



Comparisons of Sustainability Behaviors Pre- and Early Pandemic Among Botanical Garden Members

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The COVID-19 outbreak drastically altered the behaviors of millions of Americans in 2020, including behaviors that contribute to carbon emissions. As many Americans stayed home midyear, environmental groups noted the decrease in driving and transportation-related pollution, theorizing that the pandemic could have a positive impact on the environment by decreasing individuals' carbon emissions. However, it is dubious that individuals will behave in a more eco-friendly manner under the uncertain and stressful conditions of a global pandemic simply because they are more likely to be confined to their homes. We examined sustainability behaviors in 2018 and in the early pandemic in 2020 among a sample of members of a U.S., botanical garden. We surveyed members in May–July 2018, asking whether they had or had not done 11 sustainability behaviors (e.g., used alternative transportation, took shorter showers) in the past month. We resurveyed members about their engagement in those behaviors in April 2020 as well as to recall their engagement in those behaviors pre-pandemic in February 2020. We examined differences in self-reported behaviors among respondents who had taken both the May–July 2018 and April 2020 surveys (matched group $n = 227$), and then among respondents who had taken either the May–July ($n = 1057$) or the April 2020 survey ($n = 881$), but not both. Respondents in the matched group were more likely to report recycling, reducing red meat consumption, eating a plant-based diet, and reducing food waste in April 2020 compared to May–July 2018; they were less likely to compost, check the air in their tires, and use a smart thermostat. However, these differences also emerged when examining recalled behavior in February 2020, suggesting that matched group respondents' self-reports may reflect changes in behavior over time rather than due to the pandemic. The unmatched group was more likely to reduce food waste but less likely to use alternative transportation to commute, check the air in their tires for fuel efficiency, and recycle in April 2020 compared to May–July 2018. Thus, few changes in sustainability behaviors can be attributed to the pandemic, but those that do involve personal travel or home confinement.

Keywords: pro-environment behavior, sustainability behavior, COVID-19, eco-friendly behavior, individual behavior

INTRODUCTION

The global outbreak of COVID-19 drastically impacted the lives of Americans in 2020. Starting in March of 2020, as state and local authorities imposed lockdowns and stay-at-home orders to mitigate the spread of the deadly virus, many people were confined to their homes, lost their jobs, and experienced stress about the uncertainty of the pandemic. The lockdown measures touched nearly all facets of public and private life for the world's people, as well as countries' economies and the global environment.

In terms of environmental impact, there is some evidence for the contribution of lock-down measures to improved environmental outcomes, at least in the initial stages of the pandemic. Scientists observed large drop-offs in air pollutant levels during the initial lockdown phases of March and April 2020 (Beran and Ebisu, 2020; Muhammad et al., 2020), reduced demand for and use of fossil fuels (Wang et al., 2020), and enhanced wildlife activity (Manenti et al., 2020). Indeed, one study estimated that, as of May 2020, new emissions of global greenhouse gases had been reduced by 2.5 Gt, which the authors attributed to worldwide decreases in production and consumption (Lenzen et al., 2020). Another estimated an 8.8% reduction in CO₂ emissions in the first half of 2020 compared to the same time period in 2019 (Liu et al., 2020). Additionally, the popular media initially extolled the benefits of the pandemic for the environment, calling them the “silver lining” of the shutdowns (Cripe, 2020; Rochard, 2020; Walt, 2020).

An assumption of the pandemic-induced environmental benefits narrative is that these large-scale benefits are partially driven by individual behaviors—that people in lockdown, or with reduced socialization and mobilization due to the pandemic, have changed their consumption or carbon-emitting habits en masse. There is some evidence to support this pandemic-induced reduction in carbon emissions. For example, one survey of U.K. adults in April of 2020 found that food shoppers reported fewer shopping trips, increased preparation of home-cooked meals, and decreased food waste (Roberts and Downing, 2020). In the transportation sector, large decreases in traffic volume were documented in the initial months of the pandemic (Clark, 2020; Hudda et al., 2020) as the number of daily vehicle-miles decreased (Dutzik, 2020; Stavrinou et al., 2020). Additionally, residential sector emissions reductions were estimated to account for 3% of the global decrease in daily CO₂ emissions (Liu et al., 2020). We note that while most estimates of greenhouse gas emission reductions due to the pandemic include a mix of commercial or industrial sector estimates (e.g., steel production, infrastructure) as well as indices of individual behaviors (e.g., residential electricity use), there has not been a thorough comparison of individual-level versus commercial-level contributions to pandemic-linked environmental benefits.

However, there is also evidence that conditions specific to the pandemic are fostering more wasteful or higher carbon behaviors. In attempts to reduce contact with potentially virus-laden products, many people increased their consumption of single-use plastics (Patrício Silva et al., 2021), such as in food takeout containers. Market research firms have noted

sharp pandemic-linked increases in online shopping activity (Rattner, 2020) that would be associated with increases in plastic and cardboard packaging as well as use of fossil fuels for transportation linked to e-commerce. Additionally, plastic and other single-use waste from disposable personal protective equipment (PPE) in the medical sector has increased (Rizan et al., 2021) along with waste associated with disposable face masks worn by members of the general public (Fadare and Okoffo, 2020; Sangkham, 2020).

In addition, it is possible that the pandemic's influence on sustainability behaviors is more strongly seen in specific populations. For instance, the pandemic and its associated economic downturn had disproportionate negative impacts on poorer Americans. Researchers found that while private sector employment decreased by 22% in the first months of the pandemic, the impact was greater among low income workers, who saw their employment decline by 35% compared to 9% for high income workers (Cajner et al., 2020). Additionally, the kinds of jobs that can be done from home (thus not requiring a carbon-intensive commute) are linked to education and income such that high income, well-educated people are more likely to be able to work from home during the pandemic (Baker, 2020; Hoenig and Wenz, 2020). Thus, to the extent that enacting sustainability behaviors requires financial resources or status-based privileges, those with higher incomes would be expected to enact more of those behaviors than low income workers. Alternately, some sustainability behaviors, such as reducing food waste or saving water, are associated with saving money. We might expect that people with lower incomes or more financial instability would enact these sustainability behaviors, to the extent that those behaviors are cost-saving.

One drawback to most of this research on specific individual sustainability behaviors early in the pandemic is that it lacks strong reference groups against which to measure changes in behavior. Some surveys rely on self-reports that explicitly ask respondents to describe their current pandemic behavior in contrast with pre-pandemic onset behavior (e.g., Roberts and Downing, 2020), and these retrospective comparisons might not be accurate as they depend on respondents being able to accurately recall past behavior. In addition, some studies report changes in large-scale trends of consumer behaviors but lack detailed reporting of behavioral shifts at an individual level. Studies that link individuals' behaviors over time are needed to rectify issues of retrospective self-report.

In order to overcome these deficiencies in methodologies to better understand the environmental impact of the pandemic, we need to better document how the pandemic altered sustainability behaviors that are linked to greenhouse gas emissions as well as waste. Accounting for changes in individuals' sustainability behaviors pre-pandemic to early pandemic will allow a more comprehensive understanding of the role that households play in characterizing the environmental impact of the pandemic.

The current study presents a glimpse into sustainability behavior changes in the early pandemic in a sample of botanical garden members in Pittsburgh, Pennsylvania. This sample is comprised of people who are environmentally engaged and have more education than the general population (Drummond et al.,

2020), and thus are an ideal sample to examine for changes in sustainability behaviors, as they likely had higher baseline engagement in eco-friendly actions. Due to the unprecedented nature of the pandemic and the exploratory nature of this work, we ask the following research question in lieu of establishing directional hypotheses: Are environmentally engaged individuals more likely, less likely, or equally likely to report engaging in various sustainability behaviors after the onset of the COVID-19 pandemic? In general, environmental beliefs tend to predict pro-environmental attitudes and behaviors (Gadenne et al., 2011), but this relation is highly dependent on the specific environmental beliefs and behaviors in question. For example, one longitudinal study of Americans found that those who had the strongest beliefs in and were most concerned about climate change were least likely to report engaging in individual sustainability behaviors but more likely to support policies fighting climate change (Hall et al., 2018). How these relations might play out in the unprecedented context of a global pandemic remains to be seen, as it is possible that a positive relation between concern about climate change and pro-environmental behaviors could be nullified by pandemic concerns. That is, a desire to act in environmentally friendly ways could be superseded by the more immediate demands of surviving a global pandemic. Interestingly, whereas recent research has highlighted the importance of future orientation in predicting pro-environmental behaviors (Beiser-McGrath and Huber, 2018), some have speculated that the trauma of the pandemic could disrupt positive expectations for the future (Holman and Grisham, 2020), which would decrease motivation to act sustainably. However, a recent longitudinal study of U.K. adults showed no change in climate concern from 2019 to June 2020, indicating that concern for climate change is robust to the assumed insecurities of the pandemic (Evensen et al., 2021). To the extent that climate concerns motivate sustainability behaviors, this would indicate that sustainability behaviors remained constant through the pandemic. Alternatively, it is possible that those with high concern for climate change increase their sustainable behaviors given coverage of the pandemic as environmentally beneficial. In this case, a social identity as an environmentalist motivates behaviors that are in line with the expectations of others (which would be that the pandemic is allowing for nature to heal, etc.), as social identification can influence behavior *via* the desire to act in accordance with group goals (Cialdini, 2003; Oyserman et al., 2007). Thus, this study aims to determine if environmentally-conscious people did, in fact, engage in more eco-friendly behaviors due to the pandemic.

Data from this project comes from two waves of surveys of those botanical garden members—the first administered in the summer of 2018 and the second in the summer of 2020. This novel study examines changes in self-reported completion of 11 sustainability behaviors. We examine these behaviors in two ways—first with a longitudinal design that assessed changes in the same sample of respondents over 2 years, and second with a cross-sectional design that examined differences between two samples of respondents surveyed pre-pandemic and in the early pandemic. This multi-method approach allows us to verify the robustness of any changes in sustainability behaviors.

METHODS

Participants

Members of a botanical garden were twice surveyed about their attitudes and behaviors regarding environmental issues. Between May and July of 2018, a survey was sent to 21,763 members of Phipps Conservatory and Botanical Gardens and 1,284 responses were recorded (response rate: 6%). Between June and August of 2020, a similar survey was sent to 30,480 Phipps members and 1,108 responses were recorded (response rate: 4%). Of these two waves of survey respondents, 227 respondents took both surveys, resulting in the matched sample. Removing the matched sample respondents from the pre-pandemic and early pandemic samples results in a pre-pandemic unmatched sample size of 1,057 and an early pandemic unmatched sample size of 881 respondents. See **Table 1** for comparisons of these samples in terms of self-reported demographic characteristics.

Compared to the 2019 demographics of the local population of residents within the county in which the botanical garden is located, our sample is more likely to be female (77.1% May–July 2018 unmatched sample; 77.3% April 2020 unmatched sample; 72.5% matched sample vs. 51.6% locally) and have at least a Bachelor's degree (83.9% May–July 2018 unmatched sample; 84.9% April 2020 unmatched sample; 92.4% matched sample vs. 42.9% locally) (U.S. Census Bureau, 2021).

Procedure and Design

Botanical garden members were sent a link to the survey *via* emails sent to the member listserv of Phipps. Detailed response rate information for 2018 are reported in previous reporting on these data in Drummond et al. (2020). In this 2018 survey, respondents provided information on their current sustainability behaviors. In the 2020 survey, a total of 30,480 households were contacted, out of which 1,587 (5%) households accessed the link to the survey. Of those that accessed the survey, 11 did not give their consent to participate in research and were not allowed to continue to the survey and 468 did not complete the survey, leaving a final sample of 1,108 with an overall response rate of 4%. In this 2020 survey, respondents provided information on their current sustainability behaviors as well as recalled information about their pre-pandemic sustainability behaviors.

Terminology and Timeline

See **Figure 1** for a timeline of the survey distributions and associated terminology. For ease of reporting, we will refer to the pre-pandemic time, assessed by the first survey, as “May–July 2018.” We will refer to the recalled pre-pandemic time, assessed by the second survey, as “February 2020.” Finally, we will refer to the early pandemic time, also assessed by the second survey, as “April 2020.”

Survey Measures

Sustainability Behaviors

In the pre-pandemic survey, participants were presented with 11 individual actions and with the following description: “Below is a list of actions people can take to reduce a household's impacts on the environment. Please indicate which actions you

TABLE 1 | Sample characteristics.

	Pre-pandemic (May–July 2018) unmatched sample (n = 1,057)	Early pandemic (April 2020) unmatched sample (n = 881)	Pre- and early pandemic matched sample (n = 227)
Age (M, SD)	50.9 (15.6)	51.2 (15.4)	52.7 (15.3)
% Men	22.9	22.7	27.5
% with children	64.3	61.9	61.5
Educational attainment (% reporting each category)	Some high school: 0.1 High school: 3.6 Some college: 7.9 Associate's: 4.5 Bachelor's: 34.7 Graduate or professional degree: 49.2	Some high school: 0.0 High school: 1.4 Some college: 7.9 Associate's: 5.9 Bachelor's: 36.5 Graduate or professional degree: 48.4	Some high school: 0.0 High school: 0.9 Some college: 2.7 Associate's: 4 Bachelor's: 35.9 Graduate or professional degree: 56.5
Political party affiliation (% reporting each category)	Democrat: 50 Republican: 13 Independent: 19	Democrat: 52 Republican: 13 Independent: 18	Democrat: 53 Republican: 10 Independent: 19
Political conservatism-liberalism (5-point scale; 1 = very conservative; 5 = very liberal) (M, SD)	3.44 (1.01)	3.51 (0.98)	3.58 (0.95)

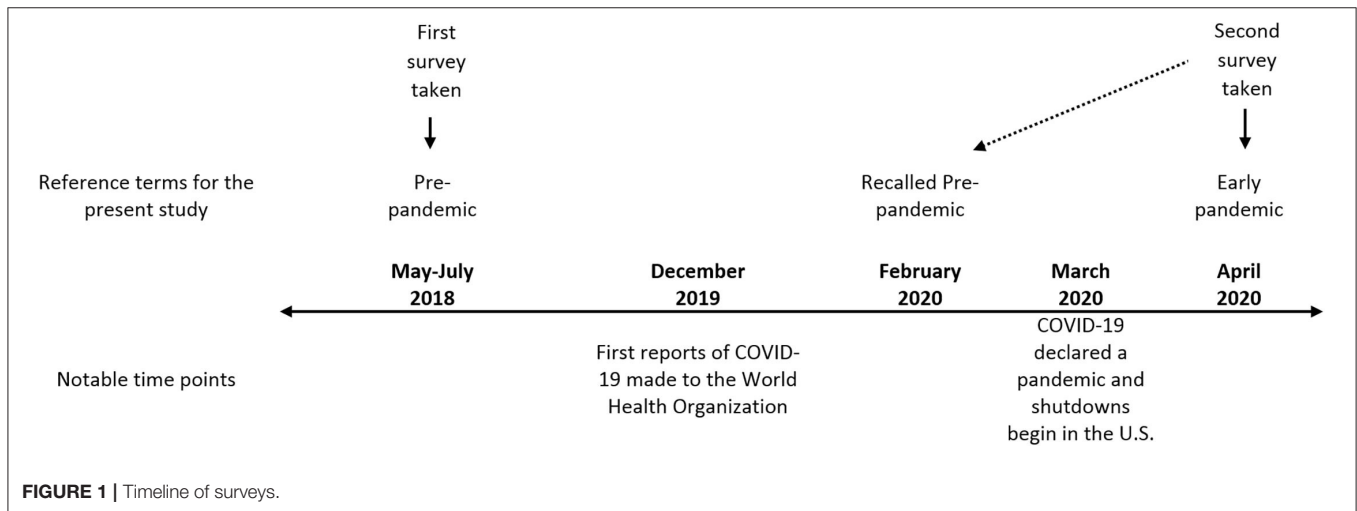


FIGURE 1 | Timeline of surveys.

personally took in the past month.” The actions were drawn from prior research on environmental behavior (Gardner and Stern, 2010; Truelove and Parks, 2012) and estimates of greenhouse gas emissions (Hawken, 2017) and are as follows: used public transportation, biked, or walked to work instead of driving; used energy efficient lightbulbs such as CFLs or LEDs; recycled; taken shorter showers; driven a hybrid or electric vehicle; reduced red meat consumption; eaten a more plant-based diet; reduced food waste; composted waste; checked the air in your tires to ensure fuel efficiency; used a smart thermostat; installed or used low-flow shower heads or faucets. Participants could respond “Yes,” “No,” or “Not applicable.”

In the 2020 survey, participants were presented with the same 11 behaviors and response options as the May–July 2018 survey in two response contexts. First, participants were asked to think back to their lives before the COVID-19 outbreak (the survey instructions for this section included the line “For many people, this will mean thinking about February 2020”) and were instructed to indicate which behaviors they

had done in February of 2020. We note that these behaviors are recalled pre-pandemic behaviors and will be denoted by “February 2020.” Then participants were asked to think about their household’s behaviors during the COVID-19 outbreak (the survey instructions for this section included the line “For many people, this will mean thinking about April 2020”) and were instructed to indicate which behaviors they had done in April of 2020. We will refer to these contemporaneous reports of behaviors as “April 2020.”

Statistical Methods

We will present two parallel sets of analyses comparing May–July 2018 sustainability behaviors to April 2020 sustainability behaviors using two samples—a matched group and an unmatched group. For the purposes of this analysis, all “Not applicable” responses are treated as missing; “No” responses were coded as 0 and “Yes” responses as 1. For the matched group comparisons, we use McNemar’s test to test for differences in the marginal probabilities of responses changing at two time points;

first comparing May–July 2018 responses to February 2020 responses and second comparing May–July 2018 responses to April 2020 responses. These analyses test for differences between changes from “No” to “Yes” responses compared to “Yes” to “No” responses. We use the McNemar’s test with a continuity correction when a cell count in the contingency table is <5 and correct for multiple comparisons with the discrete Bonferroni-Holm multiplicity adjustment. For discordant pairs of cells (i.e., those changing their response over time from “No” to “Yes” or from “Yes” to “No”) that are low-occurrence (<25), we do not perform McNemar’s test due to the increased Type I error rate (Agresti, 2014; Fagerland et al., 2014). For the unmatched group comparisons, we use chi-squared tests to test for differences in the expected frequencies and the observed frequencies of the “No/Yes” responses May–July 2018 and April 2020, correcting for multiple comparisons with the Bonferroni adjusted alpha level of 0.0045 (0.05/11) per test.

RESULTS

Matched Group Analysis

The ratios of response changes, or discordant cells, for the matched sample can be found in **Table 2**.

Used Public Transportation, Biked, or Walked to Work Instead of Driving

Due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to February 2020. The proportion of people reporting having done this action changed from May–July 2018 to April 2020, $\chi^2(1, N = 79) = 7.22$, $p = 0.007$ with continuity correction, such that the proportion of people responding “No” May–July 2018 and then “Yes” April 2020 (0.00%) is smaller than the proportion of people responding “Yes” May–July 2018 and then “No” April 2020 (65.91%). However, we note that an especially high proportion of respondents in the early pandemic selected “Not applicable” to this item—58.6% compared to less than 17% for all other sustainability behaviors. Thus, we conducted an exploratory, *post-hoc* analysis to directly account for the “Not applicable” responses in the early pandemic. We tested for changes in paired responses in a 3×3 matrix of responses in 2018 (“Yes,” “No,” or “Not applicable”) and in April 2020 (“Yes,” “No,” or “Not applicable”) using the Stuart Maxwell test and found a significant difference, $\chi^2(2, N = 227) = 62.10$, $p < 0.001$ *post-hoc* pairwise comparisons revealed a significant increase from those who selected “Yes” in May–July 2018 to “Not applicable” in April 2020 (adjusted $\chi^2 p < 0.001$), for those who selected “No” in May–July 2018 to “Not applicable” in April 2020 (adjusted $\chi^2 p = 0.0024$), and for those who selected “Yes” in May–July 2018 to “No” in April 2020 (adjusted $\chi^2 p < 0.001$).

Used Energy Efficient Lightbulbs

Due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to February 2020. Similarly, due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to April 2020.

Recycled

Due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to February 2020. Similarly, due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to April 2020.

Taken Shorter Showers

The proportion of people reporting having done this action did not change significantly from May–July 2018 to February 2020, $\chi^2(1, N = 223) = 4.37$, $p = 0.037$, as this comparison did not survive the discrete Bonferroni-Holmes multiplicity adjustment correction with alpha set at 0.0125. In addition, the proportion of people reporting having done this action did not change from May–July 2018 to April 2020, $\chi^2(1, N = 220) = 4.12$, $p = 0.042$, as this comparison did not survive the discrete Bonferroni-Holmes multiplicity adjustment correction with alpha set at 0.0167.

Driven a Hybrid or Electric Vehicle

Due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to February 2020. Similarly, due to a low count in the discordant pair, McNemar’s test was not performed comparing May–July 2018 to April 2020.

Reduced Red Meat Consumption

The proportion of people reporting having done this action changed from May–July 2018 to February 2020, $\chi^2(1, N = 211) = 47.65$, $p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” February 2020 (29.82%) is larger than the proportion of people responding “Yes” May–July 2018 and then “No” February 2020 (15.58%). In addition, the proportion of people reporting having done this action changed from May–July 2018 to April 2020, $\chi^2(1, N = 210) = 36.10$, $p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” April 2020 (27.59%) is larger than the proportion of people responding “Yes” May–July 2018 and then “No” April 2020 (22.37%).

Eaten a More Plant-Based Diet

The proportion of people reporting having done this action changed from May–July 2018 to February 2020, $\chi^2(1, N = 222) = 42.36$, $p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” February 2020 (16.95%) is larger than the proportion of people responding “Yes” May–July 2018 and then “No” February 2020 (15.34%). In addition, the proportion of people reporting having done this action changed from May–July 2018 to April 2020, $\chi^2(1, N = 223) = 42.55$, $p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” April 2020 (21.67%) is larger than the proportion of people responding “Yes” May–July 2018 and then “No” April 2020 (17.18%).

Reduced Food Waste

The proportion of people reporting having done this action changed from May–July 2018 to February 2020, $\chi^2(1, N = 222) = 114.89$, $p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” February 2020 (53.66%) is larger than the proportion of people responding

TABLE 2 | Ratios of response changes in matched sample ($n = 227$).

		May–July 2018 → February 2020	p	May–July 2018 → April 2020	p
Alternative transportation	No → Yes	3.92%	N/A	0.00%	0.007
	Yes → No	25.81%		65.91%	
Used energy efficient lightbulbs	No → Yes	66.67%	N/A	50.00%	N/A
	Yes → No	1.82%		4.98%	
Recycled	No → Yes	40.00%	N/A	20.00%	N/A
	Yes → No	0.50%		18.02%	
Shorter showers	No → Yes	22.22%	0.037	22.47%	0.042
	Yes → No	27.07%		27.48%	
Driven hybrid or electric vehicle	No → Yes	3.85%	N/A	5.66%	N/A
	Yes → No	4.00%		4.00%	
Reduced red meat consumption	No → Yes	29.82%	<0.001	27.59%	<0.001
	Yes → No	15.58%		22.37%	
Eaten more plant-based diet	No → Yes	16.95%	<0.001	21.67%	<0.001
	Yes → No	15.34%		17.18%	
Reduced food waste	No → Yes	53.66%	<0.001	57.14%	<0.001
	Yes → No	9.39%		12.71%	
Composted	No → Yes	9.24%	0.07	11.97%	0.037
	Yes → No	14.43%		19.59%	
Checked air in tires	No → Yes	36.00%	<0.001	23.61%	0.002
	Yes → No	12.95%		28.68%	
Used smart thermostat	No → Yes	22.05%	0.005	18.25%	0.001
	Yes → No	25.88%		27.06%	

Significantly different proportions that survived the discrete Bonferroni-Holmes multiplicity adjustment correction are bolded. N/A indicates that McNemar’s test were not performed due to discordant cells adding up to <25.

“Yes” May–July 2018 and then “No” February 2020 (9.39%). In addition, the proportion of people reporting having done this action changed from May–July 2018 to April 2020, $\chi^2 (1, N = 223) = 111.36, p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” April 2020 (57.14%) is larger than the proportion of people responding “Yes” May–July 2018 and then “No” April 2020 (12.71%).

Composted

The proportion of people reporting having done this action did not change from May–July 2018 to February 2020, $\chi^2 (1, N = 216) = 3.27, p = 0.07$, as this comparison did not survive the discrete Bonferroni-Holmes multiplicity adjustment correction with alpha set at 0.025. In addition, the proportion of people reporting having done this action did not change from May–July 2018 to April 2020, $\chi^2 (1, N = 214) = 4.37, p = 0.037$, as this comparison did not survive the discrete Bonferroni-Holmes multiplicity adjustment correction with alpha set at 0.01.

Checked Air in Tires to Ensure Fuel Efficiency

The proportion of people reporting having done this action changed from May–July 2018 to February 2020, $\chi^2 (1, N = 214) = 31.53, p < 0.001$, such that the proportion of people responding “No” May–July 2018 and then “Yes” February 2020 (36.00%) is larger than the proportion of people responding “Yes” May–July 2018 and then “No” February 2020 (12.95%).

In addition, the proportion of people reporting having done this action changed from May–July 2018 to April 2020, $\chi^2 (1, N = 201) = 9.31, p = 0.002$, such that the proportion of people responding “No” May–July 2018 and then “Yes” April 2020 (23.61%) is smaller than the proportion of people responding “Yes” May–July 2018 and then “No” April 2020 (28.68%).

Used a Smart Thermostat

The proportion of people reporting having done this action changed from May–July 2018 to February 2020, $\chi^2 (1, N = 212) = 8.00, p = 0.0046$, such that the proportion of people responding “No” May–July 2018 and then “Yes” February 2020 (22.05%) is smaller than the proportion of people responding “Yes” May–July 2018 and then “No” February 2020 (25.88%). In addition, the proportion of people reporting having done this action changed from May–July 2018 to April 2020, $\chi^2 (1, N = 211) = 10.19, p = 0.0014$, such that the proportion of people responding “No” May–July 2018 and then “Yes” April 2020 (18.25%) is smaller than the proportion of people responding “Yes” May–July 2018 and then “No” April 2020 (27.06%).

Unmatched Group Analysis

Raw counts of responses for the unmatched sample, as well as p -values from the chi-squared tests, can be found in **Table 3**.

TABLE 3 | Proportions and counts of responses and chi-squared results in unmatched sample.

	May–July 2018 <i>n</i> = 1,057		April 2020 <i>n</i> = 881		<i>p</i>
	No % (n)	Yes % (n)	No % (n)	Yes % (n)	
Alternative transportation	55% (412)	45% (338)	77% (328)	23% (98)	<0.001
Used energy efficient lightbulbs	4% (42)	96% (1010)	8% (60)	92% (799)	0.005
Recycled	4% (39)	96% (1011)	7% (62)	93% (802)	0.001
Shorter showers	39% (408)	61% (637)	45% (385)	55% (476)	0.014
Driven hybrid or electric vehicle	89% (880)	11% (113)	85% (636)	15% (114)	0.023
Reduced red meat consumption	33% (335)	67% (677)	35% (294)	65% (554)	0.51
Eaten more plant-based diet	32% (336)	68% (700)	34% (298)	66% (568)	0.39
Reduced food waste	24% (247)	76% (798)	18% (155)	82% (714)	0.002
Composted	62% (637)	38% (394)	64% (541)	36% (305)	0.36
Checked air in tires	37% (386)	63% (648)	48% (383)	52% (416)	<0.001
Used smart thermostat	60% (603)	40% (404)	60% (493)	40% (335)	0.92

Raw counts do not include “Not Applicable” responses. Significantly different proportions that survived the Bonferroni correction are bolded.

Used Public Transportation, Biked, or Walked to Work Instead of Driving

The proportion of people reporting having done this action differed by time, $\chi^2(1, N = 1176) = 55.74, p < 0.001$. Respondents were less likely to say that they had used alternative transportation to get to work in the past month in April 2020 (23.00%) than in May–July 2018 (45.07%). We additionally explored the selection of “NA” as an additional response option for this sustainability behavior, as we did for the matched group. In this case, the proportion of responses differed by time, $\chi^2(2, N = 1176) = 155.69, p < 0.001$. A series of *post-hoc* tests revealed that the proportion of people responding “Yes” differed by time such that fewer people responded “Yes” in April 2020 compared to May–July 2018 ($p < 0.001$), and the proportion of people responding “NA” differed by time such that more people responded “NA” in April 2020 ($n = 455$) compared to May–July 2018 ($n = 307; p < 0.001$).

Used Energy Efficient Lightbulbs

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,911) = 7.80, p = 0.005$, as the test did not survive the Bonferroni correction.

Recycled

The proportion of people reporting having done this action differed by time, $\chi^2(1, N = 1,914) = 10.68, p = 0.001$. Respondents were less likely to say that they had recycled in the past month in April 2020 (92.82%) than in May–July 2018 (96.29%).

Taken Shorter Showers

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,906) = 6.02, p = 0.014$, as the test did not survive the Bonferroni correction.

Driven a Hybrid or Electric Vehicle

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,743) = 5.17, p = 0.023$, as the test did not survive the Bonferroni correction.

Reduced Red Meat Consumption

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,860) = 0.44, p = 0.51$.

Eaten a More Plant-Based Diet

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,902) = 0.74, p = 0.39$.

Reduced Food Waste

The proportion of people reporting having done this action differed by time, $\chi^2(1, N = 1,914) = 9.27, p = 0.002$. Respondents were more likely to say that they had reduced food waste in the past month in April 2020 (82.16%) than in May–July 2018 (76.36%).

Composted

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,877) = 0.44, p = 0.36$.

Checked the Air in Your Tires to Ensure Fuel Efficiency

The proportion of people reporting having done this action differed by time, $\chi^2(1, N = 1,833) = 20.38, p < 0.001$. Respondents were less likely to say that they had checked the air in their tires in the past month in April 2020 (52.07%) than in May–July 2018 (62.67%).

Used a Smart Thermostat

The proportion of people reporting having done this action did not differ by time, $\chi^2(1, N = 1,835) = 0.01, p = 0.92$.

DISCUSSION

In a novel natural experiment, this research tracked changes in botanical garden members' self-reports of engaging in a variety of sustainability behaviors before and after the onset of the global COVID-19 pandemic. We tracked these changes in two ways. First, we identified a matched group of garden members who had responded to both a 2018 and a 2020 survey and we compared their responses over time. Second, we defined two unmatched groups of respondents who had either taken the 2018 or the 2020 survey, but not both, and compared their responses as independent samples.

Across both of our matched and unmatched samples, we find no evidence of a widespread shift in sustainability behaviors after the onset of the pandemic in either direction. While the small ($n = 227$) group of matched sample respondents were more likely to report engaging in sustainability behaviors after the onset of the pandemic than 2 years prior, this shift appears to have occurred prior to the onset of the pandemic, as respondents also were more likely to report engaging in these behaviors in February of 2020. Specifically, respondents were more likely to report that they reduced their red meat consumption and food waste, ate a more plant-based diet, and used a smart thermostat in both February 2020 and April 2020 compared to 2018. That these changes could be measured in February 2020 suggests that the pandemic, which began to impact most Americans in March 2020, is not a causal factor driving behavioral change.

This pattern of matched group respondents being more likely to report engaging in sustainability behaviors in both February and April of 2020 compared to 2018 reflects broad changes over time toward more sustainable behaviors that, while not pandemic-related, could be attributed to the composition of the matched group. This is a sample of 227 members of a botanical garden who responded twice, nearly 2 years apart, to environmental behavior surveys sent by that botanical garden. These respondents represent just 1.04% of the total botanical garden members contacted in 2018 and 0.74% of the total contacted in 2020. That is, the matched sample respondents represent a minority of all respondents who, based on their demonstrated reliability in taking multiple surveys from the botanical garden over time, might reasonably be viewed as categorically different from one-time respondents in a way that is related to their increased likelihood of engaging in sustainability behaviors over time. Indeed, the response patterns from this group may be a result of self-selection bias, whereby respondents from the first survey who wish to report on their more sustainable behaviors are more likely to participate in the second survey, but those who would not have more sustainable behaviors to report would be less likely to participate a second time. We additionally note that a larger proportion of the matched sample has a graduate or professional degree than both unmatched groups (Table 1).

We did find changes in two sustainability behaviors involving personal travel both pre-pandemic and in the early pandemic. First, *post-hoc* tests revealed that the matched group respondents selected "Not applicable" for using alternative transportation to get to work in the early pandemic when they had previously

selected "Yes" in 2018. This shift could be explained by the fact that many people in the early pandemic switched to remote work, negating the need for a commute at all, or lost their jobs. This finding, paired with their decreased likelihood to check the air in their tires to ensure fuel efficiency in the early pandemic (the only behavior that showed an early pandemic effect), suggests that the pandemic reduced driving time and driving-associated behaviors.

The findings from our unmatched samples demonstrate the complexities of pandemic life for sustainable lifestyles. Compared to pre-pandemic respondents, respondents in the early stages of the pandemic were more likely to engage in one sustainability behavior—reducing food waste. However, these respondents were also less likely to engage in three sustainability behaviors: recycling, using alternative transportation to get to work, and checking the air in their tires, compared to pre-early pandemic respondents. Instead of a widespread shift toward or away from sustainable behaviors, these findings reflect a more nuanced view of how the realities of the pandemic, and its accompanying effects on employment and leisure, have downstream consequences for sustainability behaviors.

The increased likelihood of reducing food waste is consistent with other studies on the impact of the pandemic on food usage (Rodgers et al., 2021), and reveals a potential environmental benefit of the pandemic. Reducing individuals' food waste at the point of consumption has been identified as a top priority in creating a sustainable food system that will ultimately reduce global greenhouse gas emissions (Hawken, 2017; Willett et al., 2019). While it is possible that respondents in the early pandemic reduced their food waste in the interest of making more environmentally-friendly choices, the fact that this was the sole sustainability behavior that increased suggests that another explanation is needed. First, in the early weeks of nationwide shutdowns in the U.S., there were food shortages across the meat and dairy sectors (Peel, 2021; Weersink et al., 2021) and increases in panic-buying and stockpiling behavior among food shoppers (Keane and Neal, 2021). Thus, this scarcity, or perceived scarcity, of food may have caused respondents to reduce food waste as a means to maximize their food supply. Additionally, people may have been motivated to fully exhaust their pantries before risking exposure to the virus by venturing out to the grocery store. A final possibility is that, with pandemic-related losses in income, respondents were reducing food waste as a cost-saving measure.

The finding that unmatched group respondents were less likely to report recycling in the early pandemic compared to pre-pandemic demonstrates a potential environmental disadvantage of the pandemic. Recycling is a commonly cited example of an action that reduces one's carbon footprint (Attari et al., 2010, 2016), and it is frequently recommended in environmental literature despite having a low impact on reducing carbon emissions (Wynes and Nicholas, 2017). A multitude of individual-level factors have been positively linked to recycling behaviors (e.g., self-efficacy or pro-environmental values; Geiger et al., 2019), but these factors are likely to be relatively stable in our sample population of botanical garden members. For example, our measure of concern for climate change did not differ between the unmatched groups, indicating that the pandemic did not impact climate change perceptions. Thus, it

is unlikely that the pandemic reduced recycling by negatively impacting perceptions of the environment or recycling attitudes; instead, it is likely that the contextual or incidental factors related to the pandemic were the cause. Recycling is less likely to occur in households that lack a recycling bin (Geiger et al., 2019), and with people spending more time at home with fewer opportunities to recycle in public places due to the pandemic, those without established household recycling habits were perhaps less likely to encounter opportunities to recycle. However, we note that the recycling rates for both pre-pandemic and pandemic-era groups were high, and thus we caution against interpreting a decline in recycling from 96 to 92% as a particularly dire environmental consequence of the pandemic.

The findings that relate to transportation (i.e., taking alternative transportation to work and checking the air in your tires to ensure fuel efficiency) from the unmatched group comparisons reveal the extent to which the pandemic has influenced personal travel patterns. First, as with the matched group, unmatched group respondents may be less likely to report taking alternative transportation to work because they are working remotely and thus do not need to travel in any capacity to their workplace, or because they have experienced pandemic-related job loss and have no workplace that would necessitate a commute. Thus, this decreased likelihood of using alternative transportation, while on its face seems to imply an increased reliance on traditional, high-carbon commuting, may in fact represent a decline in all commuting behaviors, which is itself a sustainability behavior on par with using alternative transportation. Unfortunately, this research cannot definitively say whether this is the case, as we did not ask for the reason behind such responses. However, pandemic-related decreases in use of public transportation specifically (Ahangari et al., 2020; Teixeira and Lopes, 2020) and mobility generally (Warren and Skillman, 2020) are well-documented and fit with our findings. Similarly, unmatched group respondents' decreased likelihood of checking the air in their tires to ensure fuel efficiency may on its face seem like a decrease in sustainable behavior, but in actuality may reflect a decrease in personal vehicle usage.

This pattern of results from the unmatched groups may reflect more net-positive environmental benefits after pandemic onset than at first glance. First, unmatched respondents in the early pandemic were more likely to reduce food waste and possibly less likely to use personal vehicles than pre-pandemic respondents, which would reflect behaviors that are commonly cited as effective for reducing individual greenhouse gas emissions (Hawken, 2017). Additionally, while the reduction in recycling behavior is potentially vexing, we note that it is a small effect among people who were likely at ceiling for the behavior. Paired with the fact that individual recycling is a relatively low-impact sustainability behavior in terms of its carbon-reduction potential (Wynes and Nicholas, 2017), we cannot conclude that our sample's decrease in recycling behavior would have a large negative environmental impact. Thus, the change in sustainability behaviors of the unmatched sample are, on balance, likely to be modestly positive.

However, there is reason to be skeptical that these changes in sustainability behaviors will outlive the pandemic era. In

countries where the recovery from the pandemic has begun, such as China, there has been an increase in domestic travel for leisure and work approaching pre-pandemic levels (Chen et al., 2020). Indeed, even in the U.S. there is emerging evidence of recoveries in traffic volume, such as in usage of toll roads (Conduent Business Services, 2020) and increased number of driver-reported trips (CNN Business, 2021). Some researchers, while acknowledging that nearly half of the global decrease in daily carbon emissions comes from the transportation sector, predict that the effect will be temporary as it does not reflect underlying changes in transport systems (Le Quéré et al., 2020).

Reductions in food waste could potentially have a long-lasting effect. Many have noted an aversion to food waste both culturally and individually after crises such as the Great Depression (Poppendieck, 1986). With the COVID-19 pandemic in particular, a recent study found that those experiencing pandemic-related unemployment spent less on food and had less confidence in their ability to afford food than those not experiencing unemployment (Restrepo et al., 2021), which could increase or perpetuate food waste reduction behaviors, as food waste minimization has been linked to a desire to not waste money (Graham-Rowe et al., 2014). To the extent that the pandemic imparts a lasting belief in frugality on those who lived through it, the transition to food waste reduction behaviors should be stable. However, to the extent that food waste reduction is linked to food or income insecurity, one would predict that this behavior would not continue post-pandemic when unemployment rates decline. Similarly, one might anticipate that a return to business-as-usual for our sample would result in a return to formerly high levels of recycling behaviors as well.

While these results are modestly positive, we recognize a primary limitation to this work is a potential lack of generalizability to the wider U.S. and international populations. The uniqueness of our sample of botanical garden members meant that they were ideal for studying changes in sustainability behaviors because they were more likely to be doing those behaviors pre-pandemic, but it also means that translating our effects to a less environmentally-engaged population is difficult. We also acknowledge that our sample could be at ceiling for these behaviors, and thus it would be fruitful for future studies to examine sustainability behavior change among those with low or average baseline sustainability behavior engagement. Additionally, our sample had higher education, and likely higher income, than a representative U.S. sample. This likely resulted in a sample that was economically secure and stable during the pandemic, so future research should clarify the role that income and financial security played in pandemic-related changes in sustainability behaviors. Future research could also examine engagement in sustainability behaviors not studied here, like reducing consumption of dairy products (Kause et al., 2019), purchasing energy-efficient household appliances, or insulating and weatherizing their home (Stern et al., 2016).

Despite the lack of certainty regarding the continuation of these sustainability behaviors, we can draw some general conclusions about the impact of the COVID-19 pandemic on sustainability behaviors in an environmentally

engaged sample. First, we find no evidence of changes in most of the sustainability behaviors measured that can be attributed to the pandemic. Second, many of the observed changes seem to center around decreases in personal travel behaviors that are probably linked to early pandemic stay-at-home orders. Finally, increases in reducing food waste and decreases in recycling were found, but further research into behaviors occurring beyond the early pandemic stage are needed to discern if these changes are long-lasting.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Michigan Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CD, RP, GW-P, and SS contributed to the design and implementation of the surveys upon which this study is based and provided feedback on the manuscript. KM, CD, GW-P, and SS contributed to the conceptual design of the study. CD organized and maintained the data. KM performed the statistical analyses and wrote the manuscript. All authors read and approved the submitted version.

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