cars and houses) (Tunçel & Hammitt 2014), but the disparity is consistently smaller in incentive-compatible designs. Consequently, studies measuring the value of environmental goods need to account for this disconnect in incentive-compatible settings. Second, environmental outcomes are nondeterministic: They happen with some probability that is either known (risk) or unknown (ambiguity). Brain imaging reveals fundamental differences in how humans represent and process choices under risk and ambiguity (Hsu et al. 2005) (see Section 3.1.1). Third, people prioritize immediate over temporally distant gains. Environmental interventions tend to take effect in the remote future, while current generations bear their costs. Behavioral economics highlights the systematic disconnect between valuations of present and future outcomes, and neuroeconomics reveals distinct neural systems related to magnitude and delay of future rewards (Ballard & Knutson 2009) (see Section 3.1.2). Fourth, environmental outcomes affect the whole of society. Thus, considerations of fairness and perceived intentions of other stakeholders affect individual action (Anderson et al. 2017). Similarly, recent evidence points toward perspective taking and mentalizing for sustainable action, akin to cooperation behavior (Langenbach et al. 2022) (see Section 3.2). Last, the impact of environmental valuation also affects institutional stakeholders such as companies and governmental and nongovernmental organizations. These parties rely on empirical insights to realize appropriate—and effective—policies. In turn, political initiatives, taxation, and regulations may shape individual and societal valuation of environmental resources.

In the light of these challenges, we present behavioral and neuroeconomic evidence along three interconnected levels that we deem specifically relevant to environmental valuation (see **Figure 1**):

- Individual level: studying behavioral particularities of human valuation, which may affect societal norms;
- Social group level: exploring typical problems of group externalities/social dilemmas associated with common pool resources; and
- Institutional level: addressing how incentives and institutions affect decisions and outcomes.

3.1. Individual Level

Understanding individual-level decision-making provides a foundational insight into people's behavior and helps to understand the interactions of groups and function of institutions (see sidebar titled Actionable Items, Individual-Level Evidence).

Willingness to pay (WTP): the maximum price a consumer is willing to pay for a product or service

Willingness to accept (WTA): the minimum monetary amount that a person is willing to accept to sell a good or service

Mentalizing: understanding the mental states of oneself and others

Social dilemma: a situation that creates a conflict between the individual's interests and the collective's interests

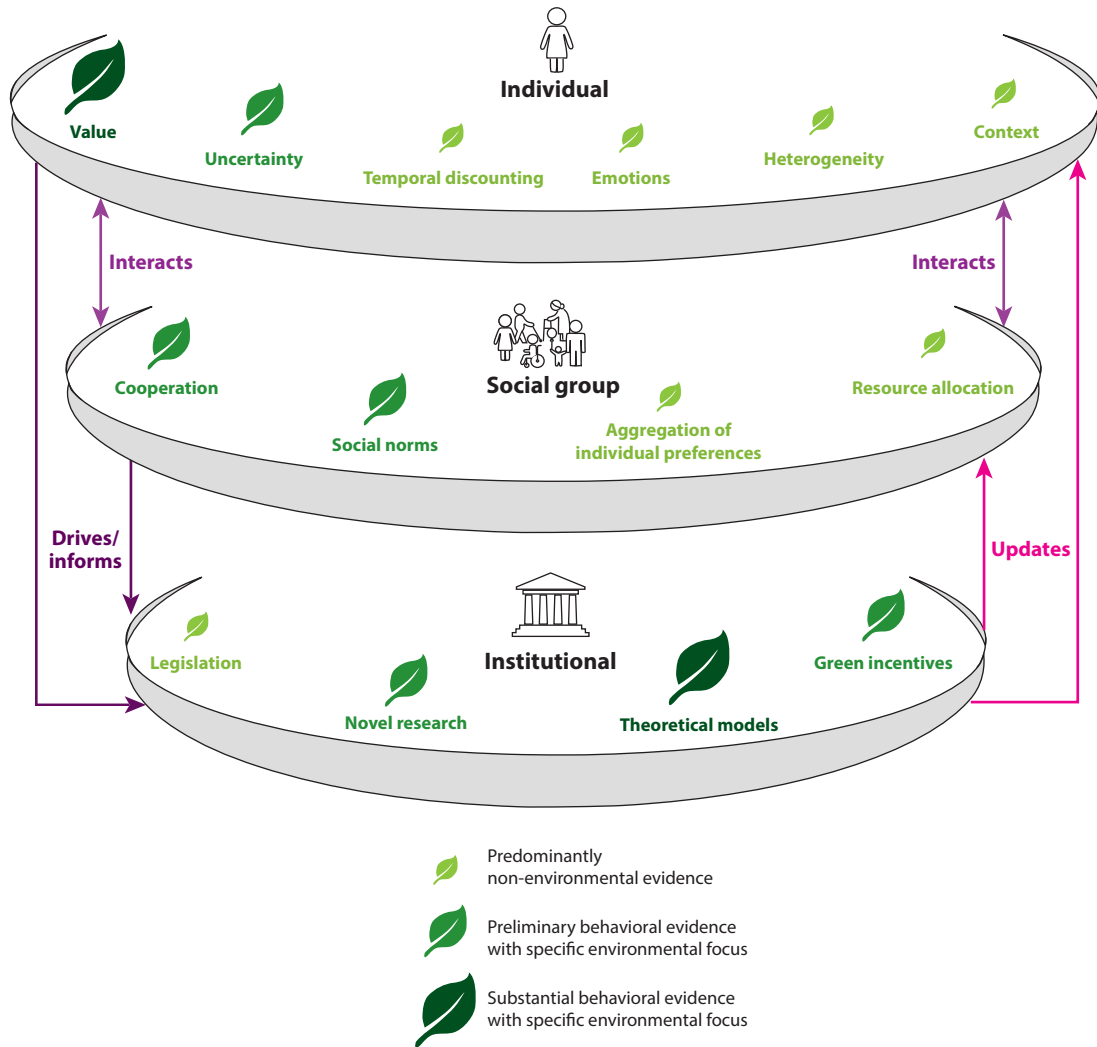


Figure 1

Schematic figure highlighting the three levels and corresponding aspects considered in this review. The size and color of leaf icons indicate the amount of behavioral literature available. Arrows highlight interdependencies between levels.

3.1.1. Gains, losses, and uncertainty in environmental outcomes. How do humans construct value concerning environmental resources? Different methods eliciting environmental values arrive at different results, pointing toward on-the-spot processing rather than stable underlying constructs (Schkade & Payne 1994). Despite methodological drawbacks associated with environmental valuation studies (Rakotonarivo et al. 2016) (see Section 2.1), behavioral evidence suggests a higher WTP for organic food (Linder et al. 2010) or environmental proposals (Khaw et al. 2015), indicating that participants inherently value green commodities. One exciting behavioral variant approaching environmental valuation assesses the trade-off between income and environmental conditions via self-reported happiness (Welsch & Kühling 2009). Strikingly, related psychological parameters such as emotional experience and satisfaction have been shown to

ACTIONABLE ITEMS, INDIVIDUAL-LEVEL EVIDENCE

- Environmental valuation models may be enriched by including affective value of natural resources (Welsch & Kühling 2009, López-Mosquera & Sánchez 2011) and accounting for cognitive biases such as myopic temporal discounting (Weber 2010, Clot & Stanton 2014), gain-loss discrepancies (Ölander & Thøgersen 2014, Jang et al. 2020), and suboptimal emotional forecasting (Nisbet & Zelenski 2011).
- Policy-makers need to account for psychological barriers to individual green action, especially humans' fundamental bias toward present gains at the expense of future outcomes (Weber 2010, Clot & Stanton 2014).
- Policies may capitalize on insights into the human green psyche, seizing, e.g., positive spillover effects (Carrico 2021).
- Effective incentives must be tailored to the individual, incorporating personal proenvironmental stances (Luo & Zhao 2021) and cognitive biases (Bergquist 2020).
- From a research perspective, there is ample room for greater focus of neuroeconomic work on mechanisms of valuation, specifically in environmental contexts.

correlate with the WTP for environmental resources (López-Mosquera & Sánchez 2011), paving the way to richer valuation models accounting for the multitude of environmental services.

Whereas behavioral economics infers how humans construct value from their actions, neuroeconomics aims to identify the neural basis of economic decision-making (for a recent review, see Serra 2021) (**Figure 2**). Specifically, this concerns the neural representation of gains and rewards, losses, and uncertainty. Neurophysiologically, the brain responds differently to different levels of reward magnitude (Haber & Knutson 2010), also reflecting relative preference among available options (Kable & Glimcher 2007). Specifically, the midbrain, orbitofrontal cortex (OFC), the striatum, cingulate cortex spanning the brain's medial midline, and regions typically associated with emotion and motivation (i.e., the amygdala) show reward-related activity (Knutson et al. 2001).

Initial neuroeconomic evidence acquired via modern neuroimaging techniques like fMRI reveals neural correlates of environmental value. For instance, Linder et al. (2010) demonstrate higher WTP for organically produced food, together with increased activity in the ventral portion of the striatum (VS; i.e., the economic reward hub). Khaw et al. (2015) show comparable brain activation [e.g., in the dorsomedial prefrontal cortex (dmPFC), posterior cingulate cortex (PCC), and VS] in participants when they contemplate their WTP for environmental proposals (e.g., protecting sea turtles, increasing the proportion of renewables) and during valuation processes for consumer items, snack foods, or activities. In stark contrast to previous studies on economic valuation, this study failed to show a linear relationship between the degree of brain activity in the prefrontal cortex or VS and behavioral preferences. This may suggest distinct neural underpinnings in the translation process from internal valuation to behavioral preference for environmental economic decisions.

Complementary to processing positive rewards, distinct brain regions are central to encoding negative utility, with striking similarities for responses to monetary loss (Dugré et al. 2018) and loss of natural resources (Sawe & Knutson 2015). Specifically, Sawe & Knutson (2015) assessed participants' WTP to prevent destructive land use in national parks while recording fMRI. Interestingly, imagery of park lands reliably increased activity within the VS, consistently associated with general economic valuation. Destructive land use, however, triggered negative arousal supported by the anterior insula and the anterior cingulate cortex (ACC). The anterior insula acts as a multifunctional integration area, putatively relaying information between different cognitive

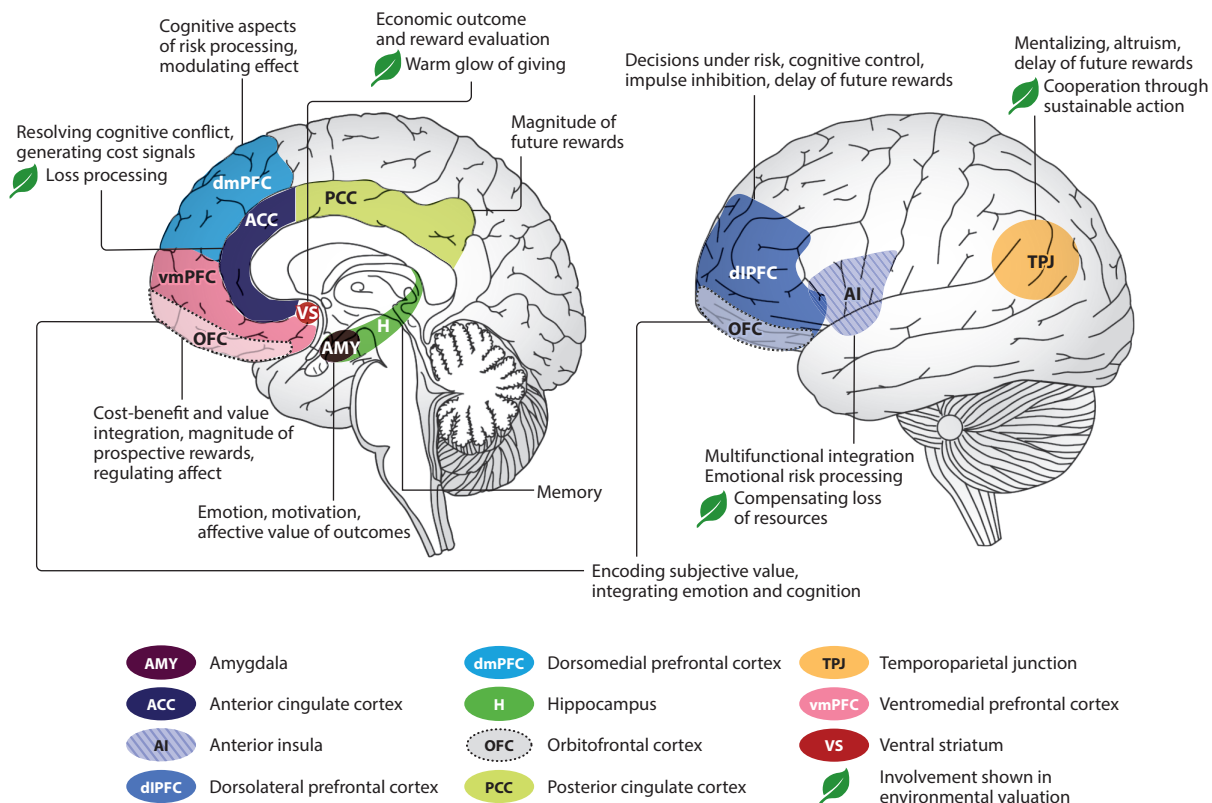


Figure 2

Schematic figure highlighting the brain areas supporting aspects of economic decision-making. Hatched areas lie beneath the brain's surface. The leaf icon signifies functional associations that have been identified specifically in the context of environmental valuation.

and social-emotional systems (Kurth et al. 2010), whereas the ACC presumably generates cost signals that exert control on decision-making to minimize losses while maximizing gains (Brown & Alexander 2017).

Typically, humans make decisions based on the likelihood of consequences, rather than absolute certainty. This requires not only a reliable representation of value, but also of probability, i.e., risk. Human brain imaging points to the striatum representing the probabilities of rewards (Hsu et al. 2005), corresponding to its canonical role in economic valuation. Moreover, risk processing in humans involves cognitive (dmPFC) and emotional (anterior insula) control regions, jointly informing decision processes in the prefrontal brain [dorsolateral prefrontal cortex (dlPFC)] (Mohr et al. 2010). Intriguingly, interindividual differences modulate activation of regions within this network: Risk-averse individuals show stronger responses to risky decisions in the anterior insula, linking cognitive and affective processes (Kurth et al. 2010). Individuals prone to sensation, conversely, show blunted anterior insula responses to both monetary gains and losses (Zheng & Liu 2015). Mirroring this complexity of neural risk processing, individuals exhibit variable and sometimes even contradictory behavior when facing risky decisions. For instance, attitude toward risk may depend on the outcome's domain (Weber et al. 2002) and elicitation method (Charness et al. 2013). Consequently, people may respond differently to incentives for taking health-related risks than environmental risks or for reducing risk compared to removing it completely (Hansson

& Lagerkvist 2012). Moreover, people tend to underestimate the probability of high-magnitude outcomes, an effect that may be remedied by adjusting how probability is communicated (Patt & Schrag 2003).

Unlike situations with known probabilities, ambiguity makes it impossible to assign likelihood (Knight 1921). In terms of environmental aspects, ambiguity may refer to outcomes (e.g., floods, droughts, hurricanes) or to costs and benefits of actions addressing those outcomes (Heal & Millner 2018). Field experiments show that farmers' risk aversion toward climate change increases under ambiguity (Alpizar et al. 2011). Notably, adaptation costs also influence individual choices, promoting coordinated action to reduce costs. Brain imaging studies reveal differing activation patterns for risky and ambiguous choices (Hsu et al. 2005). Specifically, ambiguous conditions activate regions associated with emotion (i.e., amygdala), emotion regulation (dmPFC), and integration of emotion and cognition to generate subjective value (OFC) (Hsu et al. 2005). Consequently, behavioral economics and neuroeconomics highlight important differences concerning human decision-making under risk and ambiguity, in stark contrast to classical decision theory, which fails to account for such distinction.

3.1.2. Temporal discounting of environmental outcomes. Environmental decision-making involves high stakes alongside large spatial and temporal scales. Importantly, humans tend to discount temporally distant outcomes (i.e., valuing near rewards more than future ones) not only in economic terms (adjusting for inflation, investment opportunities, and risk) but also in behavioral fashion (such as valuing any immediate outcome higher than the same one after even a minimal delay, or myopic decision-making, as discussed by Hepburn et al. 2010). For example, existing evidence from other domains suggests that in relation to the environmental outcomes, people would discount an improvement in air quality more than a same-degree deterioration in air quality. They would also discount a large-scale outcome such as a decrease in ocean pollution less than a small-scale outcome of decrease in a lake pollution and discount more the prospect of having a more balanced ecosystem in the future when the default option is to overfish now, compared to when both options are available in the future. This also affects decision-making in the domain of environmental values, such as perceptions of climate change (Weber 2010), rate of energy consumption (Werthschulte & Löschel 2021), or payment for environmental services (Clot & Stanton 2014). Although it is yet unclear whether general time-discounting models apply to environmental outcomes, the initial evidence suggests similar discounting mechanisms for environmental and financial outcomes for hypothetical scenarios (Hardisty & Weber 2009).

Much like risk preference, delay discounting varies between individuals as a function of intelligence and working memory, mediated by activity in prefrontal control regions (i.e., dlPFC) (Shamosh et al. 2008). The brain basis of temporal discounting in financial contexts has been thoroughly investigated in neuroeconomics: Ballard & Knutson (2009) distinguish neural systems related to the magnitude and delay of future rewards. Specifically, larger prospective gains elicit greater signal changes in areas typically linked to economic outcome evaluation (VS, PCC) and cost-benefit integration [ventromedial prefrontal cortex (vmPFC)]. These insights extend earlier work by McClure et al. (2007), who provided thirsty participants with small amounts of liquid to demonstrate that the mesolimbic dopamine system (VS, PCC, ACC, and OFC) additionally responds to immediate, primary rewards. The limbic system's integral part in associating emotion with cognition via its connectivity with the amygdala and OFC (Catani et al. 2013) may explain the strong human preference for immediate outcomes.

Beyond reward magnitude, varying the delay modulates activity (i.e., longer delays decrease responses) in cognitive control regions (dlPFC) and parietal areas [e.g., temporoparietal junction (TPJ)] (Ballard & Knutson 2009). Strikingly, deactivation of delay-sensitive regions in response to

Myopic decision-making: prioritizing immediate over temporally distant events while discounting future consequences

longer temporal offsets is greater for more impulsive individuals (Ballard & Knutson 2009). In line with this, stimulation of the left dlPFC via tDCS decreases temporal discounting in participants choosing between smaller-but-sooner and larger-but-later rewards, marking its crucial role in mediating temporal discounting (He et al. 2016).

However, it is yet unclear whether similar temporal discounting mechanisms apply to environmental valuation. In fact, there is some behavioral indication of domain specificity: Richards & Green (2015) found significantly lower discount rates for environmental compared to financial outcomes. As this effect could not be consistently shown in previous research (Hardisty & Weber 2009), future investigations will need to study temporal discounting across the domains and, specifically, assess whether general models also hold for environmental scenarios.

The fundamental bias toward the present in human decision-making may severely impede concrete action reducing the long-term impact of environmental challenges such as climate change. Thus, policies need to account for and overcome this critical myopia to alleviate potentially catastrophic consequences of present choices.

3.1.3. Impact of emotions on decision-making. Emotions may affect preferences and decisions (Bechara & Damasio 2005), occasionally leading to biases of judgment and systematic errors in predicting emotional outcomes (Nisbet & Zelenski 2011). For instance, individuals may fail to maximize the hedonic benefit from simple acts like talking a walk outdoors (Nisbet & Zelenski 2011). Consequently, active exposure to environmental stimuli may improve experiential learning, thus circumventing such errors in predicting future emotions (known as affective forecasting).

The interplay between emotion and decision-making has been a prominent subject of neurocognitive investigation, culminating in the so-called somatic marker hypothesis (Bechara & Damasio 2005). In short, this theory considers decision-making to be subject to biasing signals (somatic markers) arising from autonomic bodily states, including feelings and emotions. These markers consequently guide decision-making, pointing toward the most relevant alternatives based upon the individual's previous experiences. Although not devoid of criticism (for a critical evaluation, see, e.g., Dunn et al. 2006), this theory potentially explains how emotions affect decision-making.

In line with the somatic marker hypothesis, neuroeconomic investigations reveal mechanisms that may lead to biased judgment through emotions. For instance, anticipatory anxiety has a striking impact on how the brain values different choices. Specifically, anticipatory anxiety changes the neural signatures for economic valuation, away from the typical pattern involving the VS and vmPFC, toward a stronger contribution of the anterior insula, potentially shifting valuation focus to possible negative outcomes (Engelmann et al. 2015).

However, beyond the view of emotion as a stumbling block for cognition, affect may also guide decision behavior, thus producing strategies aligned with economic notions of rationality. One particularly illustrative emotion relevant to human decision-making is regret. First and foremost, engaging in counterfactual thinking, i.e., deliberating about what could have been, may invoke regret. Instead of purely maximizing expected utility, a person's choice is often motivated to avoid this highly unpleasant emotion (Zeelenberg et al. 1996), with a profound impact on decision-making (Loomes & Sugden 1982, Zeelenberg & Pieters 2007). Regret minimization guides human choice in important and challenging situations or when the decision-maker believes that they will face consequences for their actions (Zeelenberg & Pieters 2007).

A fundamental player mediating emotions like regret is the vmPFC. In their seminal line of studies taken to support their somatic marker hypothesis, Bechara & Damasio (2005) employed a gambling task to investigate individual aptitude for risk taking, impulsivity, and resistance to

immediate gratification in neurotypical controls and patients with brain lesions. Strikingly, while intellectual and cognitive abilities appear intact, patient groups with either frontal lesions or impairments of the amygdala consistently prefer short-term gains, despite larger net losses (see Bechara & Damasio 2005, section 2, for a concise review of the corresponding experimental data). Similarly, individuals with vmPFC lesions may feel disappointment but no regret after high-risk choices with adverse outcomes (Camille et al. 2004). Newer evidence suggests a more fine-grained differentiation of frontal regions, with a lack of regret stemming from lesions confined to the lowermost part of the lateral frontal lobe, the lateral OFC (Levens et al. 2014). Thus, the vmPFC may guide future decision-making, integrating choices with anticipated emotional responses, while the lateral OFC mediates after-choice emotional signaling associated with subsequent behavioral modification. Further neuroimaging work with neurotypical participants confirms vmPFC activity as a strong correlate of anticipating and feeling regret (Coricelli et al. 2005). Additionally, regret triggers enhanced activity in the ACC and within hippocampal memory structures (Coricelli et al. 2005). While the ACC is a major player in processing losses more generally (see Section 3.1.1), hippocampus activity may indicate avoidance learning based on emotional experience (Coricelli et al. 2007).

What are the potential implications of regret critically influencing decision-making in the context of environmental value? On the one hand, incorporating risk aversion in choice modeling may introduce greater behavioral realism (Chorus 2010). In fact, random regret minimization models show higher explanatory and predictive power for individual choice behavior in the context of renewable energy programs (Boeri & Longo 2017) and air quality improvement policies (Mao et al. 2020). On the other hand, putting a strong focus on the highly regretful future outcomes of environmentally destructive behavior may improve the efficiency of public campaigns promoting proenvironmental behavior (Brosch 2021).

3.1.4. Heterogeneity of preferences and attitudes toward the environment. Humans differ in many ways, including their proenvironmental attitudes. Considering sociodemographic and psychometric factors, participants that actively take proenvironmental initiative seem to have higher education and income and are more oriented toward outdoor activities (Bodur & Sarigöllü 2005). However, concerned and unconcerned individuals do not statistically differ in terms of age, gender, and occupation. Cross-cultural studies are in line with this finding, demonstrating limited evidence of heterogeneity in environmental regard driven by factors such as gender (Chan et al. 2019) or personality traits (Milfont et al. 2006). The role of age is less clear, with some studies suggesting no effect (Gray et al. 2019), but more recent accounts showing higher proenvironmental behavior in old compared to young individuals (Wang et al. 2021, Xu et al. 2021). In contrast, socioeconomic factors such as rural-urban residence or political orientation seem to affect environmental concerns (see Gifford & Nilsson 2014 for a comprehensive review of relevant factors).

From a psychological perspective, individual beliefs are profound motivational factors impacting the environmental decision-making heuristic (Deryugina 2013). A large-scale survey of more than 1,760 German households revealed that self-interested beliefs about such issues as health value and sustainability strongly motivate the choice for organic products (Moser 2016). Intriguingly, though, this effect seems to vary depending on product type, affecting healthy products more profoundly than products that tend to be more unhealthy but offer instant gratification (Van Doorn & Verhoef 2011).

Beyond individual beliefs, human economic valuation also depends on subjective appraisal of environmental beauty (Fanariotu & Skuras 2004). Specifically, economic valuation models predicting participants' WTP to prevent forest fires are significantly improved when including

individuals' ratings of scenic beauty. Thus, opening the public's eye to scenic beauty may be a worthwhile strategy to increase public investments for preserving natural resources.

Whatever reason sparks regard for ecological issues, environmental concern shapes human perception (for a review, see Luo & Zhao 2021). Based on studies suggesting stronger attentional biases toward climate-related stimuli in individuals showing initially stronger concern, Luo & Zhao (2021) speculate that a two-way interaction occurs: Larger attention to environmental issues may induce greater concern, leading in turn to greater attention, and so on. Bergquist (2020) recently provided further intriguing insights into the human green psyche: Most humans across samples and countries tend to perceive themselves as being more environmentally friendly than others. While this conception did not reduce participants' perceived obligation to act environmentally friendly, it weakly reduced proenvironmental intentions. Thus, negative spillover effects may have a detrimental effect on environmental cognition, with (perceived) proenvironmental actions subsequently warranting less environmentally friendly behavior (Carrico 2021). In contrast, recent work also reveals evidence for positive spillover, with present proenvironmental actions motivating subsequent proenvironmental behavior (Carrico 2021).

These behavioral investigations begin to form a comprehensive picture of the heterogeneity in proenvironmental attitudes. This emerging view, however, lacks substantial neuroeconomic evidence identifying neural correlates and characteristics of observed individual differences. Initial sparse data suggest that consumers favoring environmentally friendly products show differential frontal activity when engaging with green product messages (Lee et al. 2014). Similarly, individuals who endorse proenvironmental attitudes show greater anterior insula activity in response to destructive land use (Sawe & Knutson 2015), and a greater buying preference for organic food is reflected by increased economic valuation in terms of VS activity (Linder et al. 2010). Fully revealing the neural basis for green behavior will be an exciting avenue for future research.

3.1.5. Effects of decision context. So far, we have seen the complexity of human decision-making, which is subject to various factors beyond the magnitude and probability of prospective rewards and losses. To make matters even more complex, neuroeconomic evidence suggests a particularly strong influence of decision context on the neural mechanisms of environmental evaluation. Brevers et al. (2021) recently showed fundamental differences when participants contemplate being more sustainable by “doing more” or “doing less.” Behaviorally, “doing more” was judged as more feasible than reducing unsustainable actions.

Additionally, thinking about increasing the number of sustainable behaviors engaged regions connected to processing subjective economic value (OFC), together with areas typically supporting episodic memory (hippocampus). Conversely, thinking about decreasing unsustainable behaviors relied on frontal control regions (dlPFC), whereas hippocampal activity was reduced, potentially marking suppressed memory retrieval of one's own unsustainable actions (Brevers et al. 2021). Thus, the perspective context elicits distinct neural patterns for environmental cognition. Comparably, differences emerge when imagining either pleasant/beautiful or unpleasant/nonbeautiful environments (Vedder et al. 2015). Corresponding fMRI results reveal distinct neural representations for each context, with greater, more widespread activation following negative probes.

Moreover, proenvironmental behavior varies not only between individuals, but also within a person depending on context. Survey data suggest a considerable drop in proenvironmental behavior when on vacation, with only the most environmentally friendly respondents resisting the change of scene (Dolnicar & Grün 2009). These inter- and intraindividual effects need to be taken into account to realize effective green policy.

ACTIONABLE ITEMS, SOCIAL GROUP-LEVEL EVIDENCE

- Social motives for engaging in proenvironmental behavior include altruism, the concern for others, or establishing social equity, with critical implications for design and effectiveness of policy (Cai et al. 2010, Knez 2016, Xu et al. 2021).
- Effective policies mitigating global environmental crises may benefit from incorporating mechanisms that foster cooperation if accounting for both uncertainty and irrational responses that may inhibit collective action (Venmans & Groom 2021).
- Policy-makers may capitalize on “warm glow” as a social motivator, leveraging the individual intrinsic motivation of people in low-cost situations, who can financially afford to act sustainably (Van der Linden 2018, Iweala et al. 2022).

3.2. Social Group Level

Environmental resources are nonexcludable and nonrivalrous public goods. Although they benefit all members of society, they require coordinated action to maintain (see sidebar titled Actionable Items, Social Group-Level Evidence).

3.2.1. Cooperation and environmental outcomes as public goods. Financing of public goods is directly linked to social dilemmas. For example, a group of fishermen may cooperate to fish responsibly (i.e., refraining from maximizing profits by fishing excessively), thus allowing the fish to reproduce (Stoop et al. 2012). In this scenario, an overfishing free-rider would achieve higher profits. However, if everyone followed this same logic, the public good of the fish pond would deplete rapidly. Brain-wise, cooperative choice elicits activity in a network comprising areas associated with cognitive control (e.g., dlPFC), value computation (VS), emotion processing (anterior insula, amygdala), and mentalizing (TPJ), modulated by fairness, individual social preference, and strategic considerations (for a review, see van Dijk & De Dreu 2021). People care about not only their own outcomes, but also how those compare to outcomes of others (distributional preference) (Fehr & Schmidt 1999, Charness & Rabin 2002, Anderson et al. 2017), exhibiting a general willingness to redistribute outcomes more equally, even at a cost (Durante et al. 2014). This distributional preference seems to also apply to environmental outcomes, with WTP dependent on the equity of outcomes (Cai et al. 2010). In line with behavioral distributional preferences, neuroeconomic data suggest greater reward signaling in relevant brain regions (vmPFC, VS) for decisions that restore equality in social settings (Tricomi et al. 2010). Likewise, social cues elicit similar value signals as monetary gains within the economic reward hub (VS), suggesting comparable processing mechanisms (Izuma et al. 2008).

There is indicative evidence of differing inequality aversion depending on temporal distance and gain/loss domain of the outcome (Venmans & Groom 2021). In a recent review on neuroeconomic implications for climate change policy, Sawe & Chawla (2021) put forward the compelling suggestion that neural processes underlying inequality aversion may be fundamentally modulated by one's individual economic standing. Building on theoretical considerations of Fehr & Schmidt (1999), they suggest that affluent individuals may experience advantageous inequity aversion, whereas economically disadvantaged individuals more likely experience disadvantageous inequity aversion. Importantly, both variants result in different behavior, supported by different neural processes (Gao et al. 2018). Advantageous inequity aversion requires sacrificing one's own gains to balance the scales, associated with stronger activation in regions typically involved in social cognition, i.e., the anterior insula, dmPFC, and dlPFC. In contrast, disadvantageous

Free-rider: one who benefits from public goods, does not pay for them, or underpays for them

Distributional preference: decision-making under other-regarding utility, with actions depending on one's own material payoff and the payoffs of other agents

inequity aversion results in behavior that minimizes benefits of others to level the playing field, supported by regions involved in emotion and conflict resolution, i.e., the dorsal ACC, amygdala, and left posterior insula (Gao et al. 2018). Thus, motives for engaging in proenvironmental behavior may exceed intrinsic factors, also including economic circumstances, with critical implications for policy design.

The economic concept of distributional preferences is closely linked to altruism and the concern for others (Menges et al. 2005), thus touching on central topics in the field of social neuroscience. While proenvironmental actions may also stem from less compassionate motives such as peer pressure (Guagnano 2001), recent studies associate altruism with sustainable behaviors (Knez 2016, Xu et al. 2021). Corresponding neuroeconomic studies suggest that engaging in altruistic behaviors recruits regions associated with empathy and social cognition (TPJ), value integration and cost-benefit estimation (vmPFC, dmPFC), and basic emotions and drives (VS, ACC) (for a review, see Filkowski et al. 2016).

Harbaugh et al. (2007) demonstrate increased activation of reward-related brain regions (including, e.g., VS, bilateral caudate, and bilateral insula) not just for receiving money oneself, but also when money goes to a charitable purpose. Strikingly, the strength of brain activation indicated the likelihood of donating, and participants with increased responses reported higher subjective satisfaction upon donating. From a network perspective, fMRI results demonstrate interactions between involved brain regions, thus emphasizing the interplay of associated processes. For instance, making charitable donations triggers correlated signals in the TPJ, involved in social cognition, and the vmPFC, associated with cost-benefit evaluation (Hare et al. 2010). Moreover, individual differences in behavioral altruism are linked to both structure and function of the right TPJ (Morishima et al. 2012), further highlighting the importance of social cognitive processing for altruistic decision-making.

Recently, stimulation studies using TMS and tDCS identified differential contributions of prefrontal and temporoparietal regions during altruistic behavior. Stimulating the medial prefrontal cortex induced a boost in altruistic behavior in situations of disadvantageous inequality (Liao et al. 2018, Zhang et al. 2022), whereas the right TPJ may be more relevant in advantageous inequality (Zhang et al. 2022). In line with this latter notion, recent evidence points toward a crucial role of the TPJ for engaging in sustainable behaviors that have strong cooperative aspects (Langenbach et al. 2022). Specifically, Langenbach et al. (2022) let participants play a fishing game and maximize their own outcome at the expense of future generations and the virtual environment. In this setting, stimulating the TPJ via tDCS increases sustainable fishing that, simultaneously, benefits subsequent players.

Crucially, group-level models incorporate individual-level behavioral phenomena. For example, proenvironmental behavior typically involves trading-off individual gains for collective benefits. However, risky outcomes and uncertainty among cooperators hinder cooperative behavior (Raihani & Aitken 2011). Effective policies to mitigate global environmental crises need to foster cooperation, accounting for both uncertainty and irrational responses that may inhibit collective action.

3.2.2. A strong social motivator: the warm glow of giving. What motivates people to engage in prosocial behavior? Participants commonly report feelings of higher subjective satisfaction, e.g., upon making charitable donations (Harbaugh et al. 2007), but also in expectation of engaging in sustainable behavior (Van der Linden 2018).

Recent evidence from more than 800 consumers in Germany suggests this positive affect, often referred to as a warm glow, to be a strong motivator of action among specific subgroups of the population and for specific types of action (Van der Linden 2018, Iweala et al. 2022). For

instance, although the warm glow effect translates to a higher WTP only in older, more affluent, respondents, Iweala et al. (2022) demonstrate that proenvironmental causes induce positive affect just as much as prosocial causes. Zooming in on concrete sustainable behaviors, warm glow seems to be a main driver of simple and small everyday actions (e.g., switching off lights), rather than more-involved behaviors [e.g., buying energy from sustainable sources (Van der Linden 2018)]. Importantly, the role of warm glow appears to go beyond a simple mediator of altruism, strongly motivating proenvironmental behavior as an emotional reward (Hartmann et al. 2017). In line with this view, Harbaugh et al. (2007) demonstrate that reward-related brain regions (including, e.g., VS) show increased activation for donating to a charity. Strikingly, the strength of brain activation indicates the likelihood of donating and is related to higher subjective satisfaction. It remains to be shown whether similar neural processes also mediate positive affect induced by proenvironmental causes. Policy-makers may capitalize on this preliminary evidence of warm glow as an intrinsic social motivator for people who can financially afford to act sustainably (Iweala et al. 2022) in low-cost situations (Van der Linden 2018).

3.2.3. Social norms and social identities. Besides intrinsic drives, extrinsic social motivators influence sustainable action. Considerable behavioral evidence suggests a large impact of norms ascribing what others do and what others think one should do on individual behavior (for a review, see Cialdini & Jacobson 2021). Field investigations suggest that social norms affect how individuals value incentives, impacting their decisions to cooperate or overextract common-pool resources (Cardenas 2011). Consequently, an effective strategy for promoting green behavior may be to make it a social norm (Kraft-Todd et al. 2015).

However, social norms are no panacea for unsustainable behavior. First, their effectiveness strongly depends on a norm's alignment with individual social identities: Messages in line with norm perceptions of the own reference group have substantial positive impact but may be rejected if they stand in contrast to the personal in-group (Cialdini & Jacobson 2021). This challenges the effectiveness of group-based interventions, an area with ample room for future research (Masson & Fritsche 2021). Second, if social norms are effective, how can we explain gaps between ideal and actual consumer behavior? Consumers commonly report to prefer green products, which is at odds with their factual purchase behavior (Eurobarometer 2008). To investigate this curious disparity, Vezich et al. (2017) analyzed fMRI data from participants viewing green and conventional advertisements. Although green advertisements were rated more favorably as the more socially acceptable ones, participant's brain data revealed greater activation in reward-related regions (vmPFC and VS) in response to the conventional ads. Consequently, self-reports may be confounded by the desire to show socially desirable behavior, not affecting the actual decision process.

3.3. Institutional Level

Ideally, scientific insights inform institutional decision-making, e.g., as viable guidelines and policy suggestions. For instance, based on seminal field experimental evidence, Nobel Laureate Elinor Ostrom (1990, 2008) formulates suggestions such as placing common resources under the management of communities that maximally benefit from them, accompanied by local regulation. Further, her basic requirements for sustainable human-resource systems include appropriate infrastructure, advanced technologies unlocking accurate and relevant information, and raised awareness for continuous adaptation and long-term change.

Overall, the institutional-level behavioral literature is rich with suggestions and theoretical frameworks like these, but it lacks empirical evidence. A wealth of theoretical literature incorporates behavioral phenomena into policy design and evaluation [e.g., integrating temporal

ACTIONABLE ITEMS, INSTITUTIONAL-LEVEL EVIDENCE

- Numerous recommendations for state-of-the-art, scientifically informed green interventions exist (Ostrom 2008, Hepburn et al. 2010, Fischhoff 2021, Ranney & Velautham 2021); it is high time for bringing them into actual practice.
- Behavioral economists and neuroscientists need more opportunities to work jointly with policy-makers to inform interventions that leverage our knowledge of the human mind.
- Collaboration beyond one's own home discipline is necessary to account for the complexity of human behavior. This will allow researchers to expand the much-needed evidence on what behavioral interventions work for environmental outcomes and why (Bowles & Polania-Reyes 2012, Allcott & Rogers 2014, Sreen et al. 2020).

discounting in environmental policy (Hepburn et al. 2010)]. Likewise, abundant recommendations exist for policy-makers on applications of multiple behavioral principles [e.g., environmental-transport policy (Hepburn et al. 2010)], strategies to integrate behavioral science in climate models (Fischhoff 2021), and effective climate education (Ranney & Velautham 2021). However, these numerous drafts of state-of-the-art, scientifically informed interventions seldomly find their way into actual practice.

Consequently, the effectiveness of behavioral interventions in environmental public policy is still in its infancy. Initial evidence suggests that information and attention campaigns positively affect energy consumption (Reiss & White 2008) and the market share of green energy (Litvine & Wüstenhagen 2011). Ölander & Thøgersen (2014) showed how targeted nudges based on gain-loss framing, default options, and social norms may increase sustainable energy choices. Conversely, a recent survey in India failed to demonstrate a meaningful impact of government influence on individual green knowledge (Sreen et al. 2020). Similarly, adverse effects of incentives have been reported, indicating common problems of flawed policy design (Bowles & Polania-Reyes 2012). Further, it is yet unclear whether habituation over time may diminish initially positive effects of interventions. Encouraging preliminary evidence suggests that reductions in energy consumption persist even after an intervention's end (Allcott & Rogers 2014), contesting detrimental habituation. Nonetheless, there is ample room for future research to explore the temporal stability of interventions and their potential for wider application (see sidebar titled Actionable Items, Institutional-Level Evidence).

4. THE TIME IS RIPE FOR ACTION

The dramatic effects of climate change have become a dangerous reality for increasingly more humans on Earth. Consequently, we live in a time with unprecedented international awareness for environmental issues and a demand for effective environmental policy. In fact, all member states of the United Nations adopted the 2030 Agenda for Sustainable Development (Lee et al. 2016), committing themselves to a transformative vision for environmental, economic, and social development. It is of vital importance to use this momentum to enrich policies with scientifically grounded insights to make an impact now and quickly.

While the time is ripe for policy action, it is also ripe for much more concentrated research efforts. The advent of interdisciplinary and experimental approaches uncovers how humans value environmental resources, which aspects may be particularly salient, and where to expect barriers to green action. Going forward, we may continue to leverage the unique potential of experimental economics, harnessing incentive-compatible elicitations in contrast to less reliable self-reports. Similarly, applying neuroeconomic methodology to aspects of environmental valuation promises

a more direct view into the human mind. That said, although we report larger trends and preliminary lessons emerging from behavioral and neuroeconomic studies, very little is known regarding the potential and efficacy of policy interventions at much larger scales and in more economically involved domains (Velez & Moros 2021).

Integrating behavioral economics and neuroeconomics findings paves the way for more comprehensive and powerful economic models, providing economists with the means to answer fundamental questions that have so far been inaccessible. The evidence presented in this review, together with ample work distilling human-grounded recommendations for policy-makers (Ostrom 2008, Hepburn et al. 2010, Fischhoff 2021, Ranney & Velautham 2021), gives clear pointers for suitable action. This includes accounting for the inter- and intraindividual particularities of individuals (e.g., individual economic circumstance), fostering cooperation, and leveraging intrinsic motivations and extrinsic social drivers.

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