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Executive Summary

Waste is unique. As a concept, it is mostly a matter of perspective—is this something that still has use, or not? Unlike other resources, like water and energy, waste is measured as a stock (i.e., it accumulates) rather than a flow. Unlike greenhouse gas emissions, it is visible and tangible. And unlike other environmental problems, it is easy for the average consumer to connect their individual actions to global consequences: we all use items that we dispose of that are recognizable in frontline communities and the natural environment. But despite its tangibility, and despite growing consumer concern about issues of waste-related pollution, the trash problems we face are bad, and without concerted action, are going to get much worse (Borrelle et al., 2020; Kaza et al., 2018; Lim, 2021; Wilson & Velis, 2015).

This research examines what people think are effective strategies to manage waste. Understanding what people think are effective solutions to these problems could help address the gap between public concern and persistent waste issues, how consumers behave, and which type of waste management strategies they are likely to support.

Waste is primarily treated as a systems output – but it is also a systems input. In an infamous consumer culture based on perpetual production and consumption, waste is inevitable. **This research examines which part of that equation people tend to focus on (production, consumption, or disposal), and why.**

Experts agree that reducing waste at the source is much more sustainable than managing waste after it is already created, even if that management strategy is recycling (de Wit et al., 2020; U.N. Environment Programme, 2017; US EPA, 2015). However, many institutions persist in promoting opt-in recycling by individual consumers to 'sustainably' manage waste (Jaeger, 2018; MacBride, 2011; Taddonio, 2020). Emerging research has shown that the misplaced focus on recycling is intentionally encouraged by goods manufacturers, namely the fossil fuel, beverage and packaging industries, to defer waste disposal responsibilities onto consumers and prevent disruption of their business models (Jaeger, 2018; Lerner, 2019; MacBride, 2011; Taddonio, 2020).

In 2018, the curtain was pulled back on the waste and recycling industry when China passed the National Sword Act. Previously, the U.S. had been sending over 400 shipping containers of

recyclables to China per day (Dell, 2019). This wasn't solely a U.S. strategy; over 70% of the entire world's plastic waste had previously been sent to China (Brooks et al., 2018). But when China stopped taking our trash, I wondered if that would change how people saw recycling, and if losing an option to 'sustainably' dispose of goods would change the way we consumed. Given this historical emphasis on recycling and a surge of pieces that promoted recycling skepticism (Franklin-Wallis, 2019; Lubben, 2020; Taddonio, 2020), I wanted to examine how members of the American public thought about recycling in comparison to other waste management strategies.

In Study 1 (N=848), my coauthors and I found evidence of a recycling and disposal bias: participants preferred recycling over other, more effective strategies, and they tended to only think about waste at the point of disposal, not at other points in the lifecycle. And despite this preference for recycling, participants demonstrated poor knowledge about the recycling system that limited the efficacy of their preferred strategy. Our results suggested that efforts aimed at promoting recycling had only served to make recycling a salient strategy and had not educated consumers to be effective recyclers. Importantly, however, **the recycling bias was reduced when different end destinations for waste (the ocean vs. landfills) was made salient.**

Our first study had limitations: we had found some evidence for a recycling preference, but hadn't actually asked participants to *rank* different strategies in comparison to each other. We couldn't say with confidence that people thought recycling was better than other strategies, just that it came to mind more readily. Solving our waste problems also requires that people begin to think about production, consumption, and disposal as interconnected parts of the life cycle of the product. We had some evidence from Study 1 that people only thought about waste at the point of disposal, when it could be less effectively mitigated than at other points in the life cycle. In our second study, we wanted to further examine whether people understood waste as a systems problem, and which stage in the cycle they thought efforts should focus.

In Study 2 (N=473), we used four different measures to assess how participants thought about recycling in relation to other strategies and also probed how they understood waste as part of a system of production, consumption, and disposal. **Results showed that recycling was still top of mind when asked open-ended questions, but that as options narrowed, participants got better at choosing source reduction over disposal strategies.** Another

clear difference emerged: participants tended to default to recycling when actions were framed *individually*, but not when they were framed *generally*. On a systems-level, participants understood that upstream interventions would be more effective to tackle issues of waste than disposal-side strategies. However, when it came to their own actions, participants only felt empowered to act in their consumption and disposal behaviors. Qualitative results helped shed light on when people default to recycling and why.

Our results suggest that people do not default to recycling because they believe it is better than source reduction. Instead, they opt into recycling because they feel disempowered to change or opt out of the dominant disposal culture. For participants, recycling feels like the least worst option realistically available to them.

These results add to the growing evidence that limiting the production of items designed to be thrown away could have a much larger impact than focusing on individual actions for sustainable waste management outcomes. Rather than continuing to emphasize recycling as the solitary sustainable waste strategy, policies and interventions should motivate behaviors that avoid the creation of waste, including purchasing more durable products, reuse, buying second-hand goods, and sharing goods. Source reduction strategies at scale, such as large reuse programs and extended producer responsibility legislation, should also be considered as an alternative to the current status quo that makes goods intended to be disposed of and saddles consumers with the responsibility of the end product of these goods. **Recycling is a tool to be used when waste cannot be avoided, not a panacea for the overgeneration of waste.**

The contents of this dissertation include an expanded manuscript and nine appendices. The appendices include full copies of the study materials (Appendices A and B), expansion of data presented in the manuscript (Appendices C–H), as well as a description of my plans for future work (Appendix I) that builds upon this work in concrete applications.

Dedication

To our beautiful planet and all those who reside within it.

Together, may we create a better future than we ever thought possible.

Acknowledgements

When I started this journey, I was still thinking small about the ways we could reimagine our future and promote change on this planet. I'm grateful for the advisors I've had, both formal and informal, who helped set me on the path to thinking bigger. To Morela Hernandez, who provided warm guidance and advice on this challenging academic journey. To Roshni Raveendhran, who was an early and especially kind and enthusiastic academic mentor. To Leidy Klotz, who provided me with flexibility, thoughtfully introduced me to aligned collaborators, and gave me grief when I thought small. To Shahzeen Attari, whose research precision, patience, and persistence helped improve this work—and undoubtedly all my future work—immeasurably. And of course, to my advisor, Arsalan Heydarian, who has always provided enthusiastic support and guidance for my forays into the world of discard studies, waste, and behavior.

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Expanded Manuscript

Reduce, Reuse, or Recycle?

When People Don't Choose the Best Ways to Manage Waste (And When They Do)

Abstract

Reducing generation of waste is far more sustainable than mitigating the impact of waste after it is already created. However, based on two nationwide online surveys (N = 1,321), this research finds a persistent and harmful preference for recycling over source reduction and reuse. Across several measures, recycling is erroneously considered as the more effective option by a significant number of participants. This error was reduced when different destinations for waste were made salient, when fewer choice options were presented, and when actions were framed generally instead of individually. In some instances, participants' responses suggest that they do understand that source reduction is more effective—but still perceive that recycling is the least-worst option available to them. Qualitative results indicate this persistent preference for recycling may result from feelings of disempowerment to change or opt out of the dominant disposal culture. Rather than continuing to emphasize recycling as the solitary sustainable waste strategy, policies and interventions should motivate behaviors that avoid the creation of waste both at the producer and consumer levels.

Keywords: waste, sustainable production and consumption, disposal bias, recycling bias

1. Introduction

Recycling has long been promoted as a sustainable waste management strategy. However, evidence indicates that current levels of waste generation and management approaches are incompatible with a healthy and habitable planet (Geyer et al., 2017; Kaza et al., 2018; Wilson & Velis, 2015). The United States is one of the highest generators of waste per capita (Kaza et al., 2018; Wilson & Velis, 2015), with global municipal solid waste generation projected to increase 70% by 2050 (Kaza et al., 2018). Waste from consumer goods is polluting the environment at alarming rates. Microplastics, one byproduct of rapidly increasing consumer waste, have been found nearly everywhere researchers have looked: in the most remote natural environments, in food, and in human blood, among others (Lim, 2021). Beyond problems with plastic waste

specifically, the production and mismanagement of goods generally is a major source of greenhouse gas emissions, a public health concern, and a costly problem for the communities that waste ends up in (de Wit et al., 2020; Kaza et al., 2018). Waste overgeneration and associated problems are only predicted to accelerate—and in many cases, much faster than they can be mitigated (Borrelle et al., 2020).

As visibility of waste generation and mismanagement has increased, public concern about this issue has also surged (*Attitudes Towards Single Use Plastics*, 2022; *Waking Up The Sleeping Giant*, 2019). However, despite consumer awareness about the negative impact of waste, per capita waste generation has also increased, waste-related pollution has grown, and recycling rates have remained stagnant (Geyer et al., 2017; US EPA, 2020; Wilson & Velis, 2015). Understanding what people think are effective solutions to these problems could help address the gap between public concern and persistent waste issues, how consumers behave, and which type of waste management strategies they are likely to support.

Despite expert recommendations for minimizing generation of waste (Bekin et al., 2007; Ortega Egea & Garcia de Frutos, 2013; U.N. Environment Programme, 2017; US EPA, 2015), many organizations and individuals persist in focusing on opt-in recycling by individual consumers to 'sustainably' manage waste (Jaeger, 2018; MacBride, 2011; Taddonio, 2020). Emerging research has shown that the misplaced focus on recycling is intentionally encouraged by goods manufacturers, namely the fossil fuel, beverage and packaging industries, to defer waste disposal responsibilities onto consumers and prevent disruption of their business models(Jaeger, 2018; Lerner, 2019; MacBride, 2011; Taddonio, 2020). The decades-long emphasis on recycling has resulted in industries creating anti-litter, pro-recycling organizations, promoting public education to recycle, supporting the creation of municipal recycling programs, and lobbying against policies that would regulate the waste they produce (Jaeger, 2018; MacBride, 2011).

While recycling is more sustainable than some waste management strategies, it is currently not diverting a high percentage of waste from other end destinations (US EPA, 2020), nor is it displacing virgin production for certain materials, such as plastics (Geyer et al., 2017; Zink & Geyer, 2019). Recycling rates in the U.S. are only 24% of the waste stream and for some materials, such as plastics, recycling rates are less than 10% (US EPA, 2020). Moreover, recycling of plastic only represents a delay, not a diversion, of final disposal as they cannot be

recycled indefinitely and will eventually end up in landfills, incinerators, or the environment(Geyer et al., 2017). Plastic waste specifically is anticipated to triple under a business-as-usual scenario (*Global Plastics Outlook: Policy Scenarios to 2060*, 2022); emissions associated with plastic production are predicted to outpace coal emissions by the end of the decade (*The New Coal: Plastics & Climate Change*, 2021). Despite these issues, recycling is still widely seen as a sustainable, moral, and civic-minded waste behavior (Jaeger, 2018; MacBride, 2011; Steg & Vlek, 2009). However, in recent years, scientists and journalists have exposed failures of recycling to effectively recover plastic waste (Franklin-Wallis, 2019; Sullivan, 2020; Taddonio, 2020; Zink & Geyer, 2019). Given this historical emphasis on recycling and new awareness that may promote skepticism, we wanted to examine how members of the American public think about recycling in comparison to other waste management strategies.

Addressing the overgeneration of waste is key to mitigate environmental pollution, public health impacts, and climate change (de Wit et al., 2020). Therefore, experts recommend source reduction strategies that prevent creation of waste rather than those that focus on managing waste after it already exists. The waste management hierarchy, a visual tool developed by the United States Environmental Protection Agency (EPA), ranks different management strategies from most to least environmentally preferred. The most environmentally preferred options for waste management are, in order: source reduction, reuse, recycling/composting, energy recovery (i.e., incineration with energy capture), and treatment and disposal (i.e., landfilling) (U.N. Environment Programme, 2017; US EPA, 2015). Although not a strategy and not present in the hierarchy, the least preferred and most harm occurs when waste escapes management streams and pollutes the natural environment (Kaza et al., 2018). Waste disposal behaviors are the end result of an entire system of production, distribution, and consumption; creating items designed to be thrown away is energy and resource intensive and leads to a multitude of negative impacts downstream (Hyman et al., 2015; Peattie & Peattie, 2009; Sheavly et al., 2012; U.N. Environment Programme, 2017; US EPA, 2015). In contrast, source reduction prevents natural resource depletion and other negative impacts across a product's life cycle.

Waste minimization involves changing dominant consumption patterns to be more sustainable (Bekin et al., 2007; Ortega Egea & Garcia de Frutos, 2013; Peattie & Peattie, 2009). Individual behaviors that minimize waste at the source include buying fewer goods in general, purchasing secondhand goods in lieu of new ones, and buying more environmentally friendly alternatives,

among others (De Young, 1996; Ebreo et al., 1999; García-de-Frutos et al., 2018; US EPA, 2013a). Systems-level waste minimization strategies include companies producing more durable and easily repairable products, and policies that ban or limit the production of wasteful products (de Wit et al., 2020; Jaeger, 2018; MacBride, 2011).

Solving our waste problems requires that we acknowledge that production, consumption, and disposal are interconnected parts of the life cycle of the product. However, it is not clear the extent to which people think about waste outside of the act of disposal, both at the point of purchase and after waste has been thrown away. In this research, we examine how well people living in the United States understand the efficacy of different waste management strategies, and which strategies they prefer. Analogous to the findings in these studies of water and energy use, we hypothesized that participants would cite recycling and other disposal actions rather than expert-recommended waste minimization behaviors. Given the importance of correct sorting behavior for recycling's efficacy, we also explore how much members of the American public know about the recycling system and how efficacious they perceive it to be. Understanding these perceptions and beliefs can help provide guidance on how to engage with the public on issues of waste as well as help contribute to better designed systems that support waste reduction.

2. Materials and Methods

2.1 Study 1

2.1.1 Participants

Participants were recruited and completed a Qualtrics survey via Amazon Mechanical Turk (MTurk, www.mturk.com) in Spring of 2019 (*N*=995). Participants' responses were excluded if there was evidence the survey was being filled in by a bot, responses indicated a lack of proficiency in English, or it was evident that a participant took the survey more than once from different accounts. After exclusions, 848 participants remained in our sample. Participants were compensated $4 dollars in their MTurk accounts. Median age was 35.0 years and 46.1% of participants were female. Median income was between $50,000 – $79,999 and the majority of participants had a college degree or higher (65.3%). According to census data, our participants had a greater proportion of males, were slightly younger, richer, and more educated than the U.S. population as a whole (*U.S. Census Bureau QuickFacts*, 2021). Politically, 48.9% indicated

they were liberal, 30.6% indicated they were conservative, and 20.5% indicated they were politically moderate.

2.1.2 Design

This survey was modeled after Attari's work investigating individual perceptions of water use (Attari, 2014). At the beginning of the survey, participants were asked four open-ended questions in randomized order about the most effective thing they and other Americans could do to reduce landfill waste and reduce plastic pollution in the oceans. Participants then estimated how much waste they, and in a second question, the average American, generate on a weekly basis, and of those estimates what percentage of that waste is thrown away, recycled, and composted.

Participants estimated how long they thought it takes for certain items (a plastic water bottle, plastic bag, glass bottle, and aluminum can) to be made into a new product from the time they are collected when recycled. Participants then estimated the percent of plastic that has been recycled or has ended up in landfills/the natural environment out of all the plastic that has ever been produced. Participants indicated how much they (and the average American) know about recycling on a Likert scale from 1 ("None at all") to 5 ("A great deal").

To assess actual recycling knowledge, participants then indicated whether they thought a series of 18 items (e.g., paper coffee cup, waxed beverage carton, aluminum can, used diaper) were "recyclable at almost all recycling facilities", "recyclable, but only at select recycling facilities", or "not recyclable anywhere." Participants indicated how often they (and the average American) put something in the recycling that they are not sure is recyclable on a Likert scale from 1 ("Never") to 5 ("Very often"). To assess beliefs about contamination behaviors, we asked participants to indicate the extent to which they agreed with statements on a Likert scale from 1 ("Strongly disagree") to 5 ("Strongly agree").

Participants also responded to questions to assess whether they considered waste when making purchasing decisions. Sample question includes: "How often do you take into account how you will dispose of an item when you purchase it?" which participants answered on a scale from 1 ("Never") to 5 ("Very often"). We also asked participants whether they buy products specifically because they are made out of recycled materials, and, if so, what kinds of products

they buy for this reason. Lastly, participants responded to standard demographic questions. The exact wording of each survey question can be found in Appendix A.

This research was approved by the University of Virginia's Internal Review board and pre-registered through the Open Science Foundation (osf.io).

2.2 Study 2

2.2.1 Participants

A representative sample of participants (N=473, based on simplified U.S. census data and balanced on sex, age, and ethnicity) was recruited via Prolific (www.prolific.co) and completed a Qualtrics survey in spring of 2022. All participant responses met inclusion criteria and passed attention checks. Participants were compensated $2 dollars in their Prolific accounts (on average, $10.20 per hour). Median age was 46.0 years and 51.2% of participants were female. Median income was between $50,000 – $79,999 and the majority of participants (59.4%) had a college degree or higher. 58.1% self-identified as liberal, 17.1% as moderate, and 24.7% as conservative.

2.2.2 Design

Participants first responded to standard demographic questions. Participants were then told: "Household waste can cause many environmental problems" and asked an open-ended question about the most effective thing they could do to help solve this problem.

Next, participants were presented with the four waste management strategies present in the U.S. EPA's waste management hierarchy and asked to rank the choices in order of 1 (best for the environment) to 4 (worst for the environment). Participants then completed the same ranking task for the 'three R's' (reduce, reuse, recycle) and then indicated the order in which they do them most to least often.

After completing these ranking tasks, participants were asked to sort common products into virtually represented recycling, compost, and trash bins and indicate how certain they were that they had placed each item in the correct bin. Following this measure, participants were asked to rate how certain they are that items they place in recycling bins actually get recycled from 0 (completely uncertain) to 100 (completely certain). Participants were then asked to choose

between recycling waste and preventing waste in terms of environmental efficacy, which they did more frequently, and which was easier.

We then presented participants with two systems thinking questions. Participants were told "Household waste can cause many environmental problems. There is a long process for products that eventually become waste, beginning with resource extraction and ending with disposal." Alongside this description was a graphic depicting these different stages that included design of products, resource extraction, production, transportation, distribution, consumption, and disposal. Participants were asked the following two questions: "At what stage in this process do you think it is most important for efforts to focus to solve this problem?" and "At what stage in this cycle do you think YOU as an individual can have the most impact on solving this problem?"

Participants then responded to two hypothetical scenarios regarding their consumption and disposal behaviors and a reduced consumption measure (Helm et al., 2019) and materialism measure (Helm et al., 2019) as well as a series of questions about recycling heuristics. The exact wording of each survey question can be found in Appendix B.

This research was approved by Indiana University's Internal Review Board and the University of Virginia's Internal Review board.

3. Results

3.1 Study 1

3.1.1 Perceptions of the "Most Effective Thing"

Participants responded to a series of open-ended questions about the most effective thing they and other Americans could do to reduce: 1) landfill waste and 2) plastic pollution in the oceans. Responses were judged by two researchers who identified 37 categories by reviewing the first 100 survey responses together and then independently coding the remaining responses, which were later collapsed into 24 categories. Interrater agreement was very high for all four questions, κ's > 0.8. Each action was then classified as either a disposal (e.g., recycling) or source reduction behavior (e.g., buy less).

As noted, the most effective way to reduce waste is through source reduction strategies, such as buying less, in which waste is never generated in the first place. However, when thinking about reducing landfill waste, participants recommended disposal strategies most frequently (see Table 1). Many participants provided a written response that recycling, which was the largest category in comparison to other responses, would be the most effective thing to reduce landfill waste (43%) when in fact it is not. The two next most written answers were source reduction strategies: reusing items (9.1%) and using fewer plastic products (7.4%). In total, 54.4% of participants recommended disposal actions, whereas only 34.9% recommended source reduction actions (the remainder of listed items did not fit into a singular category, see Appendix C for the full table). These results point to a persistent disposal bias generally and recycling bias in particular. We define disposal bias as the tendency to think about waste (and solutions to reduce it) at the point of disposal, rather than at the point of generation. Recycling bias is a specific manifestation of the disposal bias and refers to the misplaced belief or judgment that recycling is the most effective or sustainable strategy to reduce waste, when in fact it is not. The disposal and recycling biases demonstrated by participants contradict expert recommended source reduction actions as the most effective strategy to reduce waste and its environmental impacts.

Table 1: Perceptions of the single most effective thing to reduce landfill waste and ocean plastic pollution

Activity	Source Reduction (SR) or Disposal (D)	Reduce Landfill Waste Self, %	Reduce Ocean Plastic Self, %
Recycle	D	44.9	22.4
Use fewer plastic products	SR	7.4	40.0
Reuse items / buy reusable products	SR	9.1	10.1
Reduce consumption / buy less	SR	7.1	2.5
Unspecific (e.g., “avoid waste”)	--	6.3	3.1

Compost	D	4.5	--
Seek out items with less or more sustainable packaging	SR	4.0	3.9
Reduce food waste	SR	3.7	--
Mindful purchasing	SR	2.9	0.7
Advocate for systemic change	--	1.5	4.7
Don't litter	D	0.5	5.0
Beach clean-ups	D	0.1	2.9

Table 1: Participant responses of the most effective actions they could personally take to reduce landfill waste and ocean plastic pollution. Answer categories comprising less than 2% of responses have been removed from the table. The full table is available in Appendix C.

When answering the most effective thing they could do to reduce ocean plastic pollution, however, participants were more likely to recommend source reduction strategies, with 40% of participants answering that using fewer plastic products was the most effective in comparison to 22.2% of participants who recommended recycling. These results more closely align with expert recommendations to reduce waste generation at the source. Unlike previous work that found significant differences between participants' recommendations for themselves and others in terms of effective items to conserve water and energy (Attari, 2014; Attari et al., 2010), we did not find these differences for either question.

We hypothesized that taking away the option to recycle might prompt people to think higher on the waste management hierarchy and consider source reduction and reuse strategies. However, when active recyclers in Study 1 (n=696) answered how they would respond if recycling ceased to be available in their area (as was the case in many municipalities following ripple effects from the passage of the National Sword Act (Corkery, 2019; Lieber, 2019), participants continued to focus on recycling rather than source reduction. The most common response was that they would drive recyclables to another place that still recycles (28.9%), followed by making more mindful purchases to reduce waste (17.5%), then throwing away recyclables in the regular trash (10.1%).

In sum, 53.4% recommended disposal actions versus 23.2% of participants who recommended source reduction strategies (the remaining responses did not fit neatly into one category). Thus, even when recycling was taken away as an option, people still defaulted to recycling strategies rather than source reduction actions, such as those that require them to accumulate fewer items that would need to be recycled. See Appendix D for the full table of participant responses.

3.1.2 Perceptions of the Recycling System

Participants demonstrated a persistent recycling bias, but how much did they know about the recycling system? Given the emphasis on recycling education (Jaeger, 2018; MacBride, 2011), we wanted to investigate how much people know about the recycling system, such as what products can and cannot commonly be recycled, how long items take to be recycled, and how much plastic has been recycled. We also asked participants to assess their own recycling knowledge and how much they felt they cared about recycling. Participants' perceptions of the recycling system were complex and at times contradictory. On the one hand, they perceived recycling to be their most effective option to reduce waste, as our results in the previous section demonstrate. On the other hand, they seemed to be aware of some issues with the recycling system, yet demonstrated a lack of awareness of how their behaviors may contribute to those problems.

Contamination introduced into the recycling stream by poor recycling knowledge and behaviors can greatly limit the efficacy of recycling. A behavior known as wishcycling, a shorthand of "wish recycling," refers to placing things in the recycling in the hope that they can be recycled (Robinson, 2018). Experts critique this behavior because it introduces contaminants into the recycling stream which makes recycling harder to do and more expensive (Mogensen, 2019; Robinson, 2018). We assessed participant wishcycling and contamination behaviors several ways. Participants indicated, on 1 (Never) to 5 (Very often) scale, that they believe they occasionally wishcycle (M=2.38, SE=.034, but that they think that the average American does so significantly more frequently (M=3.49, SE=.028; t[847] = -30.0, P <.001 and d = 1.08).

To measure participants' general knowledge about recycling, we asked them to indicate if common consumer goods were: recyclable at almost all facilities; recyclable, but only at select facilities; or not recyclable anywhere (see Figure 1). These categories were chosen due to the variability of the recycling system in the United States. Overall, participants had a mean score of

66.7% (*SD*=15.43) out of a possible 100% on the recycling knowledge assessment. This was better than expected given the large amount of nonrecyclables placed in the recycling stream by users (30,31). However, participants demonstrated several grave misunderstandings of the recycling system. For example, 21.7% of participants indicated that they thought used (soiled) diapers were recyclable at all recycling facilities (7.6%) or select facilities (14.7%). Similar misperceptions were held for paper towels, greasy pizza boxes, coffee cups, plastic bags, and other common recycling contaminants. When placed in the recycling stream, these items contaminate recycling loads, which adds processing costs and can lead to otherwise-recyclable items being trashed (Robinson, 2018).

Figure 1: Selected questions from recycling assessment

Figure 1: Participants were asked if a series of recyclable products and common contaminants in the recycling stream were: 1) recyclable at almost all recycling facilities; 2) recyclable, but only at select facilities; 3) not recyclable anywhere. Earth911's database of recyclable items, a resource listed by the E.P.A. (US EPA, 2013b), was used to determine acceptable answers (*Recycling Center Search - Earth911.Com*, n.d.).

A common strategy to improve people's recycling behavior is to provide clear, abundant, and accessible information about what can and cannot be recycled. However, despite the majority of

participants (66.2%) somewhat or strongly agreeing that recycling information was easy to find where they lived, most (79.9%) reported not frequently looking up this information.

To assess participant perceptions of the efficacy of the recycling system at recovering and recycling materials, we asked participants to estimate the percent of plastic that has been recycled out of all plastics ever produced versus the percent of plastic that has ended up in landfills and the natural environment. Scientists estimate that only 9% of plastics have ever been recycled since their introduction in the 1950's and that approximately 79% have ended up in landfills and the natural environment (Geyer et al., 2017). Although participants greatly overestimated the percent of plastic they thought had been recycled (*M*=25.2%, *SE*=.70) when compared to expert estimates of 9% (*MD*=16.2,t[847] = 23.19, $p < 0.001$, *d*=0.80), they still estimated that the grand majority of plastics have *not* been recycled. In fact, they estimated that the majority of plastic has ended up in landfills and the natural environment (*M*=70.62%, *SE*=1.35), although they reasoned that significantly less plastic had this fate compared to expert estimates of 79% (*MD*=-8.4%, t[847] = -6.210, $p < 0.001$ and *d*=-0.21).

There were significant differences on estimates of plastic recycled based on educational status, income, and political affiliation. In regards to income, those who made between $50,000 and $79,999 thought that significantly more plastic had been recycled than those who made between $100,000 and $139,999 (MD = 11.268, *p*=.023) and those who made greater than $170,000 (MD=13.715, *p*=.042). Conservative participants estimated that significantly more plastic had been recycled than those who indicated a liberal affiliation (MD=5.416, *p*=.002).

Participants also estimated how long it takes for a water bottle, plastic bag, glass bottle, and aluminum can to be made into a new product from the time they were collected. These results were compared to recycling industry expert responses. Any response with an estimate of over 25 years was excluded as an outlier. In every case, participants thought items took significantly longer to be recycled than experts estimated (see Appendix E).

Individual ratings of their own recycling knowledge did not significantly correlate with any actual measure of recycling knowledge we assessed. When evaluating their own recycling knowledge, participants demonstrated the better-than-average effect (Alicke & Govorun, 2005): they thought they knew a moderate amount on a 5-point scale (*M*=2.98, *SE*=.03), which was significantly more than what they estimated the average American's recycling knowledge to be (*M=2.6, SE=.03;*

MD=0.38; *t*[847] = 13.90, *p* < 0.001 and *d*=0.48). While no significant differences were found between gender for either individual or average American's rating of recycling knowledge, self-identified liberals rated the average American's recycling knowledge significantly lower than conservatives (*MD*=-0.17; *t* = 1.48, *P* = 0.01 and *d*=0.20) with no significant difference for their ratings of their own individual knowledge.

Higher educational attainment was associated with worse knowledge of the recycling system, greater confidence in their recycling knowledge and the robustness of the recycling system, and some self-awareness about their poor recycling behaviors. Despite giving themselves high ratings on their own recycling knowledge on a 5-point Likert scale(*M*=3.5, *SE*=.08), participants with graduate degrees scored the lowest on average on the assessment of recycling knowledge on a scale from 0 – 1(*M*=.63, *SE*=.01) compared to groups with less educational attainment and scored significantly less than those with college degrees (*M*=.67, *SE*=.01, *p* = .034) and some college (*M*=.68, S*E*=.01, *p* = .023). See Appendix F for the full table of results. Those with graduate degrees also thought a greater percentage of plastic had been recycled (*M*=31.27%, *SE*=2.21) than participants with every other educational attainment and significantly more than those with a college degree (*M*=24.03, *p*= .005), some college (*M*=24.00, *p*= .015), and high school (*M*=22.15, *p* = .023). Participants with graduate degrees also estimated that they wishcycled significantly more (*M*=3.02, SE= .1 on a 5-point Likert scale) than those with college degrees (*M*=2.36, *SE*=.05), some college (*M*= 2.14, *SE*=.06), and those with a high school degree or its equivalency (*M*=2.08, *SE*=.11; all *p*'s < .001).

3.1.3 Perceptions of Waste Generation and Disposal

In addition to perceptions of the recycling system, we wanted to explore how much waste participants living in the United States thought they generated and their awareness of how they disposed of it. Before conducting this survey, a pretest was done to test survey language for participant understanding. We asked participants to estimate how much waste they generate on a weekly basis in pounds, and what percentage of their weekly waste they throw away, recycle, and compost. We also asked participants to estimate the same parameters for the average American.

Participants in this study had better-than expected accuracy in their perceptions of the average Americans' waste generation and disposal behaviors. However, participants estimated that they

generated less waste and recycled more than official estimates would suggest. In addition to the better-than-average effect (Alicke & Govorun, 2005), this inaccuracy may be due to waste management infrastructure that makes waste less visible for those not living near disposal sites (e.g., landfills and incinerators) after it gets thrown "away." Respondents also tended to estimate numbers that suggested that they believed their waste behaviors to be more sustainable than what they estimated for the average American, with the exception of composting. See Figures 2 and 3 for participant estimates of waste generation and disposal for themselves and the average American compared to EPA estimates and Appendix G for the full table of responses.

Figure 2: Estimates of Weekly Waste Generation compared to EPA Estimates

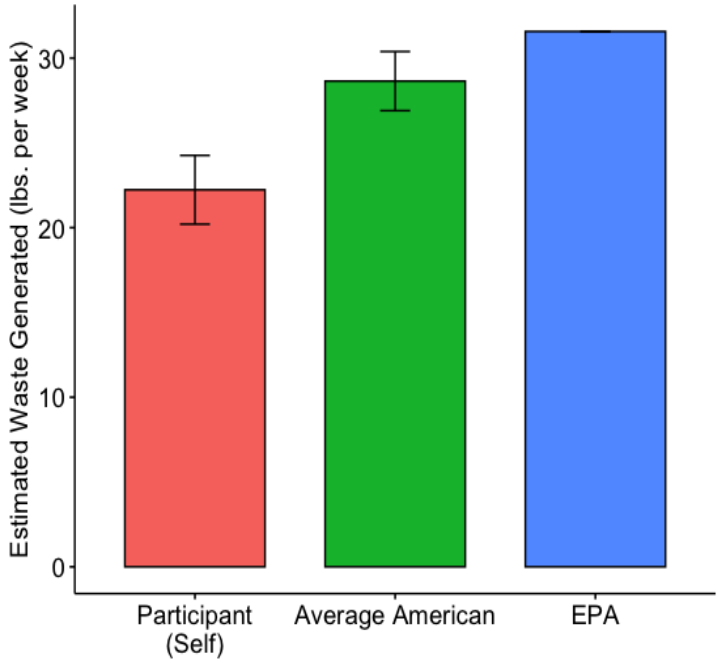

Figure 2: Participants' estimates of their own and the average American's weekly waste generation in pounds compared to EPA estimates. Error bars indicate the 95% CI.

Figure 3: Estimated Percent Waste Thrown Away, Recycled, and Composted Compared to Official Average Estimates

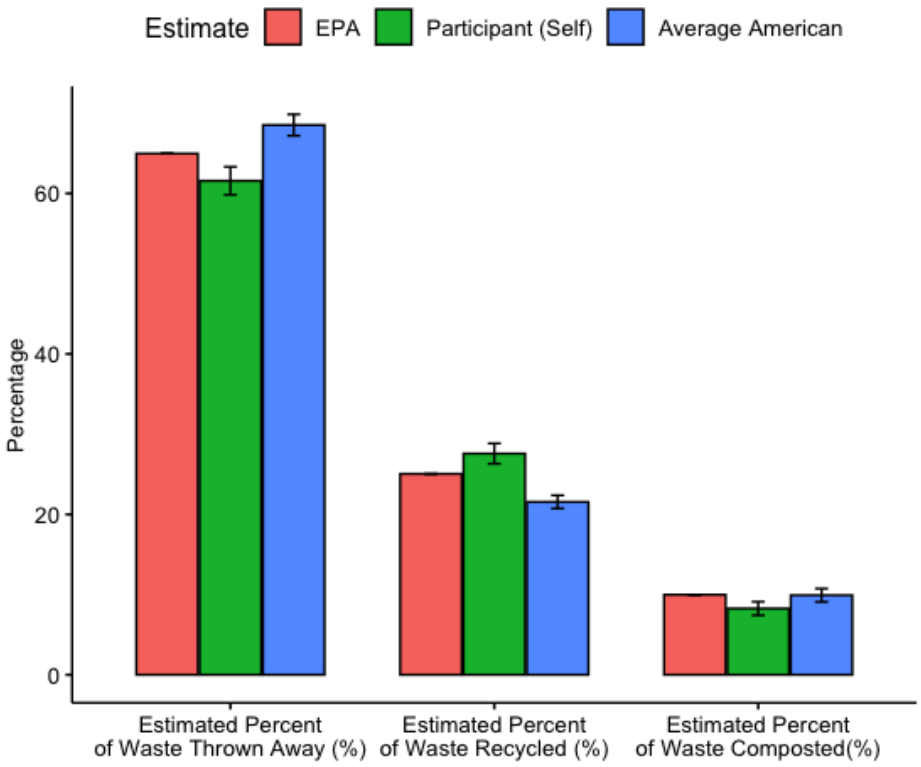

Figure 3: Participants' estimates of the percent of their generated waste they throw away, recycle, and compost compared to their estimates of these behaviors for the average American and official EPA estimates. Error bars indicate the 95% CI.

Although there were no significant income-based differences on reported waste generation, participants who reported lower incomes tended to report throwing away a larger percentage of their waste and recycling less. Specifically, participants who reported making less than $20,000 per year (n=78) reported throwing away the largest percentage of their waste (*M*=69.05, *SE*=3.25) and reported recycling a smaller percentage of their waste (*M*=18.38, *SE*=1.90) than those of every other income category. This may be due to less access to recycling infrastructure, challenges storing and transporting recyclables to recycling centers, or other factors. Income-based disparities in recycling behaviors suggest that putting the onus on consumers to recycle most of their waste and to do so correctly can only work when everyone has equal access to recycling infrastructure.

Although there were no significant differences based on educational status for estimates of waste generated, lower educational attainment was associated with estimates of recycling and composting less. Those who reported only attaining a high school degree or its equivalent estimated that they threw away a significantly larger percentage (*M*=70.89, *SE*=2.82) than those with a college degree (*M*=60.81, *SE*=1.28), those with some graduate school (*M*=52, *SE*=4.49), and those with graduate degrees (*M*=47.94, *SE*=2.13; all *p*'s <.05).

Political identification was associated with some differences on estimates of waste generation and disposal, with conservative participants estimating that both they and the average American generated more waste than liberal participants did. Of estimated waste generated by the average American, liberals assumed significantly more of it would be landfilled than conservatives did (MD = 6.94, p < 0.001). Lastly, conservatives estimated the average American composts significantly more pounds of waste weekly than liberal participants did (MD = 4.87, p < 0.001).These differences along political lines was an expected finding, as political polarization on environmental issues has been well-demonstrated in the U.S.(Funk & Hefferon, 2019; Johnson & Schwadel, 2019; McCright et al., 2014), with conservative Americans tending to be less worried about climate change and other environmental issues than liberal Americans (Mildenberger et al., 2017). Male participants also reported generating more waste than female participants, which aligns with previous findings that women tend to be slightly more concerned about the environment than men and have stronger pro-climate beliefs (Pearson et al., 2017).

3.1.4 Purchasing Behaviors and Waste Awareness

Waste generation happens at the point a good is obtained, not just at the point of disposal, so we wanted to investigate whether participants considered waste when making purchasing decisions. Participants reported that they tend not to think about waste generation at the point of purchase (see Figure 4). We also asked participants if they would purchase an item they wanted if it came in packaging that was not recyclable or compostable. The majority (55.9%), stated they would still definitely or probably buy it compared to a minority (11.5%) of participants who indicated they would definitely not or probably not buy it. These results provide continued support for the existence of a disposal bias: participants in our sample tend to think about waste when it comes time to dispose of it, not when a product that will become waste is obtained.

Figure 4: Purchasing Behaviors and Waste Awareness

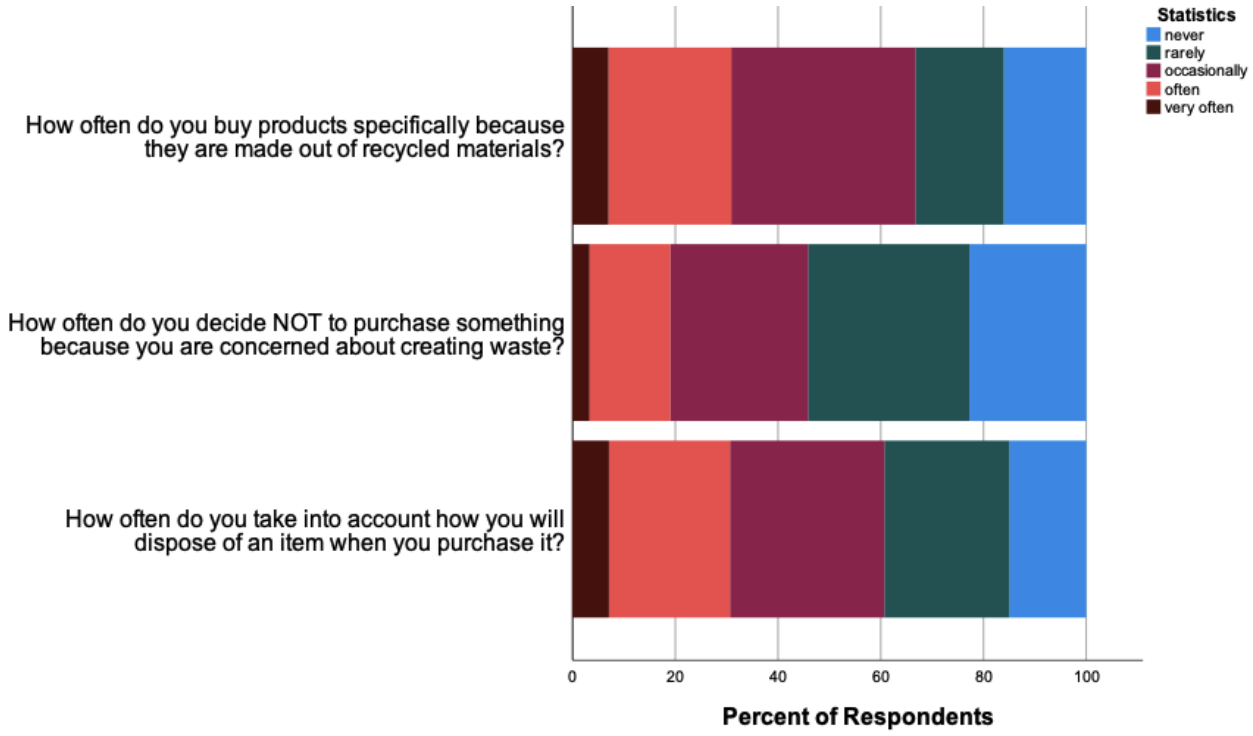

Figure 4: Participants demonstrated a good deal of variance in terms of how frequently they considered waste at the point of purchase, with the majority considering waste never, rarely, or occasionally across measures.

3.2 Study 2

Study 1 provided initial evidence for the existence of a disposal and recycling bias, as well as participants' poor knowledge about the recycling system and failure to consider waste at points outside of disposal. In Study 2, we wanted to further probe this recycling preference, including when it persists and when it doesn't, how people understand recycling in relation to other waste management strategies, and examine how people understand the full system that creates waste.

3.2.1 Perceptions of the "Most Effective Thing"

Given that both open-ended questions for study 1 focused on reducing the amount of waste that ended up in specific end destinations, we wanted to probe what solutions would come to mind

for participants when asked about solutions to the environmental problems posed by waste more broadly. We posed the following question to participants (N=473) in study 2: “Household waste can cause many environmental problems. What is the single most effective thing *you* can do in your day-to-day life that helps solve this problem?” Participants again misperceived recycling as the most effective action they could take (see Table 2), demonstrating a preference for recycling and a harmful misperception about the efficacy of different waste management strategies.

Our results point to the existence of a disposal bias: the tendency to think about waste (and solutions to reduce it) at the point of disposal, rather than at the point of generation. Recycling bias is a specific manifestation of the disposal bias and refers to the misplaced belief or judgment that recycling is the most effective or sustainable strategy that an individual can take to reduce waste, when in fact it is not. The disposal and recycling biases demonstrated by participants contradict expert recommended source reduction actions as the most effective strategy to reduce waste and its environmental impacts.

Table 2: Perceptions of the most effective thing to solve problems associated with household waste

Activity	**Source Reduction (SR) or Disposal (D)**	**Self, %**
Recycle	D	46.9
Reuse	SR	10.6
Reduce consumption/buy less	SR	6.6
Compost	D	5.9
Reduce food waste	SR	5.1
Reduce use of plastic products	SR	5.1
Mindful purchasing	SR	3.8
Seek out items with less or more sustainable	SR	3.8

packaging		
Separate waste and dispose of it ‘properly’	D	3.0
Reduce	SR	3.0

Table 2: Participant responses of the most effective actions they could personally take to solve environmental problems associated with household waste. Answer categories comprising less than 2% of responses have been removed from the table. The full table is available in Appendix H.

Studies 1 and 2 both demonstrated that participants demonstrated a misplaced preference for recycling when asked open-ended questions about the most effective actions they could take when it came to waste. A subsequent measure tested whether this misperception persist when asked to rank different waste management strategies. To explore how people understand the efficacy of different strategies in relation to each other, participants completed two tasks. First, participants (n=473) ranked the different strategies listed in the EPA’s waste management hierarchy (US EPA, 2015) from most to least environmentally preferred (see Figure 5). Overall, participants demonstrated a poor understanding of which of these strategies was most effective: 78.4% of participants failed to place the strategies in the correct order of most to least preferred. In other words, only 21.6% were able to correctly rank which strategies are better and worse for the environment. There was also a great deal of variance in how participants ranked the environmental attributes of each strategy in comparison to each other. Participants thought that source reduction and reuse were roughly equivalent to recycling and composting in terms of environmental impact. 39.7% ranked source reduction and reuse as the most effective option compared to 35.9% that placed recycling and composting in the top position.

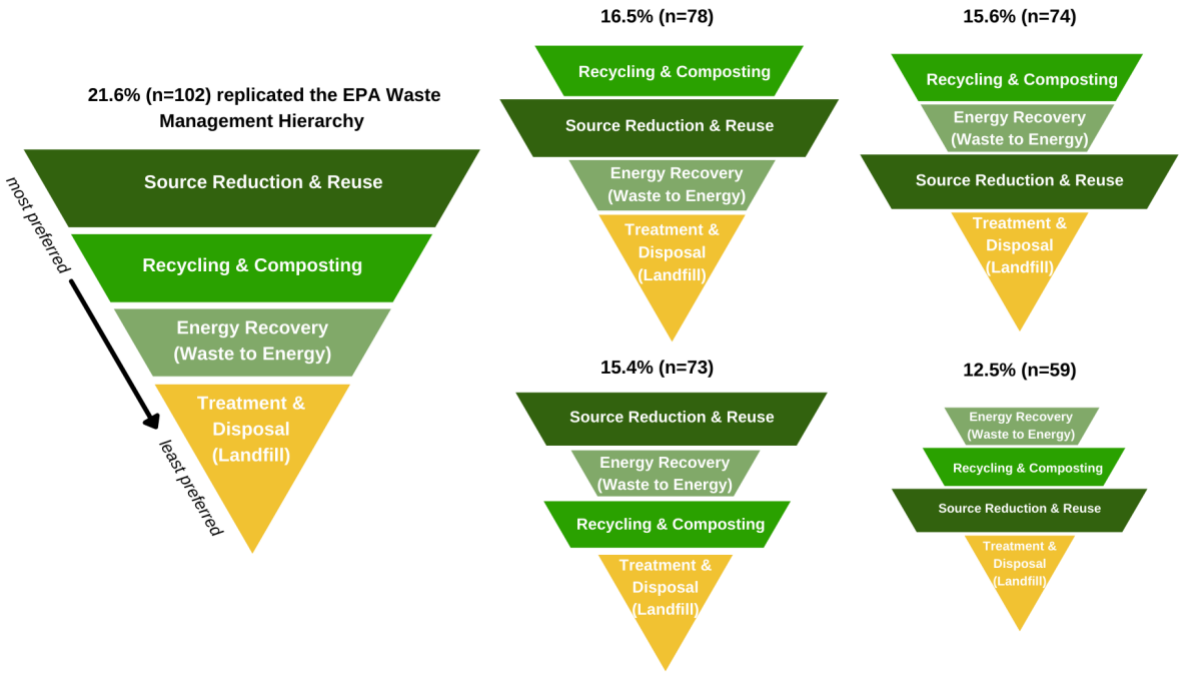

Fig. 5. The majority of participants did not correctly replicate the EPA's Waste Management Hierarchy in terms of most to least environmentally preferred. The five most common waste management hierarchies created by participants in order of frequency are shown. Hierarchies decrease in size in order of frequency.

The popular phrase 'Reduce, Reuse, Recycle' (the "Three R's") is a simplified heuristic ordered from best to worst in terms of environmental impact. In a second task asking participants to rank these items in order of best to worst for the environment, participants fared much better (see Figure 6). Over half the sample (53.9%) placed the phrase in the correct order of most to least environmentally preferred.

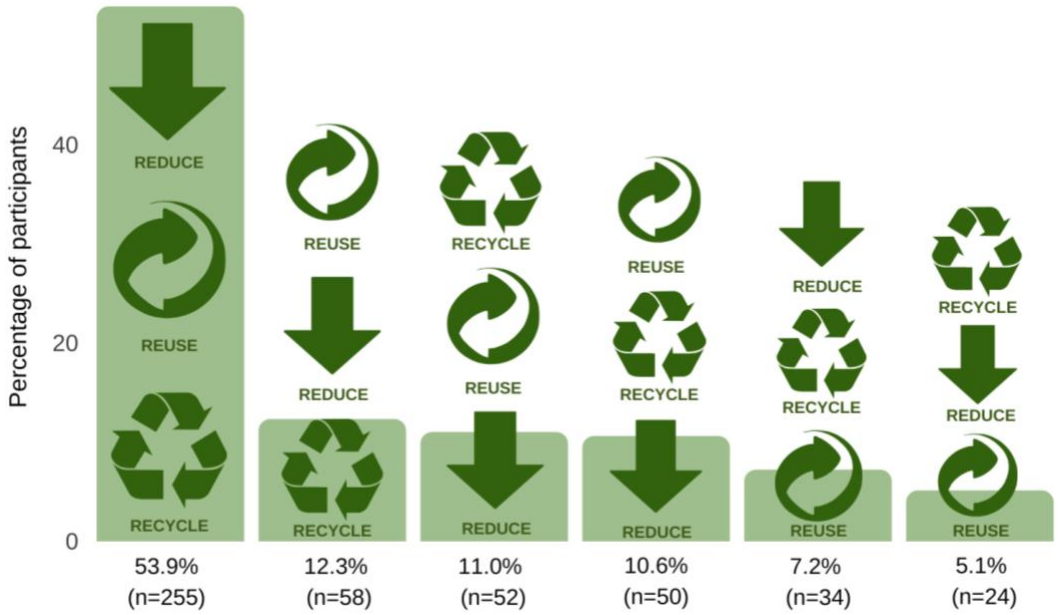

Fig. 6. Participants correctly ordered the three R's (Reduce, Reuse, and Recycle) in order of most to least environmentally preferred over half the time. Data is shown here in order of frequency.

However, when asked to place the Three R's in order of which they did most frequently, just 17.8% indicated that they followed the three R's heuristic in their daily life. The largest category of participants (24.1%) acknowledged that the order of these actions was flipped in their daily behaviors and that they recycled more frequently than they reused, and reused more often than they reduced.

Finally, we asked participants to choose between just two actions in terms of which is better for the environment generally: recycling waste and reducing waste. On a five-point Likert-type scale from 1 ('Recycling waste is much better') to 5 ('Preventing waste is much better'), on average, participants understood that preventing waste is better for the environment (m=4.18, SD=1.17).

3.2.2 Perceptions of the Recycling System

In an online task, participants (n=473) sorted common consumer goods into virtual and standard recycling, compost, and trash bins, and indicated how certain they were about their choice (see Figure 7). In this task, several common recycling contaminants, including plastic bags, disposable coffee cups, and light bulbs, were erroneously placed in the virtual recycling bin by more than 25% of participants.

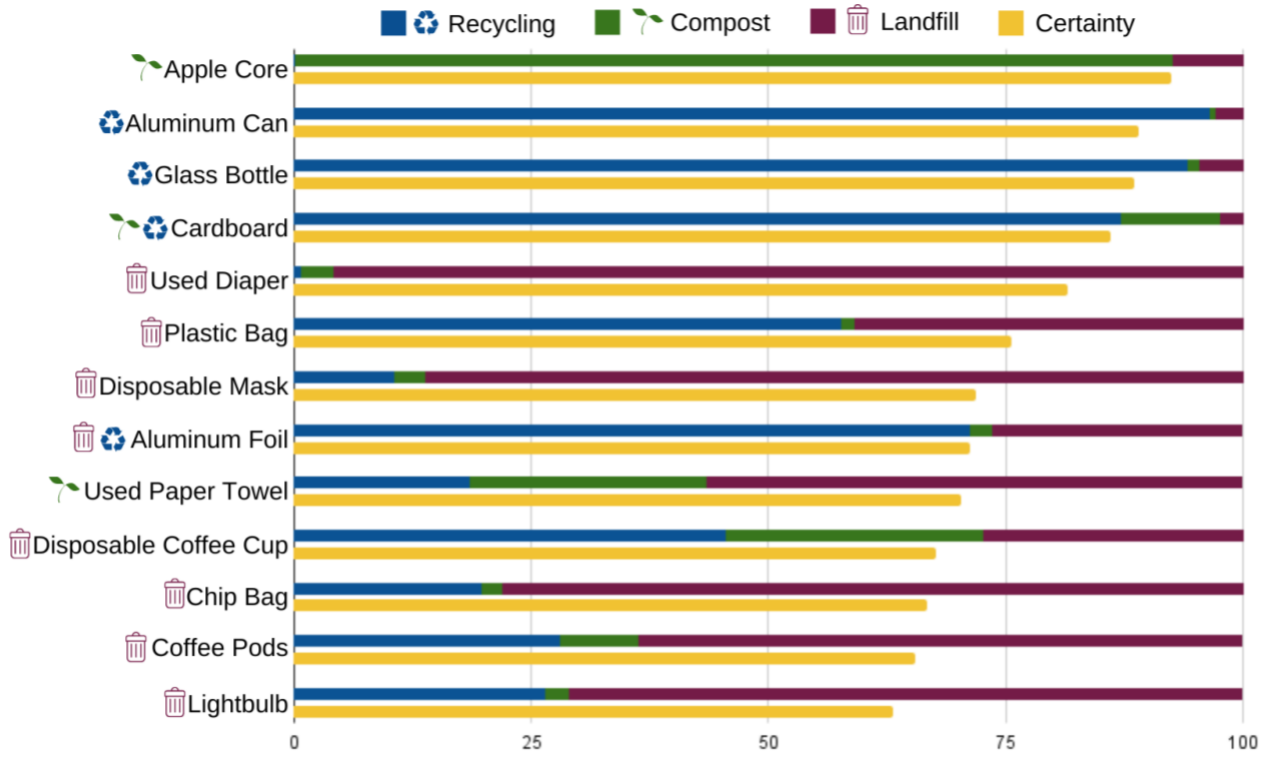

Fig. 7. Participants were asked to sort common consumer items into virtually represented recycling, compost, and trash bins, and then indicate how confident they were about their choice. The correct category is indicated by the color placed to the left of each item. For some items, more than one category is correct. For example, clean cardboard can be recycled or composted. For other items, such as aluminum foil, recyclability varies significantly. Items are placed in descending order in terms of how confident participants were, on average, about their sorting choice. Note: many of these items are recyclable if sent to specialty recyclers or placed in designated specialty bins.

Wishcyclers who erroneously placed coffee cups and plastic bags in the recycling bin were significantly more confident than participants who correctly placed these contaminants in the trash bin. For coffee cup recyclers, a one-way ANOVA revealed statistically significant differences among groups ($F(2,470)=4.305$, $p=.014$) and a Welch post-hoc test revealed that the recyclers were significantly more confident ($m=70.4$, $sd=23.94$) than trashers ($m=62.32$, $sd=28.21$), $p=.019$. Plastic bag recyclers were also significantly more confident ($m=80.03$, $sd=20.80$) than trashers ($m=69.66$, $sd=26.0$), $p<.001$ according to a one-way ANOVA ($F(2,470)=12.46$, $p<.001$) and Welch post-hoc test.

3.2.3 Confidence in the Recycling System

Although recycling was top-of-mind for many participants when asked to give the most environmentally preferred option in an open-ended format, participants did not demonstrate great confidence in recycling's efficacy. When asked how certain they were that items put in recycling bins actually get recycled, participants reported a mean certainty of 53.4% (SD=26.64). While people may mentally default to recycling when considering sustainable waste management, participants in our study were not confident in the efficacy of their preferred strategy.

3.2.4 Point of Waste Consideration

The environmental impacts of waste can be most effectively mitigated at the point of generation, not at the point of disposal. We explored whether participants considered generated waste when making purchasing decisions and where in the lifecycle of the product they thought waste could be effectively mitigated. To further examine how participants would behave when faced with different waste management strategies, we asked participants a series of questions based on real life scenarios. The first scenario asked participants to "imagine that you are away from your house and are getting thirsty. You are in a store that sells beverages in plastic bottles. Based on your normal behavior, what would you be most likely to do?" 60.3% reported that they would likely purchase and recycle a plastic beverage bottle while 18.6% indicated they would purchase and reuse the container. Only 9.5% of participants reported that they would not purchase a beverage in a plastic container, fewer than those who reported they would purchase and throw it away (10.6%). These results provide support for the existence of a disposal bias: participants in our studies report that they would likely not defer a purchase that would create waste, but rather try to mitigate the impact of waste after it has been generated (e.g., through recycling).

In a second, less frequently experienced scenario, we asked participants to imagine how they would obtain a costume for a costume party. In this scenario, more participants reported that they would likely engage in source reduction and reuse behaviors. 43.1% said that they would make a costume from items they already own, while 30.7% reported that they would purchase items secondhand and 6.6% would borrow a costume. Only 16.9% responded that they would purchase a new costume.

3.2.5 Perceptions of the "Most Important Stage"

Household waste is the end result of a long supply chain with environmental impacts at every stage. Products that eventually become waste are designed, manufactured, and distributed by companies, yet responsibility for this waste often falls on consumers (14, 35). To probe how participants understand the system that creates waste, their participation in that system, and assess their perceptions about effective intervention points, we asked participants in study 2 (n=473) two systems-thinking questions (see Figure 8). While over half of participants felt that the design stage was most important to mitigate the impact of household waste overall (53.9%), participants overwhelmingly indicated that the only two stages they felt empowered to enact change was through their consumption (72.9%) and disposal behaviors (23.3%).

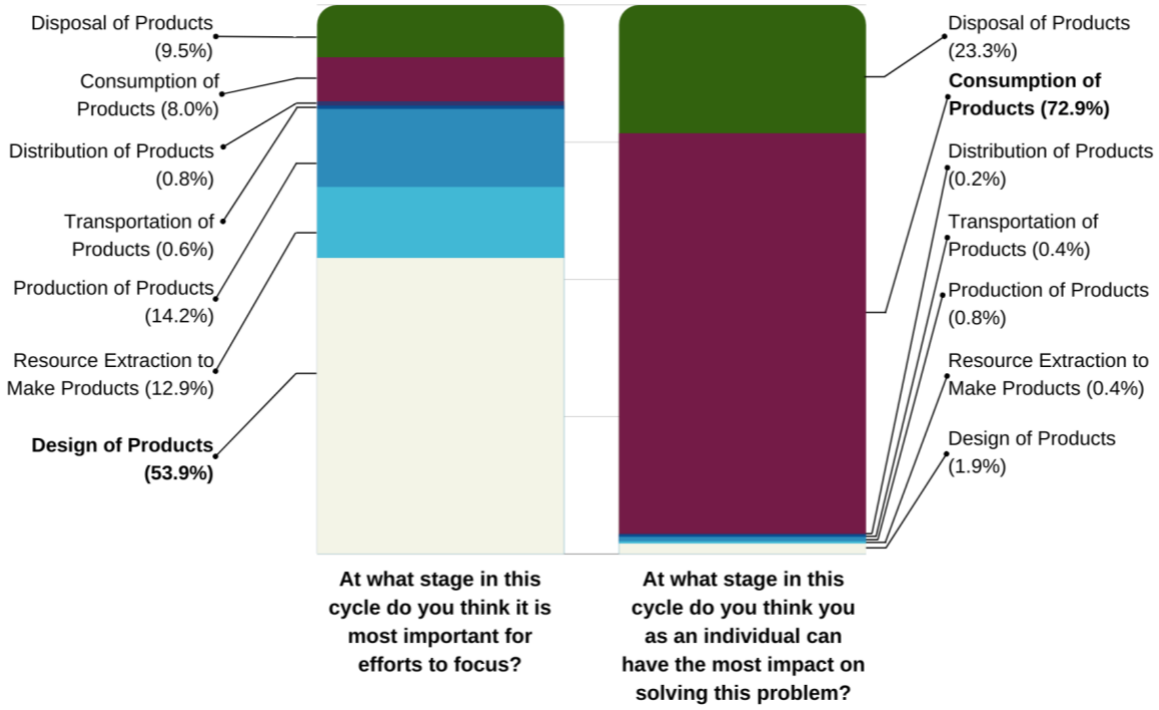

Fig. 8. Participants were told: "Household waste can cause many environmental problems. There is a long process for products that eventually become waste, beginning with resource extraction and ending with disposal." The process was depicted visually starting with the design phase and ending with the disposal phase and participants were prompted to select one stage in the cycle where change would have the most impact and where in the cycle they felt they could have the most impact as individuals. See Appendix B for the visual figure that participants selected responses from.

In open-ended responses, participants wrote about their thought process and why they selected the stages they did. The majority felt that consumption was the only stage that they had any control over. As one explained, “For me as an individual, it was easy to decide that my consumption of products has the most impact on solving this problem. I can't control much else besides the consumption and disposal.” However, additional responses revealed different sentiments about the source of this problem and how it can be solved.

For many participants, the source of the problem was with producers, not consumers. Some exhibited a sentiment that production was inevitable, so their role was to minimize the negative impact of products that already existed. One participant wrote, ““I am a strong believer in preventing a problem before it happens, so a lot of the responsibility lies with the manufacturers, who make the decisions in regards to packaging, materials, ingredients, and how much waste is produced in the creation of these products. As a consumer, it is my responsibility to decide, before bringing an item home, if there is an option available to me that will not leave behind as much waste.” One participant expressed this sentiment more baldly: “Companies gathering resources can destroy entire ecosytems [sic]. Individuals cannot do much but they can help with how it is consumed and disposed of.”

However, for other participants, consumption (i.e., consumer demand) drove all the other stages. They felt that their consumption choices would introduce feedback into the system and therefore promote upstream change through market signals. One participant captured this sentiment clearly: “Consumers have the largest impact on the market. If demand decreases, supply follows.” Another wrote that “ultimately the stuff will not be made if there is not a demand for it, so if I don't consume, there is no need for all the steps that come before it (or disposal, for that matter).”

4. Discussion

In all but a few instances (e.g., ordering of the three R’s), participants in this research exhibited poor knowledge about the efficacy of different waste management strategies. Across several measures, participants exhibited the mistaken perception that recycling is the most sustainable action when it comes to consumer waste or that it is roughly equivalent to source reduction and reuse. Producing items intended to be disposed of, even if they are recycled, is incredibly resource and energy intensive (de Wit et al., 2020; Wilson & Velis, 2015).

However, this belief that recycling is the most effective strategy was not static. When presented with fewer options, different end destinations for waste, and a systems diagram of this problem, participants indicated that they did understand that source reduction and reuse are better than recycling. Our results provide insight into when and why individuals cognitively default to disposal strategies such as recycling over source reduction and reuse. The explanation lies in how they believe the problem should be solved, where they feel they have agency in solving it, and the number of options with which they are presented. When asked what is best for the environment or what should be done *in general*, participants acknowledge that preventing waste is much better. When asked what *they* as individuals can do, participants default to recycling. Participants understand in a general sense that preventing waste is better—just not when it comes to their own actions.

However, even this misperception was improved when participants were presented with a systems diagram and prompted to choose a single stage in which they could have the most impact. Rather than default to disposal, as we see in our other results, most participants (72.9%) chose consumption as the stage in which they could have the most impact. But even this result is not as straightforward as it might seem: many participants said that companies can have the most impact creating things that can be recycled, and that customers can have the most impact by consuming recyclable products. In other words, in some instances, even a focus on consumption is not about consuming less but rather consuming things that can be 'sustainably disposed of.' One participant summed it up this way: "For the first one, I figured that its up to the manufacturers to think about what components they are using to make their products. Are they recyclable or not. For the consumer, it's at the consumption level because that is when we make decision about how and what we consume which will then have to be recycled."

Participants in our study revealed that they perceive their only locus of control to be through their consumption and subsequent disposal of products. It seems that opting out may feel so inaccessible as to not even occur to our participants, who therefore perceive recycling as their least worst option within the existing system. Opting out of the dominant, normative consumer society and engaging in source reduction behaviors on the individual level—such as buying fewer goods in general, purchasing second hand, selecting more durable goods, and opting for more environmentally friendly or package-free alternatives (Bekin et al., 2007; De Young, 1996;

Ebreo et al., 1999; García-de-Frutos et al., 2018; US EPA, 2013a)—is not easy. There are many barriers to engaging in these behaviors, including access to alternatives, time, purchasing power, and other hurdles; buying less, while logistically easier than alternatives, is non-normative (García-de-Frutos et al., 2018). Disposal strategies may more readily come to mind than source reduction actions due to consumer culture norms, ease, convenience, and the widespread emphasis on individual recycling as a sustainable waste management strategy(Jaeger, 2018). Additionally, disposal strategies are tangible, feel-good actions (e.g., recycling, composting) and whereas source reduction strategies are often actions in absence (e.g., choosing to *not* purchase something).

Dealing with waste is a systems-level problem that has often been individualized and positioned as a consumer choice problem rather than a political one. While advocating for systems changes that promote source reduction at scale is arguably the most effective action to solve this problem, our participants overwhelmingly cited downstream, individual actions that maintain the status quo. One contributor to this misplaced focus on recycling may be the aforementioned efforts by goods manufacturers to defer waste disposal responsibilities onto consumers (Jaeger, 2018; Lerner, 2019; MacBride, 2011; Taddonio, 2020). Participants reported that they felt most powerful (or disempowered) as consumers or "shoptivists" (*Shoptivism: Why Consumers (& Job Seekers) Opt In & Out of Today's Brands.*, 2021) and disposers, rather than as citizens, voters, or activists. If people were more aware of the waste potential of the products they purchase and its environmental and economic impact, they might engage in behaviors aimed at shifting the system or seek out less wasteful alternatives. Recycling, in contrast to reducing consumption of goods, does not represent a threat to dominant business interests—producers can continue to create single-use goods for consumption without consumers feeling bad about creating waste because it gets 'recycled.'

Participants in this study had better-than expected accuracy in their perceptions of the average Americans' waste generation and disposal behaviors. This may be because waste is more tangible than energy and tends to accumulate in one place, unlike household water use, which is usually measured and experienced as a flow. However, participants underestimated how much waste they likely generate and overestimated how much they recycle. In addition to the better-than-average effect (Alicke & Govorun, 2005), this inaccuracy may be due to waste management infrastructure that makes waste less visible for those not living near disposal sites (e.g., landfills and incinerators) after it gets thrown "away." Strategies to make the amount of

waste generated more visible or salient might help individuals think higher on the waste management hierarchy and consider strategies to reduce the amount of waste they produce.

There is research that having the option to recycle or 'sustainably' dispose of waste leads to increased resource use (Catlin & Wang, 2013), and our results on regional differences of perceptions of waste generation and disposal provides additional evidence for this idea. Those who lived in the Western part of the United States reported generating more waste, yet disposing of it in more sustainable ways (i.e., recycling and composting). Many states in the Western region of the U.S. have more developed (and in certain cases, mandated) waste infrastructure when compared to other parts of the country. For Americans, perceiving recycling to be a sustainable option may lead to greater resource consumption and waste generation than if they perceived it to be less environmentally friendly or effective.

We also examined how participants thought they would behave if their option to recycle were taken away. This was a scenario based on real-life events, given the shuttering of some municipal recycling programs following the passage of National Sword in 2018 (Corkery, 2019; Lieber, 2019). We hypothesized that participants would cite source reduction behaviors. Surprisingly, however, the most common response participants gave was that they would drive their recyclables to another place that still recycles. While several participants did say they would change their behaviors to produce less waste, many others wrote that they would simply throw away recyclables in the regular garbage. This provides additional evidence for a strong bias towards recycling rather than other, more sustainable upstream waste management strategies.

We also found important differences on waste disposal behaviors based on income. Those with lower incomes reported throwing away a larger percentage of their waste while recycling less. This may be due to less access to recycling infrastructure, challenges storing and transporting recyclables to recycling centers, or other factors. Income-based disparities in recycling behaviors provide additional support that putting the onus on consumers to recycle the majority of their waste and do so correctly can only work when everyone has equal access to recycling infrastructure.

The current recycling system in the United States is heavily dependent on consumer behavior to recycle correctly (Babaei et al., 2015; Knickmeyer, 2020; Varotto & Spagnolli, 2017) and have

access to good local recycling systems. Experts estimate that 1 out of every 4 items introduced into the recycling stream cannot actually be recycled (Robinson, 2018). This widespread behavior introduces contaminants into the recycling stream, which increases cost and reduces efficacy. Participants in our study demonstrated misguided beliefs about recycling practices that limit the efficacy of their preferred strategy, including recycling items that contaminate the recycling stream. Participants thought many common contaminants were recyclable and indicated that they engage in wishcycling behaviors. Importantly, although higher educational attainment was associated with enhanced perceptions of their own recycling knowledge, participants with more education tended to know much less about the recycling system when compared to those with less educational attainment. Therefore, it seems that increased education may be serving to increase confidence in one's recycling knowledge without impacting their actual knowledge. Such results suggest efforts aimed at promoting recycling have failed to educate consumers to be effective recyclers, only serving to make recycling the most salient waste management strategy and one that feels accessible within the existing system.

Participants did demonstrate awareness of at least some problems associated with recycling—on average, they estimated low recycling rates of plastic and admitted a lack of confidence in the recycling system—yet they still perceived it to be their most effective option. These misperceptions about how long items take to be recycled may be a result of increased news coverage about recycling and China, or a general sense of a broken or inefficient recycling system. Knowing what products become when they are recycled into new items (e.g., seeing a plastic bottle become a jacket when recycled) encourages good recycling behaviors (Winterich et al., 2019), and the same could be true for general familiarity with the recycling process. If individuals think that the recycling system is inefficient or disjointed, that might affect their recycling behaviors negatively. An alternate explanation may be that they think the recycling system is more complex than it is, which could account for some wishcycling and contamination behaviors. For example, if people think that recycling processors take a long amount of time to clean and sort recyclables, that might lead them to put dirtier or unrecyclable products in the recycling stream because they think it has the capacity to manage these items.

Being more explicit about what can and cannot be recycled in the current recycling system rather than what is theoretically recyclable under ideal circumstances is important to accurately inform consumers. However, given Americans' poor knowledge about what can and can't be

recycled despite decades of education, it is also imperative for companies to produce consumer goods that can easily be recycled within existing infrastructure and stop producing items that cannot be. Additionally, companies should stop mislabeling products as recyclable when they are not easily recyclable within the communities where they are purchased and disposed of.

As noted, waste generation occurs at the moment goods that will become waste are obtained, not at the point of disposal. Yet most participants indicated that they rarely think about how they will dispose of an item when they are purchasing it. This also held true regarding purchase decisions regarding product packaging and whether or not it was made from recycled products. This is problematic if we continue to rely on recycling as a primary strategy for sustainable waste management: if recycling is to get closer to its reputation as an effective waste management strategy, demand for products made from recycled materials also must increase.

Although participants may be aware of problems with recycling, if they fail to consider source reduction actions, they may see recycling as the best option out of other less sustainable disposal actions. Our findings revealed a notable exception to this recycling default: it is context dependent. When asked to reduce plastic waste in oceans, participants became more likely to cite expert-recommended source reduction strategies, such as purchasing fewer plastic products. Connecting reduction strategies with ocean plastic pollution may be due to the amount of negative publicity ocean plastic has received in recent years. Several participants (6.8%) also mentioned the importance of not littering (with several specifically emphasizing not to litter or bring plastic near the ocean), indicating a belief that the primary way that waste ends up in marine environments is through individuals discarding their waste in or nearby the ocean. While there are uncertainties about the sources of most marine plastic pollution (Carney Almroth & Eggert, 2019), a large proportion comes from land-based pollution (Carney Almroth & Eggert, 2019; Geyer et al., 2017). Highlighting the various pathways that waste arrives at the ocean (e.g., lost fishing equipment, in transit to landfills or recycling centers, transported by rivers, etc.) could help correct this misperception.

Recycling as the primary strategy for reducing landfill waste may be due to a sense that waste “belongs” in landfills (sites designed for that purpose), but not in oceans and other natural areas. Emphasizing that waste does not belong in the natural areas where landfills are found and highlighting their various environmental problems (e.g., methane gas production, groundwater

contamination, public health issues) may make issues with waste generally more salient for the public. Making the environmental impact of different end destinations for waste more salient may be one way to flip mental defaults from disposal actions to source reduction actions, which future research could explore.

Our research had several limitations. Participants were not compensated for greater accuracy and our first study used a non-representative sample of participants in the United States; however, our data has sufficient heterogeneity to discover significant misperceptions (Burnham et al., 2018). It is also possible that the framing of some questions presupposes the existence of waste, which may have prompted participants to consider disposal rather than source reduction. Future research should examine how question framing impacts individuals' perceptions of waste management strategies. Consumer perceptions of agency in regard to waste management and efficacy in solving environmental problems more broadly is also a rich area for future exploration.

Our results add to the growing evidence that limiting the production of items designed to be thrown away could have a much larger impact than focusing on individual actions for sustainable waste management outcomes. Rather than continuing to emphasize recycling as the solitary sustainable waste strategy, policies and interventions should motivate behaviors that avoid the creation of waste, including purchasing more durable products, reuse, buying second-hand goods, and sharing goods (Bekin et al., 2007; Ebreo et al., 1999; García-de-Frutos et al., 2018; Ortega Egea & Garcia de Frutos, 2013; US EPA, 2013a). Source reduction strategies at scale, such as large reuse programs and extended producer responsibility legislation (Bashir et al., 2020; de Wit et al., 2020; World Economic Forum & Ellen MacArthur Foundation, 2016), should also be considered as an alternative to the current status quo that makes goods intended to be disposed of and saddles consumers with the responsibility of the end product of these goods. Recycling is a tool to be used when waste cannot be avoided, not a panacea for the overgeneration of waste.

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Appendices

Appendix A: Survey 1 Text

[Note: the following two **blocks** are randomized]

Single most effective thing: landfill

[Note: the following two **questions** are randomized]

What is the single most effective thing **YOU** can personally do to **reduce landfill waste**?

[page break]

What is the single most effective thing **OTHER** Americans can do to **reduce landfill waste**?

[page break]

Single most effective thing: plastic pollution

[Note: the following two **questions** are randomized]

What is the single most effective thing **YOU** can personally do to **reduce plastic pollution in the oceans**?

[page break]

What is the single most effective thing **OTHER** Americans can do to **reduce plastic pollution in the oceans**?

[page break]

[Note: the following two **block**s are randomized]

Individual

Think about your trash, recycling, and composting behaviors.

[page break]

Generated waste refers to all of the items that people put in the waste stream to be landfilled, recycled, composted, or incinerated. Generated waste can include anything from plastic bottles to food, old tires, and much more.

On average, how many pounds of waste do **YOU** as an individual **generate** per **week**? Please include all waste you generate, whether you recycle, throw away, compost, or burn it.

Your best estimate is fine. Please enter whole numbers with no other text (not decimals or ranges).

[page break]

You estimated that you generate [populated number from above] pounds of waste per week. For the following questions, we will ask you to estimate what percent of your waste you throw away, recycle, or compost on **average**. Please familiarize yourself with the following definitions.

Throw away means dispose of items in designated trash bins to be sent to landfills. This includes throwing away waste in trash cans, dumpsters, or any other location where waste gets collected and taken to landfills.

Recycle means dispose of items in designated recycling bins so that they can be turned into new products. This includes disposing of recyclable items in marked curbside recycling bins, recycling dumpsters, and taking items to special drop-off recycling facilities.

Compost means disposing of food, yard, and other biodegradable waste in designated spaces to be turned into natural fertilizer. Some people compost at home while others take their compostable waste to special facilities to be composted.

[page break]

Think about how you dispose of the [populated number from above] pounds of waste you generate per week. For a reminder of the definition of the different categories, place your cursor over each question. The total must equal 100.

What percent of your waste do you throw away? _____

What percent of your waste do you recycle? _____

What percent of your waste do you compost? _____

If you dispose of your waste in another way not listed here, please describe and estimate

what percent of your waste you dispose of in this way _____

Total [note: validated to equal 100] _____

<u>Average American</u>

Think about the average American's trash, recycling, and composting behaviors.

[page break]

Generated waste refers to all of the items that people put in the waste stream to be landfilled, recycled, composted, or incinerated. Generated waste can include anything from plastic bottles to food, old tires, and much more.

On average, how many pounds of waste do you think the **AVERAGE** American individual generates per **week**? Please include all waste you generate, whether you recycle, throw away, compost, or burn it.

Your best estimate is fine. Please enter whole numbers with no other text (not decimals or ranges).

[page break]

You estimated that the average American generates [populated number from above] pounds of waste per week. For the following questions, we will ask you to estimate what percent of their waste you think the average American throws away, recycles, or composts on **average**. Please familiarize yourself with the following definitions.

Throw away means dispose of items in designated trash bins to be sent to landfills. This includes throwing away waste in trash cans, dumpsters, or any other location where waste gets collected and taken to landfills.

Recycle means dispose of items in designated recycling bins so that they can be turned into new products. This includes disposing of recyclable items in marked curbside recycling bins, recycling dumpsters, and taking items to special drop-off recycling facilities.

Compost means disposing of food, yard, and other biodegradable waste in designated spaces to be turned into natural fertilizer. Some people compost at home while others take their compostable waste to special facilities to be composted.

[page break]

Think about how the average American disposes of the [populated number from above] pounds of waste they generate per week. For a reminder of the definition of the different categories, place your cursor over each question. The total must equal 100.

What percent of their waste do you think the average American throws away? _____

What percent of their waste do you think the average American recycles? _____

What percent of their waste do you think the average American composts? _____

Total [note: validated to equal 100]

_____

[page break]

<u>Decomposition and recycling time estimates</u>

How long do you think it takes the following items to decompose? Please enter a number and select a unit of time from the drop down. Example: if you think one of these items takes 2 days to decompose, please write '2' and select 'days' from the drop-down menu.

If you do not think that a particular item ever decomposes, please put N/A in the box and select 'never.'

	Amount of time to decompose. Please enter a number.	Unit of time (please select days, weeks, months, or years from the drop-down).
Plastic water bottle.		
Biodegradable plastic bag.		
Plastic bag.		
Glass bottle.		
Aluminum can.		

[page break]

When you were thinking about how long it takes the following items to decompose, which type of environment did you picture them in? Please select all that apply.

	Ocean/ marine	Landfill	City/urban	River/lake/ freshwater	Streetside/ park	None of these
Plastic water bottle						
Biodegradable plastic bag						
Plastic bag						
Glass bottle						
Waxed milk/juice carton						
Aluminum can						

[page break]

When the following products are recycled, how long do you think it takes for them to be made into a new product from the time they are collected? Example: if you think one of these items takes 2 days to be made into a new product, please write '2' and select 'days' from the drop-down menu.

	Amount of time to be made into a new product. Please enter a number.	Unit of time (please select days, weeks, months, or years from the drop-down).
Plastic water bottle.		
Plastic bag.		
Glass bottle		
Aluminum can		

[page break]

Amount of plastic recycled

[Note: the following two **questions** are randomized]

Out of all of the plastic that has ever been produced, what percent do you estimate has been recycled?

Please enter a percent with no other text (not decimals or ranges).

[page break]

Out of all the plastic that has ever been produced, what percent do you estimate has ended up in landfills or the natural environment?

Please enter a percent with no other text (not decimals or ranges).

[page break]

Recycling knowledge

[Note: the following two **questions** are randomized]

How much do **YOU** know about recycling?

For example: what can and can't be recycled, how items are recycled, and where recyclable items go? (None at all --- A little --- A moderate amount --- A lot ---A great deal)

How much do you think the **AVERAGE** American knows about recycling?

For example: what can and can't be recycled, how items are recycled, and where recyclable items go? (None at all --- A little --- A moderate amount --- A lot ---A great deal)

[page break]

Recycling Knowledge Images

Now we are going to show you images of common items. Please indicate whether or not you think that each item is **recyclable**. [Note: Bolded indicate acceptable answers. Recyclability of each item was assessed using the website Earth911 (earth911.com)'s recycling guide, a

website that the EPA links to on their “How Do I Recycle?” page for users to find recycling resources and locations (1).]

[Note: the following questions are randomized]

Paper Coffee Cup

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Cardboard

- **Recyclable at almost all recycling facilities**
- Recyclable, but only at select recycling facilities
- Not recyclable anywhere

Tin (steel) can

- **Recyclable at almost all recycling facilities**
- Recyclable, but only at select recycling facilities
- Not recyclable anywhere

Lightbulb

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Glass peanut butter jar that still has peanut butter in it

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Coffee pods

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Plastic water bottle

- **Recyclable at almost all recycling facilities**
- Recyclable, but only at select recycling facilities
- Not recyclable anywhere

Styrofoam food container

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Aluminum can

- **Recyclable at almost all recycling facilities**
- Recyclable, but only at select recycling facilities
- Not recyclable anywhere

Aluminum foil

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Glass bottle

- **Recyclable at almost all recycling facilities**
- Recyclable, but only at select recycling facilities
- Not recyclable anywhere

Greasy cardboard pizza box

- Recyclable at almost all recycling facilities
- Recyclable, but only at select recycling facilities
- **Not recyclable anywhere**

Chip bag

- Recyclable at almost all recycling facilities
- **Recyclable, but only at select recycling facilities**
- Not recyclable anywhere

Paper towel

- o Recyclable at almost all recycling facilities
- o Recyclable, but only at select recycling facilities
- o **Not recyclable anywhere**

Used diaper

- o Recyclable at almost all recycling facilities
- o Recyclable, but only at select recycling facilities
- o **Not recyclable anywhere**

Electronic cords

- o Recyclable at almost all recycling facilities
- o **Recyclable, but only at select recycling facilities**
- o Not recyclable anywhere

Plastic bag

- o Recyclable at almost all recycling facilities
- o **Recyclable, but only at select recycling facilities**
- o Not recyclable anywhere

[page break]

[Note: the following questions are randomized]

<u>Products remade</u>

What type(s) of products do you think **plastic bottles** get made into when they are recycled? Please list as many as you can think of.

What type(s) of products do you think **glass bottles** get made into when they are recycled? Please list as many as you can think of.

[page break]

<u>Cessation of recycling</u>

How important is recycling to **YOU**?

(Not at all important --- Somewhat important --- Moderately important --- Important ---Extremely important)

How important do you think recycling is to the **AVERAGE** American?

(Not at all important --- Somewhat important --- Moderately important --- Important ---Extremely important)

Do you currently recycle?

(Yes --- No)

If yes → Why do you recycle?

If no → Why don't you recycle?

If yes → If recycling were no longer offered in your area, would you change any behaviors?

(Yes --- No)

If yes → Please describe how you think you would change your behaviors if recycling were no longer offered in your area. List as many examples as you can think of.

[page break]

Wishcycling

[Note: the following two **questions** are randomized]

How often do ***YOU*** put something in the recycling that you are NOT sure is recyclable?

(Never --- Rarely --- Occasionally --- Often --- Very Often)

[page break]

How often do *you* think the **AVERAGE** American puts something in the recycling that they are NOT sure is recyclable? (Never --- Rarely --- Occasionally --- Often --- Very Often)

[page break]

Purchasing Decisions

How often do *you* take into account how you will dispose of an item when you decide to purchase it?

(Never --- Rarely --- Occasionally --- Often --- Very Often)

If an item you wanted came in packaging that was not recyclable or compostable, would you still purchase that item?

(I would definitely not buy it --- I would probably not buy it --- I might or might not buy it --- I would probably buy it --- I would definitely buy it)

How often do *you* decide **NOT** purchase something because you are concerned about creating waste?

(Never --- Rarely --- Occasionally --- Often --- Very Often)

How often do you buy products specifically because they are made out of recycled materials?

(Never --- Rarely --- Occasionally --- Often --- Very Often)

If rarely – occasionally – often – very often What products do you buy specifically because they are made out of recycled materials?

[page break]

Recycling contaminants

[Note: the following three **questions** are randomized]

If someone does not know whether or not something is recyclable, it is better for them to **put it in a recycling bin** than to throw it away.

(Strongly agree --- Somewhat agree--- Neither agree nor disagree --- Somewhat disagree --- Strongly disagree)

If someone does not know whether or not something is recyclable, it is better for them to **throw it away** than to put it in a recycling bin.

(Strongly agree --- Somewhat agree--- Neither agree nor disagree --- Somewhat disagree --- Strongly disagree)

Items are still easy to recycle even if they are not totally clean.

(Strongly agree --- Somewhat agree--- Neither agree nor disagree --- Somewhat disagree --- Strongly disagree)

When recycling, it is not a big deal if items have some food residue left on them.

[page break]

Attention/Bot Check

Please select 'No' if you are reading this question. (Yes --- No)

[page break]

China's National Sword Policy

Now we are going to ask you some questions about recycling policy. Please answer to the best of your ability without searching the internet or other sources.

[page break]

Have you heard about recent policy changes that have impacted recycling in the U.S.? (Yes --- No)

[page break]

If no For many years, China was the single largest consumer of recyclable materials generated in the United States. Starting in January 2018, China has implemented a series of bans and strict new standards and has greatly decreased how much recyclable material they import. These policy changes have caused upheaval in U.S. recycling. Some municipalities have increased the costs of recycling programs or have shut them down altogether. Others are continuing to collect recyclable materials, but are storing them in warehouses, landfilling them, or incinerating (burning) them.

Now that you are more familiar with these changes to recycling, do you think you would change any of your behaviors? (Yes --- No)

If yes Please describe how you would change your behaviors. List as many examples as you can think of.

[page break]

If yes (Have you heard . . .) Please briefly describe this policy change to the best of your knowledge.

[page break]

For many years, China was the single largest consumer of recyclable materials generated in the United States. Starting in January 2018, China has implemented a series of bans and strict new standards and has greatly decreased how much recyclable material they import. These policy changes have caused upheaval in U.S. recycling. Some municipalities have increased the costs of recycling programs or have shut them down altogether. Others are continuing to collect recyclable materials, but are storing them in warehouses, landfilling them, or incinerating (burning) them.

If yes Have these changes in recycling prompted a change in any of your behaviors? (Yes --- No)

If yes and yes Please describe how these changes in recycling have prompted a change in your behaviors. List as many examples as you can think of.

[page break]

<u>Numeracy</u>

To answer the following questions, please enter whole numbers or decimals with no other text (not ranges or percent signs).

Imagine that we flip a fair coin 1,000 times. What is your best guess about how many times the coin would come up heads in 1,000 flips?

In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1000 people each buy a single ticket from BIG BUCKS?

In ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSTAKES win a car?

[page break]

New Ecological Paradigm

The following set of questions pertain to environmental attitudes.

Please indicate the extent to which you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
We are approaching the limit of the number of people the earth can support.					
Humans have the right to modify the natural environment to suit their needs.					
When humans interfere with nature it often produces disastrous consequences.					
Human ingenuity will ensure that we do NOT make the earth unlivable.					
Humans are severely abusing the environment.					
The earth has plenty of natural resources if we just learn how to develop them.					
Plants and animals have as much right as humans to exist.					

[page break]

Please indicate the extent to which you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
The balance of nature is strong enough to cope with the impacts of modern industrial nations.					
Despite our special abilities, humans are still subject to the laws of nature.					

The so-called “ecological crisis” facing humankind has been greatly exaggerated.					
Humans were meant to rule over the rest of nature.					
The balance of nature is very delicate and easily upset.					
Humans will eventually learn enough about how nature works to be able to control it.					
If things continue on their present course, we will soon experience a major ecological catastrophe.					

[page break]

Waste Services

Where you live, which of the following waste services are available? If you are not sure whether or not it is available, do not select it.

- Curbside recycling pick-up
- Drop-off recycling center
- Recycling dumpster at my housing unit
- In-home (self) composting
- Curbside composting pick-up
- Drop-off composting center
- Curbside garbage pick-up
- Drop-off garbage station
- Garbage dumpster at my housing unit

[page break]

Of these, which do you use? [carry-forward choices from above question]

Where you live, are you charged based on the amount of garbage you throw away?
(Yes --- No--- Unsure)

Has your cost of garbage gone up in the past year? (Yes --- No--- Unsure)

Has your cost of recycling gone up in the past year? (Yes --- No--- Unsure)

Where I live, finding information on what can and cannot be recycled is easy.
(Strongly agree --- Mildly agree--- Unsure --- Mildly disagree --- Strongly disagree)

How often do you look up information on what can be recycled?
(Never --- Rarely --- Occasionally --- Often --- Very Often)

[page break]

Demographics

How many people are there in your household (including yourself)?

How would you describe your political beliefs? (Very liberal --- Liberal --- Slightly liberal --- Moderate --- Slightly conservative --- Conservative --- Very conservative)

What is your gender? (Male --- Female --- Other (please specify))

During 2018, what was your yearly household income before tax? Your best estimate is fine.

- o Did not have an income
- o Less than $20,000
- o $20,000 - $49,999
- o $50,000 - $79,999
- o $80,000 - $109,999
- o $110,000 - $139,999
- o $140,000 - $169,999
- o Greater than $170,000

Which statement best describes your current employment status?

- o Working (paid employee)
- o Working (self-employed)
- o Not working (temporary layoff from a job)
- o Not working (looking for work)
- o Not working (retired)
- o Not working (disabled)
- o Not working (other) _____
- o Prefer not to answer

What is the highest level of education you have attained?

- o Some schooling, but no diploma or degree.
- o High school diploma or GED
- o Some college
- o College degree
- o Some graduate school
- o Graduate degree

What is your year of birth?

What type of home do you live in?

- Single family house
- Apartment building
- Condominium
- Townhouse
- Duplex
- Student residential housing
- Other (please describe)

Have you lived at your current address for one year or more? (Yes --- No)

In which state do you currently reside? (Drop-down menu)

What is your zip code?

Do you have any thoughts to share or comments? (open-ended)

Appendix B: Survey 2 Text

Demographics
How many people are there in your household (including yourself)?

_____

How would you describe your political beliefs?
- Very Liberal (1)
- Liberal (2)
- Slightly Liberal (3)
- Moderate (4)
- Slightly Conservative (5)
- Conservative (6)
- Very Conservative (7)

How would you describe yourself?
- Asian or Pacific Islander (1)
- Black or African American (2)
- Hispanic or Latino (3)
- Native American or Alaskan Native (4)
- White or Caucasian (5)
- Multiracial or Biracial (6)
- Other (please describe) (7) _____

What is your gender?
- Male (1)
- Female (2)
- Other (please specify) (3) _____

During 2021, what was your yearly household income before tax? Your best estimate is fine.
- Did not have an income (1)
- Less than $20,000 (2)
- $20,000 - $49,999 (3)

- $50,000 - $79,999 (4)
- $80,000 - $109,999 (5)
- $110,000 - $139,999 (6)
- $140,000 - $169,999 (7)
- Greater than $170,000 (8)

Which statement best describes your current employment status?

- Working (paid employee) (1)
- Working (self-employed) (2)
- Not working (temporary layoff from a job) (3)
- Not working (looking for work) (4)
- Not working (retired) (5)
- Not working (disabled) (6)
- Not working (other) (7) _____
- Prefer not to answer (8)

What is the highest level of education you have attained?

- Some schooling, but no diploma or degree. (1)
- High school diploma or GED (2)
- Some college (3)
- College degree (4)
- Some graduate school (5)
- Graduate degree (6)

What is your year of birth?

_____

Have you lived at your current address for one year or more?

- Yes (1)
- No (2)

In which state do you currently reside?

- Drop-down list

What is your zipcode? _____

[page break]

Single Most Effective Thing: Disposal Block

Household waste can cause many environmental problems. What is **the single most effective thing YOU can do** in your day-to-day life that helps solve this problem? (open-ended)

[page break]

Three R's Block

There are many strategies to manage waste. We are interested in which waste management strategies you think are **best for the environment**. Please drag the choices so that **1 = best for the environment and 4 = worst for the environment.**

	Drag items here in order of best for the environment (1) to worst for the environment (4)
Source reduction of waste and reuse Recycling and composting waste Converting waste to energy Landfilling waste	

[page break]

Which of the following actions do you think is the **best for the environment**? Please drag the choices so that **1 = best for the environment and 3 = worst for the environment.**

	Drag items here in order of best for the environment (1) to worst for the environment (3).
Reduce Reuse Recycle	

[page break]

Which of the following actions do **YOU PERSONALLY** do most often? **Please drag the choices so that 1 = action you do most often and 3 = action you do least often.**

	Drag items here in order of what YOU do most often (1) to what YOU do least often (3).
Reduce Reuse Recycle	

[page break]

Sorting Measure Block

For the following questions, please drag each item into typical recycling, trash, or compost bin based on how you would normally dispose of these items.

Assume you have access to each of the following bins. How would you dispose of a typical disposable coffee cup? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Disposable Coffee Cup 	

How certain are you that you placed the coffee cup in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of clean aluminum foil? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Clean Aluminum Foil 	Recycling
	Compost
	Trash

How certain are you that you placed the aluminum foil in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain

0 50 100

Assume you have access to each of the following bins. How would you dispose of an empty aluminum can? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Empty Aluminum Can 	Recycling
	Compost
	Trash

How certain are you that you placed the aluminum can in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of an empty foil lined chip bag? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Foil Lined Chip Bag 	Recycling
	Compost
	Trash

How certain are you that you placed the chip bag in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

[page break]

Assume you have access to each of the following bins. How would you dispose of an apple core? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Apple Core 	Recycling
	Compost
	Trash

How certain are you that you placed the apple core in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of a conventional used baby diaper? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Used Baby Diaper 	Recycling
	Compost
	Trash

How certain are you that you placed the used diaper in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of a glass bottle? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Empty Glass Bottle 	Recycling
	Compost
	Trash

How certain are you that you placed the glass bottle in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

[page break]

Assume you have access to each of the following bins. How would you dispose of a disposable mask? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Disposable Mask 	Recycling
	Compost
	Trash

How certain are you that you placed the disposable mask in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of a light bulb? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Light Bulb 	Recycling
	Compost
	Trash

How certain are you that you placed the light bulb in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of clean cardboard? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Clean Cardboard 	Recycling
	Compost
	Trash

How certain are you that you placed the clean cardboard in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of a plastic bag? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Plastic Bag 	Recycling
	Compost
	Trash

How certain are you that you placed the plastic bag in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

[page break]

Assume you have access to each of the following bins. How would you dispose of a typical coffee pod? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Coffee Pods 	Recycling
	Compost
	Trash

How certain are you that you placed the coffee pods in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Assume you have access to each of the following bins. How would you dispose of a typical paper towel used to clean up water? Please drag it into the bin you would normally use. These are **standard** recycling, compost, and trash bins.

Used Paper Towel 	Recycling
	Compost
	Trash

How certain are you that you placed the paper towel in the correct bin?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

[page break]

Recycling Vs. Source Reduction Block

How certain are you that items you put in recycling bins actually get recycled?

Completely uncertain - - - - - - - - - - - - - - - - - I - Completely certain
0 50 100

Which of the following options do you think is **better for the environment?** (drag slider positioned at neutral)

Recycling waste is much better 1	Recycling waste is somewhat better 2	Neutral 3	Preventing waste is somewhat better 4	Preventing waste is much better 5

Which of the following options do **YOU do more often?** (drag slider positioned at neutral)

I recycle waste much more often 1	I recycle waste somewhat more often 2	I do them both equally 3	I prevent waste somewhat more often 4	Preventing waste is much better 5

Which of the following options do you think is easier **for individuals?** (drag slider positioned at neutral)

Recycling waste is much easier 1	Recycling waste is somewhat easier 2	They are equally easy 3	Preventing waste is somewhat easier 4	Preventing waste is much easier 5

[page break]

Systems Thinking Block

Household waste can cause many environmental problems. There is a long process for products that eventually become waste, beginning with resource extraction and ending with disposal.

At what stage in this process do you think **it is most important** for efforts to focus to solve this problem? Please click on the **ONE** stage you think is the **most important.**

At what stage in this cycle do you think **YOU as an individual** can have the most impact on solving this problem? Please click on the **ONE** stage you think **YOU can have the most impact** on this problem.

How did you make the decision for which of these stages was most important to focus on? Please share as much information as possible about your thought process when making these decisions. (open-ended)

[page break]

Waste at Purchase Block

Imagine that you are away from your house and are getting thirsty. You are in a store that sells beverages in plastic bottles. Based on your normal behavior, what would you be most likely to do?

- I would not purchase a beverage in a plastic bottle
- I would purchase a beverage in a plastic bottle and reuse it when empty
- I would purchase a beverage in a plastic bottle and recycle it when empty
- I would purchase a beverage in a plastic bottle and compost it when empty
- I would purchase a beverage in a plastic bottle and throw it in a trash bin when empty
- I would purchase a beverage in a plastic bottle and litter it when empty

Imagine that you are going to a costume party and you do not already have a costume. Based on your normal behavior, what would you be most likely to do?

- I would make a costume from items I already own
- I would purchase a new costume
- I would buy items from a thrift or second hand store to make a costume
- I would borrow a costume from someone
- Other (please describe) _____

[page break]

Attention Check

The color test you are about to answer is very simple. Please select the color 'Green.' This is an attention check.

Based on the text above, which color have you been asked to select?

- Yellow (1)
- Blue (2)
- Purple (3)
- Green (4)
- Orange (5)

[page break]

Helm Reduced Consumption Measure

Please indicate how much you agree or disagree with each of the following statements:

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
I avoid buying products that I do not really need (1)	o	o	o	o	o	o	o
I repair things that are broken rather than buy new ones whenever possible (2)	o	o	o	o	o	o	o
I avoid impulse purchases (3)	o	o	o	o	o	o	o

[page break]

Helm Materialism Measure

Please indicate how much you agree or disagree with each of the following statements:

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)

I would be happier if I had the money to buy more things for myself (1)	o	o	o	o	o	o	o
I would love to buy more expensive things (2)	o	o	o	o	o	o	o
The kind of job I want is one that pays a high salary (3)	o	o	o	o	o	o	o
I really enjoy shopping for new things (4)	o	o	o	o	o	o	o

[page break]

Recycling Heuristics Agree/Disagree

Please indicate how much you agree or disagree with each of the following statements:

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)

I prefer products that are recyclable to those that are not (1)	o	o	o	o	o	o	o
I avoid buying products that generate waste (2)	o	o	o	o	o	o	o
Recycling is sustainable (10)	o	o	o	o	o	o	o
If a product has the recycling triangle on it, it can always be recycled (11)	o	o	o	o	o	o	o

[page break]

Attention Check & Feedback

In your own words, please describe what this survey was about. (open-ended)

Do you have any thoughts to share or comments? (open-ended)

Appendix C: Full Table: Study 1, Perceptions of the Most Effective Thing

		Reduce Landfill Waste		Reduce Ocean Plastic	
Activity	Source Reduction or Disposal	Self, %	Americans, %	Self, %	Americans, %
Recycle	D	44.9	45.5	22.4	25.1
Use fewer plastic products	SR	7.4	6.5	40.0	38.6
Reuse items / buy reusable products	SR	9.1	9.3	10.1	8.7
Reduce consumption / buy less	SR	7.1	7.9	2.5	1.8
Unspecific (e.g., “avoid waste”)	--	6.3	6.8	3.1	3.7
Compost	D	4.5	2.6	--	--
Seek out items with less or more sustainable packaging	SR	4.0	3.9	3.9	2.2
Reduce food waste	SR	3.7	4.1	--	--
Mindful purchasing	SR	2.9	2.5	0.7	0.9
Advocate for systemic change	--	1.5	1.6	4.7	4.7
Seek out biodegradable items	D	1.2	0.9	1.3	0.5
Donate or sell old items	D	1.4	1.3	0.0	0.1
Burn or bury waste	D	1.1	0.5	0.0	0.4
Engage in other pro-environmental behaviors	--	1.2	2.0	0.4	0.4
Separate waste and dispose of it ‘properly’	D	0.7	0.9	1.1	1.5
The “Three R’s”: Reduce, reuse and recycle	--	0.7	0.9	--	--
Don’t know/unsure	--	0.6	0.7	0.6	0.5
Reduce	SR	0.6	1.1	0.5	0.5
Don’t litter	D	0.5	0.2	5.0	7.4

Nothing	--	0.2	0.1	0.4	0.2
Die or stop existing	SR	0.2	0.1	0.1	0.1
Don't reproduce	SR	0.1	0.1	--	--
Beach clean-ups	D	0.1	0.2	2.9	2.1
Don't bring plastic to the beach	--	--	--	0.5	0.4
Stop eating fish	SR	--	--	0.0	0.2

Participant (N=848) responses of the most effective actions they could take to reduce landfill waste and reduce plastic pollution in the ocean. Items were coded by two independent judges and categorized into source reduction or disposal actions. Some items defied this categorization, either because they could reasonably constitute both (e.g., "the three Rs," which is commonly understood to be the trio of actions reduce, reuse, and recycle) or neither (i.e., indirect or other pro-environmental behaviors, such as "drive more fuel-efficient vehicles").

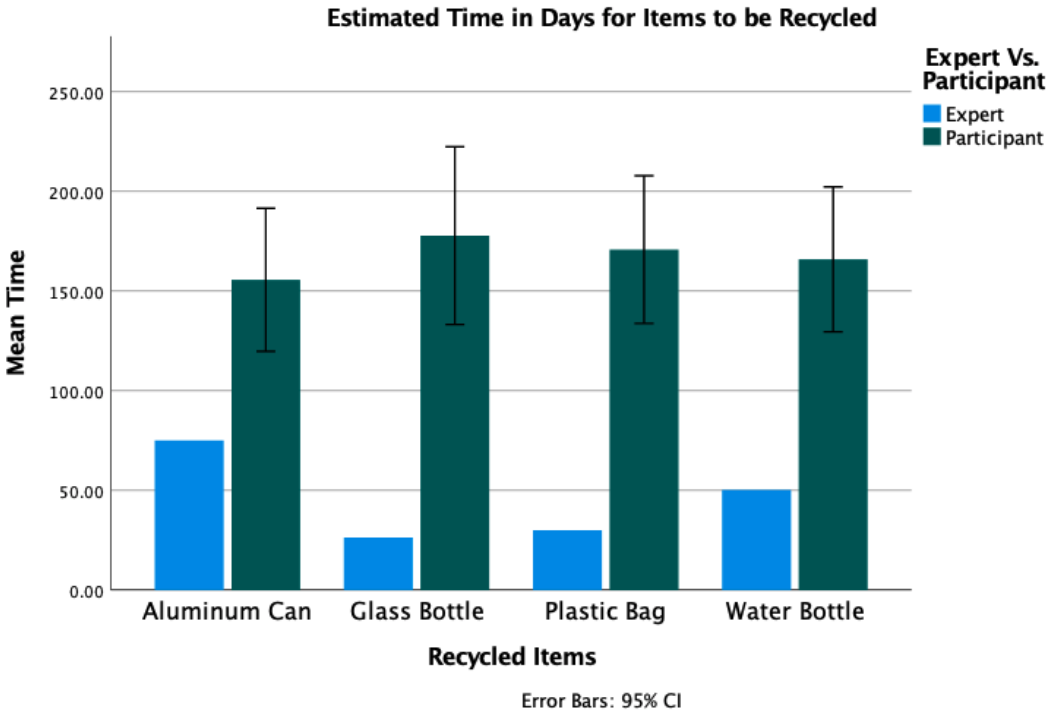
Appendix D: Reported Behavior Changes if Recycling Were Taken Away

Reported Behavior Changes	Source Reduction (SR) or Disposal (D)	Percent
Drive recyclables to another place that still recycles	D	28.9
Limit consumption and make more mindful purchases to generate less waste	SR	17.5
Throw recyclables away in the regular garbage	D	10.1
Don't know/unsure	--	7.5
Switch from recyclable to reusable	SR	5.7
Start composting/compost more	D	3.4
Vague "find other ways" to recycle	D	2.6
Raise awareness to start a community recycling program	D	2.6
Buy things that can biodegrade or be burned	D	2.3
Be more aware of waste	--	1.6

Wouldn't change behaviors because currently behave in unwasteful ways	--	1.0
Buy in bulk	SR	0.9
Would move somewhere that offers recycling	D	0.6
Feel angry or disappointed	--	0.6
Make art with recyclables	D	0.4
Do nothing - "my actions don't matter"	--	0.4

Participant responses of how they would change their behavior if recycling were no longer offered in their area.

Appendix E: Recycling Times Estimates: Participants vs. Experts



Participants' estimates of how long common recyclables take to be made into a new product from the time they are collected compared to expert estimates. Extreme outliers (>25 years) were excluded. Error bars indicate the 95% CI.

Appendix F: Educational Attainment and Recycling Knowledge

Recycling Knowledge Score by Educational Attainment

	N	Mean	SE	95% CI
Some schooling, no degree	5	.68	.05	[.53, .83]
High School Degree or Equivalent	75	.67	.17	[.64, .71]
Some College	214	.68	.01	[.66, .70]
College Degree	388	.67	.01	[.66,.69]
Some Graduate School	35	.65	.03	[.59, .71]
Graduate Degree	131	.63	.01	[.60, .66]
Total	848	.67	.01	[.66, .68]

Participants' scores on an assessment of what items can be recycled (scored from 0 – 1 or 0% to 100%) by educational attainment.

One-way ANOVA of Recycling Score by Educational Attainment

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.278	5	.056	2.352	.04
Within Groups	19.889	842	.024		
Total	20.166	847			

Comparisons of recycling knowledge by educational attainment as measured by a one-way ANOVA.

Self-Assessment of Recycling Knowledge by Educational Attainment

	N	Mean	SE	95% CI
Some schooling, no degree	5	3.00	.32	[2.12, 3.88]
High School Degree or Equivalent	75	2.69	.08	[.2.53, 2.86]
Some College	214	2.75	.06	[2.64, 2.86]

College Degree	388	2.99	.04	[2.91, 3.08]
Some Graduate School	35	3.00	.13	[2.74,3.26]
Graduate Degree	131	3.5	.08	[3.34, 3.67]
Total	848	2.98	.03	[2.93, 3.04]

Participants' self-assessments of their own recycling knowledge on a Likert-scale from 1 to 5 by educational attainment.

One-way ANOVA of Self-Assessment of Recycling Knowledge by Educational Attainment

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	53.742	5	10.748	15.007	.000
Within Groups	603.058	842	.716		
Total	656.801	847			

Comparisons of self-perceived recycling by educational attainment as measured by a one-way ANOVA.

Appendix G: Differences in Estimates of Waste Generation and Disposal

	EPA estimate (test value)	Participant Estimates	MD	95% CI of the difference	t	df	Sig. (2-tailed)	Cohen's d
Waste generated in lbs. (you)	31.57	22.23	-9.34	[-11.37, -7.31]	-9.04	847	.000	-.310
Waste generated in lbs. (avg. American)	31.57	28.64	-2.97	[-4.67, -1.18	-3.30	847	.001	-.113
Percent waste thrown away (you)	64.97	61.58	-3.39	[-5.14, -1.65]	-3.81	847	.000	-.131

Percent waste thrown away (avg. American)	64.97	68.53	3.56	[2.23, 4.90]	5.24	847	.000	.180
Percent waste recycled (you)	25.05	27.57	2.52	[1.25, 3.79]	3.90	847	.000	.134
Percent waste recycled (avg. American)	25.05	21.55	-3.50	[-4.32, -2.68]	-8.38	847	.000	-.288
Percent waste composted (you)	9.98	8.26	-1.71	[-2.56, -.87]	-3.98	847	.000	-.137
Percent waste composted (avg. American)	9.98	9.92	-.06	[-.89, .77]	-0.15	847	.882	-.005

Participant estimates of the amount of waste they and the average American generate, and of that waste, how much they throw away, recycle, and compost compared to official EPA estimates.

Appendix H: Full Table: Study 2, Perceptions of the Most Effective Thing

Activity	**Source Reduction (SR) or Disposal (D)**	**Self, %**
Recycle	D	46.9
Reuse	SR	10.6
Reduce consumption/buy less	SR	6.6
Compost	D	5.9
Reduce food waste	SR	5.1
Reduce use of plastic products	SR	5.1
Mindful purchasing	SR	3.8
Seek out items with less or more sustainable packaging	SR	3.8
Separate waste and dispose of it ‘properly’	D	3.0
Reduce	SR	3.0
Indirect, other pro-environmental behaviors	--	1.9

The “Three R’s”: Reduce, reuse and recycle	--	0.8
Miscellaneous/vague	--	0.8
Burn trash	D	0.6
Spread awareness	--	0.6
Activism/systems change	--	0.6
Don’t litter	D	0.4
Nothing/hopelessness	--	0.2
Buy biodegradable items	D	0.2

Participant responses of the most effective actions they could personally take to solve environmental problems associated with household waste. The first 100 items were coded by 2 members of the research team together to determine categories, and the remaining items were coded by 1 researcher except for items that could reasonably fit into more than one category, which were determined by the team.

Appendix I: Plans for Future Work

The findings of this work were more nuanced and complex than I first expected. In Study 1, I lamented my (expected) finding that participants defaulted to recycling and disposal rather than source reduction. In Study 2, I began to question my own assumptions about what the most effective actions were that individuals can really take. Would I give gold marks if participants cited reuse or purchase deferrals rather than recycling? While opting out challenges the system, how effective an agent of change is it?

This leads me to a question that has been top-of-mind lately: **how do we conceive of individual action for environmental change?** In the past few years, I have seen a pendulum shift: from an undue focus on individual action (Maniates, 2001) to a focus on government action, corporate responsibility, and systems change. I applaud this shift and acknowledge the desperate need for systems change—yet I am also wary of these binary narratives. In this shift, I’ve also seen a total absolution of individual responsibility. Because 100 companies are responsible for the bulk of emissions (Riley, 2017) mean that we are powerless? Does the phrase “there’s no ethical consumption under capitalism” mean that we are absolved to participate in these systems without question and efforts to change them?

In my future work, I'd like to examine how we conceive of individual action, and how we can expand what individual action is to be bigger than recycling, vegetarianism, and even voting, the individual action most often aimed at systems change. **How do individuals change the systems of which they are a part to create more sustainable options and defaults for those around them?**

I have to acknowledge the impact of my own business, KnoxFill, in the development of this thought process. KnoxFill is a zero waste refillery and where I have practically applied the insights of my own research. Rather than be militant about disposables entering my own home (an ongoing struggle, I'm afraid), I was able to create change that led to over 800 households in my region reducing their waste. Individual action led to collective impact – how else might this apply?