

## How do we reinforce climate action?

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## **Summary**

Humanity has a shrinking window to drastically reduce greenhouse gas emissions, yet climate action is severely lacking on the individual and policy levels. We argue that this is because behavioral interventions have largely neglected the basic principles of operant conditioning as one set of tools to promote collective climate action. In this perspective, we propose an operant conditioning framework that uses reinforcement to encourage low-emission behaviors and punishment to discourage high-emission behaviors in the domains of transportation, food, waste, housing, and civic actions. This framework not only helps explain positive and negative spillovers, but also provides a recipe to design individual-level and system-level interventions to generate and sustain low-emission behaviors to help achieve net zero.

## Introduction

Humanity needs to reduce greenhouse gas (GHG) emissions by 45% by 2030 to reach net zero emissions by 2050 to prevent the worst effects of climate change.<sup>1</sup> Despite a crushing sense of urgency to act, most countries are falling short of their climate targets. A recent analysis examined 180 countries' national efforts to mitigate climate change, and found that 97% of them are not on track to reach net zero by 2050.<sup>2</sup> In fact, global GHG emissions from fossil fuels have increased by 1% from 2021 to 2022, setting a new record of 37.5 billion tons (4.7 tons per person),<sup>3</sup> making emission reduction even more difficult.

To reduce emissions, we need to address the action gap where collective behavior change is severely lacking. For example, electric vehicles (EVs) continue to have a low market share in most countries, despite their increasing availability and affordability.<sup>4</sup> In the U.S., only around 5% of people follow a vegetarian diet, 0.5% of whom are vegan;<sup>5</sup> people throw out an average of their own body weight in garbage every month;<sup>6</sup> and the majority of the public continue to consume fossil-fuel based energy rather than renewable energy,<sup>7</sup> despite robust evidence that these behaviors contribute immensely to anthropocentric climate change.<sup>8</sup> For civic action, only 1% of the U.S. population is participating in a campaign to convince elected officials to take action to reduce global warming.<sup>9</sup>

Changes to people's behaviors, infrastructure, and technology can reduce emissions by 40-80% in industry, food, transport, and building end-use sectors.<sup>10</sup> A recent study estimates that living car-free can reduce GHG emissions by 2 tCO<sub>2e</sub> per capita per year on average, eating a plant-based diet by 0.9 tCO<sub>2e</sub>/cap, sharing and consuming services rather than material items by 0.3 tCO<sub>2e</sub>/cap, and using renewable energy by 1.5 tCO<sub>2e</sub>/cap.<sup>8</sup> These four actions collectively can reduce 4.7 tCO<sub>2e</sub>/cap which will help reach net zero from the current level of 4.7 tCO<sub>2e</sub>/cap.

It is important to first recognize the enormous inequality in GHG emissions across countries, where higher-income countries emit disproportionately more than lower-income countries.<sup>11</sup> Even within a given country, higher-income individuals emit disproportionately more than lower-income individuals.<sup>12</sup> This inequality emphasizes the need for equity considerations when promoting climate action across income groups and countries. In this paper, we focus on climate action within the higher-income industrialized context, although proposed solutions may also apply to other contexts.

The big question is: Why are people not taking action to combat climate change? There are several barriers at the individual level and the system level that contribute to a lack of climate action. At the individual level, climate action tends to emphasize the need for personal sacrifice to reduce consumption-related emissions (e.g., drive less, fly less, eat less meat),<sup>13</sup> framing the choice as an agonizing tradeoff between immediate individual well-being and future planetary well-being.<sup>14</sup> Climate action is often moralized, with undertones of shame and guilt to try to make people feel responsible for their carbon-emitting behaviors.<sup>15</sup> In addition, the doom-and-gloom narratives that portray the devastations from climate change can leave people feeling paralyzed, anxious, and afraid.<sup>16–18</sup> Moreover, climate action, such as taking public transit, purchasing renewable energy, and paying for carbon taxes, is often perceived as inconvenient and costly.<sup>19</sup> Beyond cost concerns, cognitive biases (e.g., status quo bias, present bias) can prevent people from switching their current high-emission behaviors to low-emission behaviors.<sup>20,21</sup> Finally, tangible rewards for climate action, such as rebates for purchasing EVs, and receiving \$0.10 for every recycled bottle, are often rare, infrequent, or too small to meaningfully change behavior.<sup>22,23</sup>

At the system level, there is a lack of climate-friendly policy (e.g., subsidies for plant-based foods) and infrastructure (e.g., renewable energy, bike lanes, public transit).<sup>24</sup> The current climate-

unfriendly policies that remain in place (e.g., government subsidies to fossil fuel and cattle industries) increase the difficulty for people to take climate action.<sup>25,26</sup> These system-level barriers are incredibly hard to remove, especially since they are partly driven by strong interest groups from the fossil fuel industry.<sup>27</sup> The lack of immediate and effective government action on climate change has caused many people, especially youth, to feel hopeless and depressed,<sup>28</sup> which does not encourage individual climate action.

Beyond barriers, there are also enablers at the individual and system levels that contribute to the maintenance of existing high-emission behaviors. In industrialized countries at the individual level, driving a gasoline-powered vehicle is still the most convenient mode of transport for most people;<sup>29</sup> beef, lamb, and dairy attract consumers based on their taste and relative affordability;<sup>30</sup> it is often easier to throw away and replace clothes and items rather than repairing them; and single-family homes powered by fossil fuel based energy are the most common housing type in developed countries and are viewed as a status symbol.<sup>31</sup> These enablers are supported by system-level driving forces, such as car-friendly public transit systems, government subsidies to fossil fuel and cattle industries, and landfill dumping waste management practices.

### **Challenges with Previous Behavioral Interventions**

Behavioral interventions can help remove the barriers for climate action and remove the enablers for current climate-unfriendly action, with the goal of instigating, spreading, and sustaining behavior change to reduce GHG emissions.<sup>32,33</sup> Policy and infrastructure change (e.g., installing bike lanes) can serve as system-level interventions to promote collective climate action and is instrumental in removing the barriers and enablers for behavior change. However, previous behavioral interventions have not been able to significantly reduce GHG emissions. In past studies, personal values, beliefs, and attitudes have been shown to influence climate action; therefore,

many existing interventions have focused on changing values, beliefs, and attitudes about climate change to elicit climate action.<sup>34,35</sup> Climate anxiety (i.e., feeling worried about climate change) has been shown to predict some, but not all, types of environmental action.<sup>36</sup> Yet, values, beliefs, and attitudes take a long time to establish and are often not predictive of actual behavior.<sup>35</sup> Motivations for engaging in climate-friendly behaviors often differ between socio-economic groups. Higher-income individuals tend to engage in climate-friendly behaviors for environmental concerns, whereas lower-income individuals tend to engage in these behaviors due to financial concerns.<sup>37</sup>

Recent studies have focused on other ways to nudge climate behaviors, such as changing the choice architecture (e.g., making renewable energy the default), using social comparisons (e.g., showing how others are doing), and providing personalized information (e.g., using tailored recommendations), which have shown small to moderate effects.<sup>32,33,38,39</sup> Many nudges to promote climate action have not been highly effective. For example, a recent study conducted five large-scale field experiments nudging employees of a large organization to carpool. They sent letters and emails, provided non-cash incentives, and created personalized travel plans, but found no effect of these interventions; the reason is likely due to difficulties in changing habitual behaviors, the lack of cultural norms, and the lack of climate-friendly infrastructure.<sup>40</sup> Moreover, the longevity of the intervention effects is not well understood, since most studies do not track long-term behavior change beyond a few weeks.

Even if desirable behavior change does occur, it does not mean that the behavior change will result in intended benefits (e.g., reduced GHG emissions) because of potential negative spillover. Negative spillover is when an intervention leads to a change in the target behavior but decreases the likelihood of engaging in a subsequent behavior, which can cancel out the overall effects.<sup>41</sup> An example is a nudge that makes renewable energy the default may conversely reduce

public support for a carbon tax policy.<sup>42</sup> Another example is new consumers of cheaper, more efficient solar-powered electricity knowingly or unknowingly increase their energy consumption.<sup>43</sup> By some measures, negative spillover can reduce efficiency gains by 60-100% across the economy.<sup>44</sup> However, spillovers are not always negative. Positive spillover occurs when an intervention leads to a change in the target behavior and also increases the likelihood of engaging in a subsequent behavior. An example is that a small fee (\$0.06) reduced the use of single-use plastic bags and increased the use of reusable bags, and also increased people's support for other environmental policies.<sup>45</sup> To date,<sup>45</sup> there is no consensus on when or why spillovers occur. Only a few existing frameworks have been proposed to explain spillovers.<sup>41,46,47</sup> These frameworks suggest that negative affect-based decisions tend to produce negative spillovers, whereas role-based decisions that enhance environmental identity tend to produce positive spillovers.<sup>41</sup> Interventions targeting intrinsic motivations or similar behaviors tend to produce positive spillovers.<sup>48</sup> Interventions supporting personal autonomy, with an explicit rationale explaining why the behavior is important, and addressing normative goals (environmental protection) or personal gain goals (financial savings) tend to produce positive spillovers.<sup>49</sup> Positive spillovers are likely due to environmental identity, a desire for consistency, and self-efficacy beliefs; in contrast, negative spillovers are likely due to moral licensing and rebound effect.<sup>46</sup> However, the evidentiary basis for these frameworks has been weak, since multiple recent meta-analyses suggest that there are no consistent overall spillovers across pro-environmental behaviors or intentions.<sup>41,46,48,49</sup>

The challenge of changing behaviors, mitigating negative spillover, and promoting positive spillover to address climate change has remained difficult. We believe that past behavioral interventions have shown limited efficacy because they have not considered the fundamental principles of behavior change from an operant conditioning perspective. Previous interventions

have primarily focused on the determinants of a target behavior,<sup>50</sup> by removing the restraining forces or increasing the driving forces of that behavior.<sup>51</sup> However, rarely has any intervention examined what happens after the behavior, despite the consequence of the behavior playing a critical role in shaping that behavior.

To close the action gap and reduce emissions, operant conditioning can be particularly useful as one set of tools to promote climate action. It involves using reinforcement or punishment that follows the behavior to influence that behavior.<sup>52–54</sup> Operant conditioning principles have been used over the past century to effectively change behavior in a large number of domains, including weight loss,<sup>55</sup> smoking cessation,<sup>56</sup> reducing mobile phone use,<sup>57</sup> improving sports performance,<sup>58</sup> and reducing procrastination.<sup>59</sup> In fact, many industries such as gambling and social media have used operant conditioning principles successfully to promote user behaviors to reap profits that can be harmful to the users themselves (e.g., to increase the use of slot machines, or user engagement on social media).<sup>60</sup> Our goal in this paper is to use operant conditioning principles ethically to promote positive behavior change to increase human and planetary well-being.

Here we propose a framework using operant conditioning principles to encourage low-emission behaviors and to discourage high-emission behaviors in the domains of transportation, food, waste, housing, and civic actions. The reason to focus on behaviors in these domains is that they tend to have the largest carbon reduction potentials to reach net zero emissions.<sup>8</sup> The principles underlying this framework can be considered universal across cultures;<sup>61</sup> however, the application of these principles may vary across different groups and socio-economic contexts. This framework also offers a new account for spillovers and suggests strategies to mitigate negative spillover and promote positive spillover.



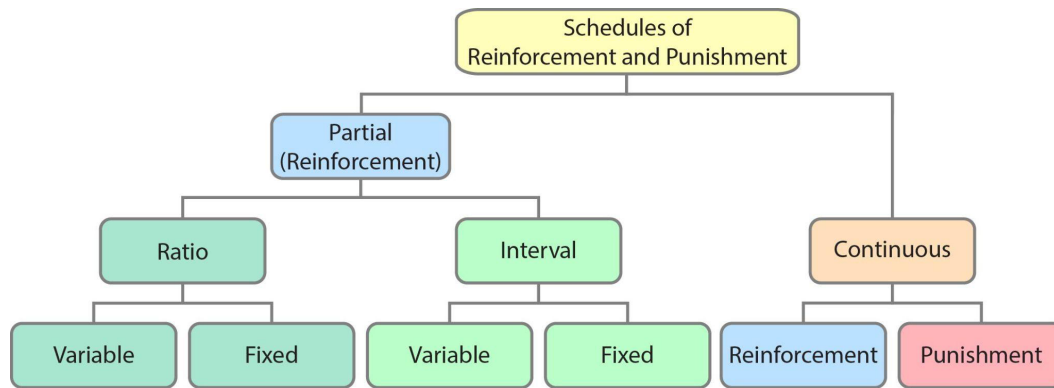
## An Operant Conditioning Framework for Climate Action

Operant conditioning is a form of associative learning about the relationship between a consequence and a behavior. **Behavior** refers to both covert internal behavior, such as decision making, and overt, externally observable behavior, such as executing a decision. The premise of operant conditioning is that behaviors followed by pleasant consequences tend to be repeated and behaviors that produce unpleasant consequences are less likely to be repeated.<sup>62</sup> This framework aims to reinforce the behaviors themselves rather than the outcomes. This means that reinforcement occurs following a target behavior (e.g., biking), not the outcome of the behavior (e.g., reduced emissions). This is because focusing on outcomes rather than the behavior itself can result in maladaptive behaviors (e.g., cheating). For example, weight-loss interventions that reward people based solely on how many pounds they lose can lead to unhealthy lifestyle changes (i.e., starving oneself). This is why most interventions reward healthy behaviors (e.g., exercising, healthy food choices) that lead to weight loss instead of rewarding how many pounds are lost.<sup>55</sup> In our context, the proposed interventions are designed to reward the behaviors that lead to reduced emissions, instead of rewarding based on reduced emissions per se.

**Reinforcement** occurs when a consequence has increased a behavior. There are two types of reinforcement: positive and negative. **Positive reinforcement** is when a consequence is *added* following a behavior that *increases* the likelihood of that behavior occurring in the future. **Negative reinforcement** is when a consequence is *removed* following a behavior that *increases* the likelihood of that behavior occurring in the future. It is also important to distinguish between rewards and reinforcers. A **reward** is a consequence perceived to be of positive value, such as natural rewards (e.g., sugar), financial rewards (e.g., money), social rewards (e.g., praise), and symbolic rewards (e.g., stars). A **reinforcer** is a consequence that functions to increase the desired

behavior in the future, regardless of perceived value. A reward is not a reinforcer if it does not increase the behavior.<sup>52</sup>

Reinforcement can help remove the individual-level and system-level barriers mentioned earlier. For example, some climate actions can feel punishing because they involve substantial upfront cost or effort (e.g., purchasing renewable energy, taking public transit). Positive reinforcement can use a variety of rewards (e.g., financial, social, symbolic, natural) to reduce or remove these barriers to encourage low-emission behaviors. Negative reinforcement can also promote climate action by reducing feelings of guilt, shame, and anxiety (predicated, of course, on someone experiencing these feelings).<sup>36</sup> There are different schedules of reinforcement (Figure 1). **Continuous reinforcement** (i.e., each instance of a behavior is reinforced) is best when establishing a new behavior because it allows people to associate the new behavior with the reinforcer quickly.<sup>63,64</sup> **Variable ratio schedule** (i.e., an individual receives a reinforcer after a variable number of behavioral responses) tends to be the most effective in sustaining the new behavior over time<sup>63</sup> and is the most resistant to **extinction** (i.e., when the behavior is no longer reinforced and subsequently diminishes).<sup>65,66</sup> In general **variable schedules** (i.e., reinforcement is delivered unpredictably) tend to be more effective than **fixed schedules** (i.e., reinforcement is delivered predictably), and **ratio schedules** (i.e., reinforcement is contingent on the number of behavioral responses) tend to be more effective than **interval schedules** (i.e., reinforcement is contingent on the behavioral response after a certain amount of time).<sup>63,66</sup>



**Figure 1.** Schedules of reinforcement and punishment.

While reinforcement can encourage low-emission behaviors, it does not discourage high-emission behaviors. **Punishment** is a necessary tool to reduce high-emission behaviors by eliminating the individual-level and system-level enablers. **Punishment** occurs when a consequence decreases a behavior.<sup>52</sup> There are two types of punishment: positive and negative punishment. **Positive punishment** occurs when a consequence is *added* following a behavior that *decreases* the likelihood of that behavior occurring in the future. Positive punishment may use a variety of financial punishments (e.g., fees, taxes) and social punishments (e.g., disapproval, shame), but it often produces unintended consequences such as reactance, aggression, and response substitution, so positive punishment must be used with caution.<sup>67</sup> **Negative punishment** is when a consequence is *removed* that *decreases* the likelihood of that behavior occurring in the future. Negative punishment is typically preferable over positive punishment, as it removes the existing reinforcers that are maintaining high-emission behaviors and may produce fewer unintended consequences in the target audience.<sup>68</sup> It is important for punishment to always follow a continuous schedule,<sup>74</sup> because if punishment is not continuous (i.e. an individual is sometimes punished for an undesirable behavior), it then becomes variable reinforcement for the undesirable behavior which becomes harder to extinguish in the future.<sup>64,65</sup>



**Figure 2.** Examples of positive and negative reinforcement to encourage low-emission behaviors and positive and negative punishment to discourage high-emission behaviors in transportation, food, waste, and housing domains.

The key principle of this framework is to **reinforce low-emission behaviors**, while **punishing high-emission behaviors**, such that low-emission behaviors eventually come to replace the previous high-emission behaviors (Figure 2). This is called **differential reinforcement of alternative behavior**, which is a technique that involves implementing positive reinforcement for the desirable behavior in conjunction with punishment for the undesirable behavior.<sup>69,70</sup>

### **Factors to Consider**

Several factors can influence the effectiveness of reinforcement, such as immediacy, satiation and deprivation, and the magnitude of the reinforcer.<sup>71,72</sup> One important factor that is often neglected in climate incentive programs is the **immediacy** of the reinforcement. For any intervention to be effective, reinforcement must be delivered immediately following the behavior. Reinforcement delivered with a delay can reduce the impact on the behavior. Many current incentives (e.g., EV rebates) are provided weeks or months following the initial behavior, which can weaken the effect of the reinforcement.<sup>73</sup> Other rebates (e.g., carbon tax rebates) are automatically processed in the tax system months later, which means that people may not remember what the rebate is for.<sup>74</sup> It is imperative that reinforcement occurs as close to the target behavior as possible for maximum effectiveness.<sup>75</sup>

**Satiation** is when the impact of the reinforcer is reduced if the individual perceives that they already have enough of the reinforcer being offered, and **deprivation** is when the impact of the reinforcer is strengthened if the individual perceives that they are deprived of the reinforcer being offered.<sup>72</sup> This means that the same financial incentive from climate rebate may be less attractive to higher-income individuals than to lower-income individuals, because of the relative magnitude of the incentive. The **magnitude** of the reinforcer also correlates with the effectiveness. This means that the small financial rewards for recycling bottles or bringing reusable bags may

not be sufficiently incentivizing for most people. Continuous reinforcement could lead to satiation which can reduce the effectiveness of the intervention, whereas satiation is less likely to occur when using partial reinforcement.

The type of reward, such as natural (e.g., sugar), social (e.g., praise), financial (e.g., cash), symbolic (e.g., a gold star), or intrinsic (e.g., warm glow), affects the efficacy of an intervention. Which reward works best is highly idiosyncratic, depending on the preferences and experiences of the individual. Studies have found that financial incentives can promote the initial behavior change more effectively than social rewards,<sup>76,77</sup> but financial rewards are often not effective for maintaining long-term behavior change, and instead natural, intrinsic, or social rewards tend to be more effective over time.<sup>78</sup>

**Generalization** is another factor to consider when designing interventions. It occurs when a behavior change has lasted over time, occurred in many environments, or spread to related behaviors.<sup>79</sup> One type of generalization is **response generalization**, when the individual spontaneously engages in a new behavior that is functionally equivalent (i.e., serves the same function) to the target behavior.<sup>79</sup> Generalization can help inform our understanding of spillovers in climate action. While most studies on pro-environmental behavior interventions examine spillovers as an unintended consequence of the intervention,<sup>48,49</sup> here we view spillovers as response generalization that can be incorporated into the intervention.

In what follows, we propose individual-level and system-level interventions to encourage and sustain low-emission behaviors, while discouraging high-emission behaviors, in domains of transportation, food, waste, housing, and civic action. Since different rewards may function as reinforcers for different behaviors, we will provide examples of a variety of rewards in each domain.

## Transportation Behaviors

Increasing low-emission transportation behaviors such as biking, taking public transit, driving EVs, and carpooling can greatly reduce GHG emissions. At the system level, positive reinforcement can involve installing bike lanes, making the public transit system safer, and providing subsidies to EVs as a financial reward. Once it becomes feasible and safe for people to bike and take public transit, a continuous reinforcement schedule can be used to establish the new bus-taking or subway-taking behavior by providing financial rewards (e.g., a free bus pass for a month),<sup>80</sup> or providing praise every time they board the bus or subway as a social reward (e.g., “Thank you for riding the bus, you are helping save the planet!”).

To sustain the behavior after it has been established, a variable ratio schedule can be used by providing a free ticket to the passengers as a financial reward at random intervals. A variable interval ratio schedule can be used to provide praise at random intervals on the ticket machine as a social reward. The addition of bike lanes can be positive reinforcement to biking because of the increased feelings of safety, and the physical exercise and euphoric feeling provided by biking as a natural reward.<sup>81</sup> Charging stations for EVs, and bike or car rental stations, could be set up like slot machines to provide rewards to reinforce driving EVs or renting bikes and cars. For example, the station could generate an intermittent reward (e.g., a gift card). Carpooling is another form of positive reinforcement that provides the social reward of spending time with friends or family in the car, but these social rewards are likely insufficient to overcome larger barriers, such as the lack of climate-friendly infrastructure.<sup>40</sup> Other forms of positive reinforcement (e.g., a free delicious meal for everyone who carpooled to work) can be used to encourage more people to begin carpooling. This behavior should then be relatively easy to sustain since it is inherently socially reinforcing. A form of negative reinforcement to encourage people to choose low-emission

behaviors over driving alone can be removing parking fees or tolls for EVs, or reducing the effort of taking public transit by making public transit more prevalent by building more rapid transit systems, which will make public transit more easily accessible and more convenient for people to choose. Working from home or video-conferencing may also result in negative reinforcement because it removes the time and monetary cost of travel.

At the same time as reinforcement, punishment can be used to discourage high-emission behaviors to encourage people to switch modes of transport. A form of positive punishment is adding a carbon tax to gasoline or diesel, or adding congestion fees to reduce driving.<sup>82</sup> However, there are negative side effects of positive punishment that can decrease its efficacy. For example, one requirement of punishment is that it has to be sufficiently large at the outset to discourage the undesirable behavior. If the punishment is not large enough, it gives people time to cope with the punishment rather than change their behavior.<sup>71</sup> Many carbon tax policies keep the tax relatively small to not provoke public outrage, and then slowly increase it over time.<sup>83</sup> This strategy is unlikely to decrease driving unless the cost is substantially increased. Moreover, side effects can include avoidance behavior and aggression.<sup>67</sup> Companies tend to move to areas without carbon tax rather than changing their high-emission practices, and individuals sometimes express anger toward a carbon tax.<sup>84,85</sup> This can lead people to act in opposition to climate policy and not vote for similar taxes or pro-climate political leadership.<sup>85</sup> Negative punishment is preferred instead to decrease the negative side effects, for example, by removing government subsidies to the fossil fuel industry and reallocating them to renewable energy industries as a form of differential reinforcement. To encourage low-emission transportation behaviors, governments can reallocate funding that was budgeted for new parking structures and highways and revenue from carbon tax to improving public transit (e.g., building rapid transit).



## Food Behaviors

Encouraging higher consumption of plant-based food can help reduce GHG emissions.<sup>86</sup> At the system level, governments can provide subsidies to the plant-based food industry as positive reinforcement to businesses, and businesses can make plant-based food more tasty, nutritious, and affordable, and offer rewards (e.g., free meals) as positive reinforcement to consumers to remove the barriers of cost and less appealing taste of some plant-based food. For example, restaurants can offer discounted but delicious plant-based meals to attract consumers first, and then use a reward program that allows people to receive a random plant-based meal for free as a variable ratio schedule of reinforcement. The reward program itself acts as a symbolic reward, the free plant-based meal is a financial reward, and the tastiness of the meal is a natural reward. Stamp cards can also work as a fixed ratio schedule of reinforcement that provides every  $n$ th meal for free. Negative reinforcement for choosing to eat plant-based food can also be used by removing the barriers of inconvenience or lack of availability of plant-based food. For example, restaurants and grocery stores can make plant-based food more readily available and easier to access for consumers. Recently, 11 public hospitals in New York City have made plant-based meals as the primary dinner option by default for inpatients.<sup>87</sup> Making plant-based meals the default is a form of negative reinforcement by removing the effort involved in food decision-making for people who want to eat plant-based food, but may be positive punishment for people who want to eat meat because the effort of ordering a meat-based meal is increased.

Speaking of punishment, high-emission food behaviors (e.g., eating beef, lamb, and dairy products) can be discouraged with positive or negative punishment, at the same time as using reinforcement to encourage people to switch to the plant-based diet. Positive punishment involves adding a meat tax to beef, lamb, and dairy products to make them more expensive than plant-based

alternatives, and negative punishment involves removing government subsidies to the cattle industry. These subsidies and the revenue from the meat tax can be reallocated to the plant-based food industry as a form of differential reinforcement. This said, punishment should be used with caution to avoid exacerbating the existing food insecurity problems in certain communities.<sup>88</sup>

## **Waste Behaviors**

Reducing consumer waste is an important step toward reducing GHG emissions. Low-emission behaviors include reducing food waste, repairing or donating clothes and technology products, reusing and recycling items. At the system level, policies can be enacted to incentivize companies to upcycle or donate food, clothing, and consumer products instead of throwing them away. Right-to-repair policies can be set up to support businesses and manufacturers in offering repair services that are easy to access and affordable for consumers. To encourage waste reduction behavior at the individual level, positive reinforcement can be providing financial rewards for using meal planning services to reduce food waste, creating tasty and attractive dishes using leftover ingredients or food products that are about to be thrown away, and providing sufficiently large financial rewards for repairing, reusing, or recycling personal items. There are at least two reasons to provide sufficiently large financial rewards. First, they can prevent crowding out intrinsic motivations from receiving small financial incentives.<sup>78,89</sup> Second, small incentives may not be sufficiently motivating for people to engage in the behavior. For example, some recycling policies provide \$0.05 or \$0.10 for each bottle returned,<sup>23</sup> which follows the continuous reinforcement schedule but the amount may be too small for most people. A potentially more effective intervention is to change this policy to a variable ratio schedule that provides a larger financial reward after a variable number of bottles returned (e.g., instead of receiving \$0.10 per bottle, there is a 1% chance of getting \$10 per bottle). Making rewards uncertain has been shown

to increase the frequency of a repetitive behavior, even when the certain reward is larger in magnitude.<sup>90</sup> This reinforcing-uncertainty effect is consistent with the fourfold pattern of risk preference, where people prefer a small chance to win a large reward over getting a guaranteed small reward.<sup>91</sup> The variable ratio schedule should complement rather than replace the continuous reinforcement schedule, since some individuals rely on the certain rewards from bottle returns for their livelihood.<sup>92</sup> Another positive reinforcement intervention may be to encourage people to get together with friends to swap used items, which can serve as a social reward (social interactions) and a financial reward (a free item). Negative reinforcement for choosing to reduce waste may occur by reducing the effort and time involved in accessing these services (e.g., repair, recycle, upcycle) that lead to waste reduction.<sup>37,92</sup>

Positive punishment can be used to discourage high-emission waste behaviors such as dumping waste in landfills. Many cities impose a small fee for single-use items (e.g., plastic bags),<sup>93</sup> but these fees can be increased as a form of positive punishment to more effectively discourage the use of single-use items. Another form of positive punishment is to fine excessive waste dumping, or to ban dumping food waste in landfills altogether. The revenue from the fees can be used as incentives for upcycle and repair services. Negative punishment can involve removing the convenience of garbage disposal by reducing the garbage bins or putting them in inconvenient places. However, punishment alone may backfire (e.g., public outrage, contamination in recycling and compost bins),<sup>94</sup> so it is important to use punishment selectively and strategically in tandem with reinforcement.

## **Housing Behaviors**

Living in an attached home (e.g., apartments, townhomes) with renewable energy can greatly decrease GHG emissions compared to living in detached houses with fossil fuel-based

energy. At the system level, housing policies can increase property taxes for single detached houses, reduce property taxes for attached houses, and make renewable energy and heat pumps the default in newly constructed buildings. Governments can incentivize the switch to renewable energy by providing substantial subsidies. At the individual level, the decision of choosing where to live and what energy to use is rare compared to decisions around transportation, food, and waste behaviors. Thus, there are fewer interventions for reinforcing housing behavior and they are mostly constrained to continuous schedules of reinforcement or punishment. For example, to encourage people to live in attached homes or to choose renewable energy, positive reinforcement such as large financial incentives could be helpful (e.g., a \$10,000 moving bonus, a \$500 bonus to offset electricity bill when a household switches to renewable energy). Negative reinforcement for choosing renewable energy can be accomplished by removing the effort involved in switching to renewable energy or getting solar panels (e.g., simplifying the application process). Positive punishment to discourage people from choosing to live in detached houses can include substantially increasing property tax and inheritance tax for detached homes. Negative punishment can involve removing subsidies and financial aid for detached home buyers and owners. The revenue from the taxes and subsidies can be reallocated to incentivize living in attached homes and the switch to renewable energy.

### **Civic Behaviors**

Civic behaviors such as voting, protesting, and signing petitions can lead to larger system-level changes that substantially decrease GHG emissions.<sup>13</sup> Social rewards such as social support, connection, and recognition can reinforce the likelihood of joining climate rallies and protests and voting. These social rewards can occur through social interactions at the events in person or on social media. Free public transit can be provided to people attending the rallies or going to vote as

a financial reward. The “I voted” sticker is a symbolic and social reward that can reinforce voting behavior. Similarly, a lottery could be used for people who have voted, similar to the vaccination lottery from the Government of Canada to encourage Canadians to get vaccinated against Covid-19.<sup>95</sup>

To help people make a decision on whether to participate in civic actions in the first place, negative reinforcement can help by reducing the current barriers. Most civic behaviors (e.g., voting, contacting elected officials) take a lot of effort and time which can serve as punishment. Thus, reducing the effort involved in voting, contacting elected officials, and participating in climate rallies can be a form of negative reinforcement to increase the frequency with which people engage in these actions. For example, creating an accessible “cheat sheet” of different parties and candidates that outline their policy goals and proposals would make it easier for people to make a decision on who to vote for. Another intervention is to increase the number of polling stations to decrease wait times to make voting less time consuming. Making information readily available (e.g., through a website) about each elected official, their contact information, and what concerns they handle, would make it easier for constituents to decide who to contact in their jurisdiction to discuss climate policy. Finally, for people experiencing climate anxiety and depression, engaging in civic action can help alleviate these negative emotions which may serve as negative reinforcement.<sup>96</sup>

## **Spillovers**

Behavioral interventions at the individual level have been criticized for the resulting negative spillover onto system-level interventions.<sup>97</sup> We argue that it is because the behavior from the intervention is rarely positively reinforced. We propose three conditions for positive spillover to occur from an initial behavior to a subsequent behavior: (1) the initial behavior is positively

reinforced (e.g., by social or symbolic rewards, or identity reinforcers like the warm glow),<sup>98</sup> (2) the subsequent behavior is followed by a naturally occurring positive reinforcer, and (3) the subsequent behavior is functionally equivalent to the initial behavior. For example, a small fee (\$0.06) reduced the use of single-use plastic bags and increased the use of reusable bags, and also generated positive spillover to increase public support for other similar policies such as adding charges for plastic bottles and excessive packaging in the UK.<sup>45</sup> This may be due to the possibility that the increased use of reusable bags enhanced people's environmental identity, which serves as natural positive reinforcement (e.g., feeling good about themselves for using reusable bags). The resulting increase in support for similar policies may enhance people's environmental identity as natural positive reinforcement, and provide the same function of reducing plastic waste.

We also propose two conditions for negative spillover to occur from an initial behavior to a subsequent behavior: (1) the initial behavior is not positively reinforced, and (2) the subsequent behavior is perceived to lead to a similar consequence. Negative spillover is especially likely if the initial or subsequent behavior involves personal sacrifice (e.g., costs, effort), which functions as a form of punishment that can decrease the behavior. For example, a default nudge made people purchase renewable energy which involved more costs, but subsequently lowered people's support for a carbon tax policy which would cost them even more.<sup>42</sup> This may be due to the possibility that the additional cost was perceived as a punishment and the behavior was not positively reinforced, which made subsequent behaviors that also involved financial cost less likely (e.g., paying for carbon taxes). This framework bridges a critical gap in the literature by highlighting the importance of reinforcement and punishment for understanding spillovers.

The type of reward also influences the likelihood of spillovers. For example, financial rewards, which are often perceived as compensation for a given behavior rather than an inherent

consequence of the behavior, are unlikely to generate positive spillover to other behaviors. Free bus passes are likely to reinforce bus-taking behavior, but they may not lead people to take shorter showers. Other types of rewards, such as natural, social, and intrinsic (e.g., biker's high, feeling good after hanging out with friends) are more likely to generate positive spillovers. For example, if an individual experiences a positive mood after biking to work, their behavior might spill over to walking to work, if walking is also followed by the positive mood.

The current framework can explain previous accounts of spillovers. Attitude change<sup>99</sup> from an intervention (i.e., greater care for the planet) can broaden the set of behaviors that are experienced as functionally equivalent, making seemingly different behaviors serve the same function to help the environment. However, changing attitudes may take a long time. Additionally, identity reinforcement<sup>41</sup> and increased self-efficacy<sup>46</sup> can be considered as forms of positive reinforcement in our framework. For negative spillovers, the moral licensing effect can be explained by a lack of positive reinforcement following the initial behavior, which leads people to seek a reward for the behavior by generating moral credits. The crowding out effect is a case of a financial reward not functioning as a reinforcer. The rebound effect is a form of negative reinforcement because the efficient product removes the higher cost of the inefficient product, which increases the consumption of the more efficient product. Finally, risk compensation occurs when a risk-reducing intervention lowers the perceived risk of the behavior as a form of negative reinforcement and therefore increases the risky behavior itself.<sup>46</sup> These examples suggest that negative reinforcement alone is not sufficient to promote positive spillovers. Existing climate action tends to be negatively reinforced (e.g., reduced feelings of guilt, shame, and anxiety), but negative reinforcement is likely insufficient for generating positive spillover.<sup>15,36</sup> This framework highlights the need to use positive reinforcement to promote positive spillover in climate action.

## **Conclusion**

In summary, the operant conditioning framework presented here can encourage low-emission behaviors using reinforcement and discourage high-emission behaviors using punishment across multiple domains, while promoting positive spillover with positive reinforcement. Researchers can test the efficacy of this framework by examining the different schedules of reinforcement, different types of rewards, and spillovers across diverse sets of behaviors and audiences. Policymakers, businesses, and stakeholders can implement this framework at the system level and individual level to help achieve the net zero target by 2050.



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