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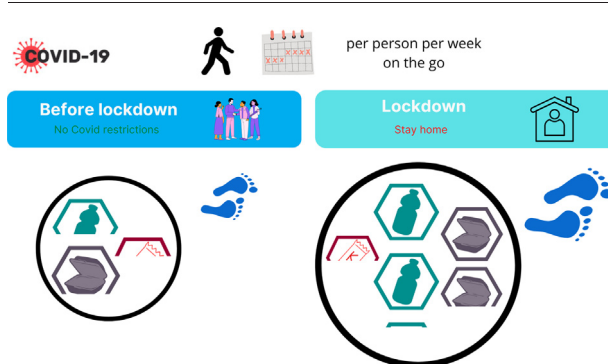
Drivers of public plastic (mis)use — New insights from changes in single-use plastic usage during the Covid-19 pandemic

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HIGHLIGHTS

- On-the-go plastic consumption increased during Covid-19 lockdowns.
- Food wrappers (54 %), takeaway containers (12 %) and bottles (9 %) most used.
- After lockdowns, plastic consumption remained higher than pre-Covid conditions.
- Government top-down action influenced consumer behaviour.
- Further policies needed to encourage reusable use, targeting businesses and public

GRAPHICAL ABSTRACT



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ABSTRACT

The coronavirus pandemic (Covid-19) has influenced resource use and how people interact with their environment, with changing priorities and competing public health factors affecting pro-environmental behaviours at individual, societal, business and political levels.

We used data from an online plastic footprint calculator to explore temporal changes, purchasing patterns and consumer behaviours around on-the-go plastic use during the pandemic. We hypothesised that 1) people's plastic use when on-the-go would change in response to the pandemic and related government restrictions and; 2) single-use plastic use on-the-go would decrease during lockdown periods due to restrictions against leaving home.

The calculator received 1937 responses, with 13,544 plastic items recorded. Most used were food wrappers (54 % of all items), takeaway containers (12 %) and bottles (9 %). Six out of seven items showed increased use during lockdowns, in-line with our first hypothesis, but not the second. Three times more bottles were used, food wrapper consumption almost doubled, and takeaway container use more than doubled. Increased container use occurred alongside increased takeaway meal consumption during lockdowns. Patterns were similar between different periods of lockdown, with no significant differences in the number used of any items, or percentage of respondents using them. Results indicate that during lockdown, people found it harder to avoid single-use plastic while on-the-go, supporting evidence from other studies that plastic use can be driven by perceptions of hygiene benefits and lack of "safe" alternatives. Our results indicate opportunities to reduce single-use plastic consumption and we provide examples of successful implementation. Our findings evidence that, when properly applied, government-led guidance can effectively support consumer choices for reduced plastic use, encourage use of reusables, increase provision of alternatives, and dispel hygiene myths. The

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sudden increase in plastic waste due to the Covid-19 pandemic amplifies the need to substantiate plastic reduction policy promises without further delay.

1. Introduction

In 2020, the coronavirus pandemic (Covid-19) instigated a change in the way people interact with their environment and use resource. During this period, national and local governments across the globe introduced restrictions to movement and business operations. This had direct impacts on people's daily routines; including increased working from home, the use of personal protective equipment (PPE) and changes to travel and eating habits. Greater awareness of personal hygiene and concern about disease transmission changed people's behaviour, both in and out of the home, affecting consumption and purchasing patterns. Uncharacteristic and unprecedented temporal fluctuations were seen across the retail and hospitality sectors (ADHB, 2020; Food Standards Agency, 2020; Statista, 2021).

This resulted in a number of reported impacts, both positive and negative, on the natural environment. Improved air and water quality, and reduced energy consumption were recorded in countries across the globe after their lockdowns (Bhat et al., 2020; Muhammad et al., 2020; Rupani et al., 2020; Liu et al., 2022).

However, despite some initial environmental gains resulting from Covid-19 policies (due to reduced travel and decreased economic activity), the initial positive impact appears to have been short-lived, as economies and lifestyles revert back to pre-pandemic conditions (Helm, 2020; Irfan et al., 2021; Le Quéré et al., 2021). Pro-environmental behaviours were impacted as changing priorities and competing public health factors affected decisions at individual, societal, business and political levels. A study of pandemic impacts on global biodiversity conservation ranked "Increased plastic and other solid waste pollution" fifth out of 70 effects for its likely impact on biodiversity conservation globally, concluding that "the pandemic has led to a substantial increase in plastic pollution with associated negative impacts on biodiversity, with weakened restrictions on single-use plastics and reduced recycling provision" (Gibbons et al., 2022). Published studies on the increase in global plastic use during Covid-19 and its contribution to short and long-term environmental impacts are increasing, specifically related to increased toxic and greenhouse gas emissions from plastic production and incineration facilities; increased litter compounding the existing plastic pollution problem on land and at sea, endangering biodiversity and human health; and increased plastic pollution aggravating the micro and nanoscale plastic problem into the future (Silva et al., 2020b; Benson et al., 2021; Shams et al., 2021; Parashar et al., 2022). A review by Bastos de Sousa (2021) highlights the three key causes of increased plastic pollution as inefficient waste management, lack of policy and poor awareness among the global population.

Plastic production has seen increased demand since 2020, specifically for plastic packaged products including PPE, pharmaceuticals, cleaning products and groceries (Tenenbaum, 2020; Vanapalli et al., 2020; World Economic Forum, 2020; Parashar and Hait, 2021). The consequent increases in waste disposal requirements overwhelmed capacity in many countries, leading to extensive waste mismanagement (Klemeš et al., 2020; Parashar and Hait, 2021; Silva et al., 2020a, 2020b).

Politically, governments prioritised human health over environmental health, reversing or postponing plastic reduction policies and waste management strategies (Klemeš et al., 2020; Prata et al., 2020). This has resulted in a delay on impending bans for single-use plastic, particularly in the US (Greenpeace, 2020) and restrictions have been placed on recycling programmes in many countries worldwide (Irfan et al., 2021; Tripathi et al., 2020; Vanapalli et al., 2020). Due to a perceived hygiene risk, many retail businesses stopped accepting reusable bags, cups and water bottles (Irfan et al., 2021) and consumer choice became more limited to single-use plastics, with reduced access to non-plastic products

(Tenenbaum, 2020; Scaraboto et al., 2019). This return to dependence on single-use plastics occurred despite evidence that coronavirus is inactivated much more quickly on paper products (three-hour lifespan), cardboard (one day) or cloth (two days) than plastic surfaces (three days) (van Doremalen et al., 2020).

These marked changes in business and consumer behaviour are likely to persist beyond the pandemic, with long-term implications on the transition towards a more circular economy (Vanapalli et al., 2020). There is a real threat to progress made to reduce consumption of single-use plastic. Through a combination of environmental campaigns and legislation, including single-use plastic bans and business commitments to reduce their plastic footprint, there has been clear public pressure and behavioural change to reduce consumption and littering (Rivers et al., 2017; Xanthos and Walker, 2017; Defra, 2018; Statista, 2018a; European Union, 2019; Heidbreder et al., 2019; City To Sea, 2019; Eunomia, 2020; Costa et al., 2020; Upstream, 2021). Although relaxations and pauses on single-use plastic bans, recycling programmes and other related policies are temporary, their impact on consumer perception will likely last much longer (Vanapalli et al., 2020). In this "new normal", there is an even greater urgency to find solutions to the over-consumption and unsustainable production, use and management of plastics. Such solutions require sound data and information on people's plastic use (Klemeš et al., 2020).

For over a decade, personal carbon footprint calculators have been used as an online tool for public engagement in climate change action. The general premise of these calculators is to help people understand how much carbon they emit into the atmosphere through their daily activities and indicate how they can reduce their emissions by changing specific behaviours and choice related to, for example, diet and transport. Given the growing evidence of the long-term consequences of plastic waste in the environment (Beaumont et al., 2019; Winton et al., 2020; Galgani and Loiseau, 2021), we developed a similar footprint calculator tool to engage the public in the issue of plastic pollution, as well as provide vital information on rates and behaviours around consumer plastic use. The calculator was designed to raise individuals' awareness of their total plastic use, its potential impact on the environment and provide them with information for how to reduce it. The calculator was devised to provide information on geographic and temporal changes in behaviours specifically around on-the-go plastic use. The present analysis is focused on the temporal changes in plastic use in relation to changes in Covid-19 restriction policies.

2. Methods

2.1. Data collection

In January 2020, the On-the-Go Plastic Footprint Calculator was launched in English to a largely UK and European audience (link in Supplementary Material). The calculator was promoted in social media in the UK, therefore obtained the largest number of respondents in the UK (88 %). The remaining 12 % were mainly from other European countries including Italy, the Netherlands, Portugal and Switzerland. As some respondents did not provide a postcode, it was not possible to identify their location.

Through the calculator, respondents provided anonymous information about their use of plastic items during time spent out of the home, i.e. on-the-go, such as when at work, commuting or socialising. Questions on plastic use followed the format of "Estimate how many new plastic drinks bottles you used over the past week, while out of your home" and required a round number entry. Questions were also asked about the number of hours spent outside of the home per week, and the activities that were engaged in while out of the home, specifically eating and drinking out,

Table 1

Overall use (in a one week period) of plastic items reported between 24th January and 1st December 2020. Total number of respondents = 1937. Usage per hour on-the-go is across all respondents, calculated from the total number of items used (13,544 items) divided by total number of hours on-the-go for all respondents (59,492 h). All data and calculations are per week.

Item	Number of users per week	Number of people not using per week	% of respondents using item	Total number used per week	% of total items used	Average number used per respondent per week	Average number used per user per week	No used per hr on-the-go
Bags	445	1492	23.0 %	1007	7.44 %	0.52	2.26	0.02
Bottles	497	1440	25.7 %	1255	9.27 %	0.65	2.53	0.02
Condiment sachets	290	1647	15.0 %	711	5.25 %	0.37	2.45	0.01
Cups	476	1461	24.6 %	962	7.10 %	0.50	2.02	0.02
Food wrappers	1341	596	69.2 %	7267	53.7 %	3.75	5.42	0.12
Straws, stirrers, cutlery	311	1626	16.1 %	743	5.49 %	0.38	2.39	0.01
Takeaway containers	679	1258	35.1 %	1599	11.8 %	0.83	2.35	0.03
Total (all items)	–	–	–	13,544	100 %	7.00	–	0.23

exercising, entertainment and social activities. We also asked how often per month respondents bought takeaway meals.

Once a respondent's usage information was entered, they were presented with a list of their top three most used items. For each of those items, they were asked about any actions they already took to reduce their use of it. These questions followed the following format:

“Food wrappers: Which of the following are you already doing? (select all that apply)

- I have reduced the quantity of plastic-wrapped food that I buy
- I buy food in larger quantities (and use my own re-usable containers)
- I have substituted items with alternatives not wrapped in plastic
- I recycle food wrappers”

Respondents were then presented with a list of potential barriers (e.g. convenience, cost, awareness of alternatives) and asked which prevented them from further reducing their use. The full set of questions is presented in Supplementary Material.

The calculator was designed to take no >20 min to complete, and tests were completed successfully within this timeframe. Due to known problems of poor self-reporting of behaviours by respondents in surveys, when developing the survey, we asked people to focus on a specific time and situation, i.e. only when out of the home (“on-the-go”), and a short period of observation (one week). These decisions were based on reported medical and related studies, as no similar studies were available (Fadnes et al., 2009). Through this approach we expect to have reduced (although not eliminated) the possibility of error.

The only demographic data collected were age (within a range) and postcode (optional). We gave the option to provide an email address for purposes of future communications, but this data was removed for analysis. Data are stored within an access restricted database. At all stages we ensured data was collected and stored in line with UK data protection guidelines.

For this study, we use data acquired from the launch of the calculator on 24th January 2020 (two months before the first lockdown in the UK) until 2nd December 2020, the end of the second lockdown in the UK. Data on use of seven food-related plastic categories were analysed: bottles; bags; cups; condiment sachets; food wrappers; straws, stirrers and cutlery; takeaway containers. The data analysed were limited to respondents in the UK, as they were divided into five time periods, based on the timescale of Covid-19 related restrictions in the UK (Institute for Government Analysis, 2021):

- o Before lockdown – 24th January (data collection begins) to 25th March
- o Lockdown 1 – 26th March to 1st June 2020
- o Lockdown-eased (phased re-opening of schools, businesses, retail and hospitality) – 2nd June to 13th September 2020
- o Rule of six (ban on indoor and outdoor social gatherings of more than six people; this time period also included introduction of a regional level three-tier restriction system) – 14th September to 4th November 2020
- o Lockdown 2 – 5th November to 2nd December 2020

2.2. Data analysis

We defined plastic usage in two ways: 1) the total or average number of items used per week per respondent, and 2) the percentage of respondents who used that item.

Data distributions were highly skewed and non-parametric approaches were used. Outliers were removed using interquartile ranges and median values. Plastic items were ranked according to total usage to identify the most and least used items across the entire timeframe, and within each of the five time periods. Usage patterns in each time periods were compared using Kruskal–Wallis, Mann-Whitney tests and Pearson's Chi squared. Bonferroni correction was used for multiple comparisons. Mann-Whitney tests were based on median values for number of items used, hours spent on-the-go and number of takeaway meals. Chi-squared tests were used on relative frequency of people using each item, spending hours on-the-go or having takeaway meals.

Activity levels were investigated in a similar manner, after grouping hours on-the-go into categories (categories = 0, 1–14, 15–28, 29–42, 43–56, 57–70, >71 h per week).

3. Results

Data from 1937 respondents who completed the footprint calculator between 24th January and 2nd December 2020 were gathered. Age distribution was biased towards older persons, with the majority (64 %) over 41 (Under 21 = 7 %; 22–30 = 13 %; 31–40 = 17 %; 41–50 = 19 %; 51–60 = 20 %; Over 60 = 25 %). This is higher than the UK population overall, of which 50.5 % were over 40 at this time, according to mid-2020 early data indicators (Office for National Statistics, 2020). Nearly half of respondents completed the calculator before lockdown (49.8 %), with the lowest percentages of respondents during the two lockdown periods (1.9 % and 1.5 % for lockdowns 1 and 2 respectively) (full breakdown table in Supplementary Material).

A total of 13,544 of selected plastic items were recorded with a median of 8 items used per week per person (Table 1). The most used items were food wrappers (54 %, 3.75 used per person per week), followed by takeaway containers (12 %, 0.83) and bottles (9 %, 0.65) (Fig. 1). The top three items when ranked by percentage of respondents using them followed the same pattern, with 69 % of people using food wrappers, followed by takeaway containers (35 %) and bottles (26 %) (Table 2). Food wrappers were the most common item used across all five time periods, while condiment sachets were the least (Figs. 1 & 2).

Of all respondents, 12.9 % (249 individuals in total) reported zero use for all items in the previous week. The percentage of respondents who were not using any of the items was highest before lockdown (5.6 %) and lowest during both lockdowns (0.1 %) (see Supplementary Material). If we extrapolate this based on our reported average of 8 items used per week per person, these respondents each use 416 fewer plastic items per year than the average consumer.

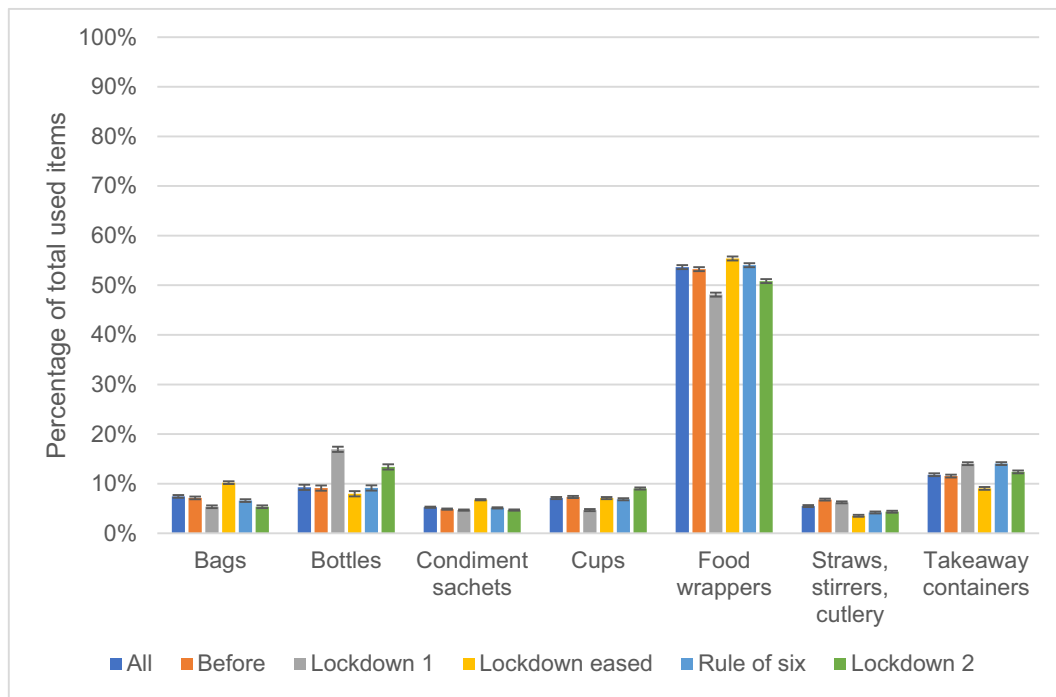


Fig. 1. Percentage of total used items for each plastic category, across the entire dataset and for each time period individually. Standard error bars shown.

Of those asked whether they used reusable alternatives, 75.2 % used reusable bottles, 86.1 % used reusable bags, 78.7 % used reusable cups, 49.7 % used reusable straws, stirrers and cutlery; and 64.6 % used reusable options for takeaway containers (e.g., lunch box, beeswax wraps). No data was collected on the frequency of use of reusables, so this will include a range from occasional use to frequent or everyday use.

Most items showed the highest use during lockdowns 1 and 2 in terms of number of items used per hour on-the-go and number of items used per person (Table 2). For bottles, people used 0.07 bottles per hour on-the-go during lockdown, which decreased by three-fold during the period of lockdown-eased, similar to pre-lockdown levels (0.02 bottles per hour on-the-go). This translated to each person using 2.11 bottles per week during lockdown 1, compared to 0.45 bottles per week during lockdown-eased. This includes all types and sizes of drinks bottles, respondents were expected to include every one they used outside of the home, including for example water, soft drinks, smoothies, juices, milk. During Lockdown 1, respondents used almost twice as many food wrappers both per person and per hour on-the-go and used more than twice as many takeaway containers. The use of both food wrappers and takeaway containers returned to previous levels

once lockdown eased. Note that these are trends across all respondents, and not the changing trends of specific individuals.

The increase in the number of bottles, takeaway containers and condiment sachets used weekly during lockdown 1, compared to pre-lockdown conditions was significant, as was percentage of respondents using these items (Table 3). The increase in the use of food wrappers was not significant.

Comparing lockdowns 1 and 2, there were no significant differences in the number used or percentage of respondents using any of the item categories (Table 4). During the periods of lockdown-eased and Rule of Six, there were no significant changes in the numbers of items used, compared to lockdown conditions.

There was no significant difference in number of hours on-the-go between lockdown 1 and before lockdown, but the percentage of respondents reporting any hours on-the-go (i.e. >0 h) decreased significantly during Lockdown 1. Compared to before lockdown, the average number of hours on-the-go and percentage of people on-the-go decreased during the periods of lockdown-eased and Rule of Six but was not different during lockdown 2 (Table 5).

The distribution showed increased positive skewness during the lockdown-eased and Rule of Six periods, indicating more people

Table 2

Usage rates of each item during each time period, based on number used per person per week and per hour on-the-go. † indicates statistically significant increase compared to before lockdown. *UK ban on straws and stirrers brought in 1st September 2020, towards the end of lockdown-eased, just before Rule of Six.

Time period	Bags		Bottles		Condiment sachets		Cups		Food wrappers		Straws, stirrers, cutlery*		Takeaway containers	
	Per person	Per hr	Per person	Per hr	Per person	Per hr	Per person	Per hr	Per person	Per hr	Per person	Per hr	Per person	Per hr
Before lockdown	0.52	0.01	0.66	0.02	0.35	0.01	0.53	0.01	3.88	0.10	0.49	0.01	0.84	0.02
Lockdown 1	0.67†	0.02†	2.11†	0.07†	0.58†	0.02†	0.58†	0.02†	6.00†	0.19†	0.78†	0.02†	1.75†	0.05†
Lockdown-eased	0.58†	0.03†	0.45	0.02	0.38†	0.02†	0.40	0.02†	3.14	0.14†	0.20	0.01	0.51	0.02
Rule of Six	0.46	0.02†	0.63	0.03†	0.35	0.02†	0.48	0.02†	3.74	0.17†	0.29	0.01	0.97†	0.04†
Lockdown 2	0.55†	0.02†	1.38†	0.05†	0.48†	0.02†	0.93†	0.03†	5.24†	0.19†	0.45	0.02†	1.28†	0.05†
All (average)	0.52	0.02	0.65	0.02	0.37	0.01	0.50	0.02	3.75	0.12	0.38	0.01	0.83	0.03

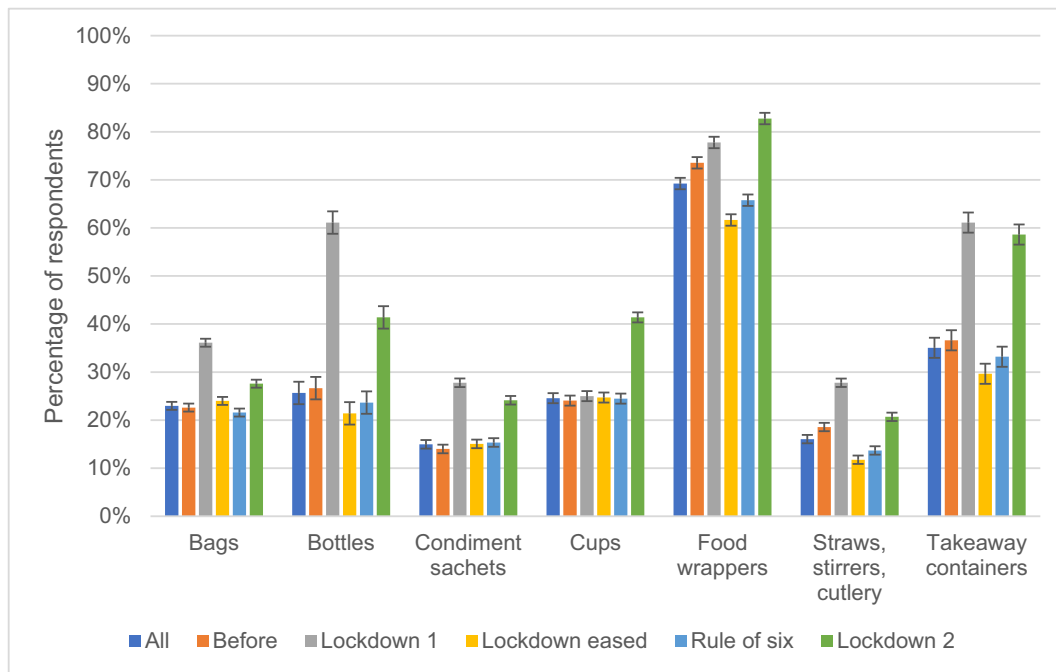


Fig. 2. Percentage of respondents using items in each plastic category, across the entire dataset and for each time period individually. Standard error bars shown.

spending a small number of hours on-the-go (0-7 h per week), and fewer people spending high numbers of hours on-the-go compared to before lockdown (>64 h per week), with the crossover at around 35 h per week (Fig. 3).

The number of takeaway meals consumed per week increased during lockdown 1 compared to before lockdown, as did average number of containers used. Percentage of respondents having takeaway meals also increased during lockdown 1, as did percentage of people using containers. During lockdown 2, number of takeaway meals also increased compared

to pre-lockdown conditions, but use of takeaway containers remained similar (Table 6).

4. Discussion

The results of the online calculator uncovered surprising changes to public behaviour during the Covid-19 pandemic, particularly during periods of lockdown. Contrary to our original hypothesis that people would have a lower plastic footprint during lockdown, there was an increased

Table 3

Results comparing Before Lockdown and Lockdown 1: a) number of plastic item used per person per week; b) Number of each item used per hour on-the-go; c) Mann-Whitney comparison of number used per person per week; d) Chi-square comparison of relative frequency of people using each plastic item. B = Before lockdown; L1 = Lockdown 1.

	Bottles		Bags		Cups		Straws, Stirrers, Cutlery		Takeaway containers		Food wrappers		Condiment sachets	
	B	L1	B	L1	B	L1	B	L1	B	L1	B	L1	B	L1
a) Number used per person	0.66	2.11	0.52	0.67	0.53	0.58	0.49	0.78	0.84	1.75	3.88	6.00	0.35	0.58
b) Number used per hour on-the-go	0.02	0.07	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.05	0.10	0.19	0.01	0.02
c) Mann-Whitney (two tail) p-values for mean number used per person	↑ 0.0000		↔ 0.0636		↔ 0.8428		↔ 0.1569		↑ 0.0018		↔ 0.0977		↑ 0.0197	
d) Chi-square p-values for relative frequency of people using the item	↑ 0.0000		↔ 0.0592		↔ 0.8977		↔ 0.1658		↑ 0.0029		↔ 0.5714		↑ 0.0212	

Table 4

Comparisons between Lockdown 1 and Lockdown 2 of, a) mean number per person, and b) percentage of people, for plastic items used and level of activity undertaken.

	Activity undertaken		Plastic item used						
	Hours on-the-go	Takeaway meals	Bottles	Bags	Cups	Straws, Stirrers, Cutlery	Takeaway containers	Food wrappers	Condiment sachets
a) Mann-Whitney (two tail) p-values for mean number per person	↔ 0.4704	↔ 0.4395	↔ 0.0966	↔ 0.5287	↔ 0.1727	↔ 0.4359	↔ 0.4539	↔ 0.5491	↔ 0.7258
b) Chi-square p-values for relative frequency of people taking part in the activity or using the item	↔ 0.8230	↔ 0.6178	↔ 0.1134	↔ 0.4650	↔ 0.1604	↔ 0.5096	↔ 0.8386	↔ 0.6178	↔ 0.7399

use of plastic bottles, takeaway containers, food wrappers and straws, stirrers and cutlery.

It is important to note that respondents to online environmentally focused activities are unlikely to be representative of the overall population. In fact, nearly 13 % of respondents reported that they had not used any of the on-the-go plastic items in the last week, suggesting that the audience using the calculator were “greener” than the average person. In a recent UK survey (YouGov, 2021), only 3 % of respondents said they did not use single-use plastics. Therefore the increase in plastic use during lockdowns is possibly an underestimate of the true scale of plastic use across the entire population. The percentage of respondents who were not using any of the items was significantly lower during both lockdowns compared to before lockdown, suggesting that people found it harder not to use plastic when on-the-go during lockdown.

It is notable that use of plastic cups did not change during lockdown 1 and was significantly higher during lockdown 2, compared to before lockdown. We expected cup use to decrease during lockdown as a large proportion of takeaway drinks are bought by people commuting or while on-the-go at work, activities which decreased during lockdown (Lokesh and Marsden, 2021). The persistence of single-use cups, and the increase in plastic bottles, takeaway containers and condiment sachets, could be attributed to a number of causes:

- i) Takeaway options were available, but eat-in options were not, so those who would normally eat in were forced to take out.
- ii) Fewer outlets were accepting reusables for takeaway food and drink.
- iii) People were less confident in the hygiene of reusables, so switched back to single-use.

iv) People who would not normally get takeaway food or drink began doing so during lockdown.

Changes in behaviour observed between the two lockdowns coincide with changes in restrictions, including the re-opening of restaurants and other establishments where people could “eat-in”. In these periods, people wishing to eat outside of the home were no longer limited to takeaway only, and “eat-in” meals are more often served using reusable crockery, cups and cutlery. In addition, a number of campaigns were run by environmental NGOs to dispel myths about the hygienic benefits of single-use cups and other items and encourage the use of reusable options once more (e.g. campaigns “Return to Refill” and “Contactless Coffee”, City to Sea, 2022). This was supported by an open letter signed by >100 experts declaring reusables safe as long as they are cleaned between each use (Greenpeace, 2020). Many businesses responded to this and reinstated acceptance of reusable cups, including small independent companies and big businesses such as Starbucks (Starbucks, 2020).

Comparing these results to other studies reporting that consumers have reverted away from reusables and back to single-use plastics for reasons of hygiene, our results suggest that the increase in plastic use was driven by a perception of hygiene rather than a change in time spent on-the-go (Tenenbaum, 2020; Scaraboto et al., 2019). Our results also support studies that report an increase in the presence of plastic litter in the environment during the pandemic, particularly takeaway food and drinks packaging (CPRE, 2020). A survey in June 2020 found that 67 % of the general public were concerned about increased plastic waste during lockdown and its impact on the environment (TIPA, 2020).

Table 5

Comparisons between time periods of a) number of hours on-the-go per person per week and b) percentage of people reporting hours on-the-go (>0 h per week).

	Before lockdown - Lockdown 1	Before lockdown - Lockdown-eased	Before lockdown - Rule of six	Before lockdown - Lockdown 2
a) Mann-Whitney (two tail) p-values	↔ 0.3590	↓ 0.0000	↓ 0.0000	↔ 0.0773
b) Chi-square p-values	↓ 0.0269	↓ 0.0000	↓ 0.0000	↔ 0.0703

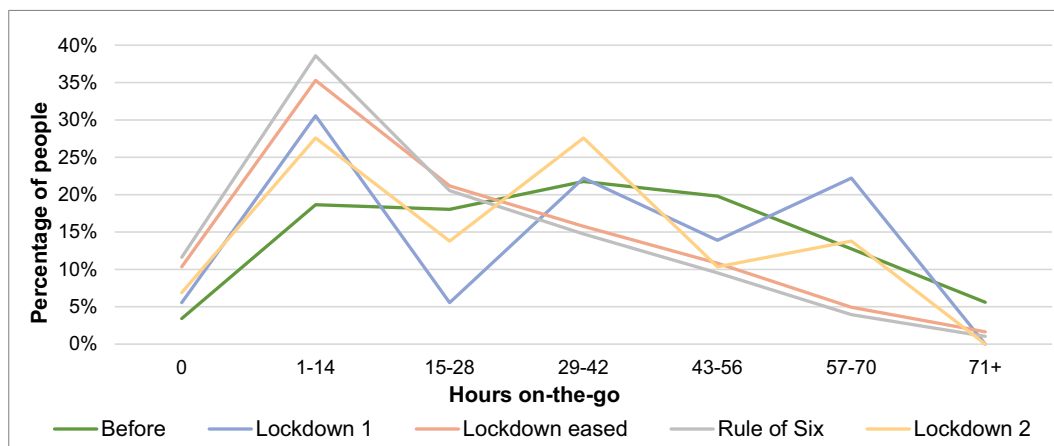


Fig. 3. Hours on-the-go per week reported by respondents for each time period, showing percentage of people within each 7 h range.

The data on food wrappers is also relevant here. While there was an apparently higher number of food wrappers used during lockdowns, there was no statistically significant difference and the data exhibited a large variance (Lockdown 1 range = 0–25 items used on-the-go per week, median = 4.5, mean = 6, 77.8 % using; Lockdown 2 range = 0–45 items used on-the-go per week, median = 4, average = 5.2, 83 % using; before lockdown (range = 0–40 items used on-the-go per week, median = 3, mean = 3.9, 73.6 % using). As food wrappers are an item for which there is not a simple reusable alternative, the issue of hygiene around alternatives is not a factor in an individual's decision for whether or not to consume a product sold in single-use plastic. Therefore, if hygiene was the reason people used more single-use bottles and cups, food wrapper use would not be expected to change in the same way. This could explain why there was not a significant change in purchasing patterns for food wrappers.

Our results show a behavioural change towards increased consumption of takeaway meals on-the-go during lockdown and other periods of restrictions. This trend has not been reported before, as other studies have not distinguished between takeaway on-the-go and takeaway delivered to the

home (e.g. ADHB, 2020; Food Standards Agency, 2020). We conclude that increased restrictions led to an expanded consumption of on-the-go takeaway meals and, consequently, use of single-use takeaway containers. This distinction is important, as takeaway plastic items (especially when consumed outside) are more likely to end up as litter than plastic items used in the home.

Respondent numbers were relatively low during both lockdowns, with response patterns skewed by communication efforts (mainly promotional adverts on social media platforms), which led to spikes in responses in the immediate aftermath of each communication event - one before lockdown, and a second between the two lockdowns (see timeline in Supplementary Material). It is also possible that during lockdowns, people might have seen the calculator but not filled it in because they were not taking part in any on-the-go activities, in compliance with lockdown rules. It would be useful to have comparable data on use of the same products in the home, as well as on-the-go, to explore the extent to which individual plastic use might have changed overall, and identify patterns of use in the household. An increase in home delivery of groceries and delivery of

Table 6

Comparisons between time periods of a) number of takeaway meals consumed and takeaway containers used per person per week and b) percentage of people consuming takeaway meals and using takeaway containers.

	Before lockdown - Lockdown 1	Before lockdown - Lockdown-eased	Before lockdown - Rule of six	Before lockdown - Lockdown 2
a) Mann-Whitney (two tail) p-values				
Takeaway meals	↑ 0.0113	↔ 0.3132	↑ 0.0001	↑ 0.0004
Takeaway containers	↑ 0.0018	↓ 0.0021	↔ 0.3093	↔ 0.0464
b) Chi-square p-values				
Takeaway meals	↑ 0.0002	↓ 0.0000	↑ 0.0000	↑ 0.0001
Takeaway containers	↑ 0.0029	↓ 0.0118	↔ 0.1996	↔ 0.0158

takeaway meals has been widely reported, and the increase in food packaging consumption is heavily attributed to this (Vanapalli et al., 2020). We hypothesise that consumption of plastic bottles, food wrappers, bags and takeaway containers will have increased in the home as well as on-the-go, because of similar hygiene concerns, but there is no comparable data to analyse to confirm this.

Our findings provide an insight into why people choose plastic bottles and point to solutions for a reduction in their use. In addition to hygiene concerns, the reduced availability of refill outlets is likely to have contributed to plastic bottle use during lockdowns. During periods of lockdown, fewer retailers and food and drink establishments were open, reducing the number of outlets for water bottle refills. Although the majority of respondents (75 %) had reusable bottles available, respondents may have been forced to revert to single-use bottles, even if they were still happy to use a reusable. When more outlets were open (when lockdown was eased and during Rule of Six), fewer people were using single-use plastic drinks bottles. This is based on the assumption that people continued to drink the same amount of water while on-the-go, and that when people were not purchasing plastic bottles, they were using reusables. This assumption was supported by the fact that the periods of least plastic bottle use were during the summer months (Figs. 1 & 2, "Lockdown eased"), when water consumption tends to be higher. This confirms the importance of water refill provision by the public sector (Bethurem et al., 2021), rather than a dependence on private retailers, and the need for a greater number of water refill stations that do not require people to enter a private establishment. Water fountain provision has proven successful in other countries, for example Italy, where outdoor fountains providing filtered water are maintained by local governments and water companies.

The consistency in plastic use during the two lockdowns demonstrates that government action can significantly modify public behaviour in relation to their use of plastic, even if this was largely indirect: a consequence of reductions in freedom, convenience and facilities, and increased concern for hygiene levels. Despite plastic use behaviours changing again after Lockdown 1 when restrictions were eased, Lockdown 2 saw a return to similar levels of plastic use as Lockdown 1. This suggests that the change followed a top-down approach, influenced by government restriction, rather than being a bottom-up change led by consumer choice. The authors do not underestimate the potential for impact that consumer choice has in creating change from the bottom-up, but in this exceptional circumstance of the global Covid-19 pandemic, it appears that top-down government restrictions were the over-riding influence.

Silva et al. (2020b) investigated how the precautionary measures for Covid-19 are contributing to worldwide plastic pollution and challenging environmental sustainability measures. They concluded that the scientific evidence does indicate a preference for use of single-use-plastics over reusable alternatives when proper hygiene and sterilisation procedures can be assured. Our results support the argument that people's perception of increased hygiene issues with reusables may be unnecessarily affecting consumer choice. Given the expanded use of plastics, including personal protection items, being used during Covid-19 (Ammendolia et al., 2021; Liu et al., 2021a, 2021b), there is a growing urgency for improved information to the public and greater availability of alternatives to reduce reliance on single-use products, alongside improvements to plastic waste management, such as increased capacity and efficiency of recycling systems and reduced leakage from holding facilities.

5. Conclusions

Better environmental decision making is contingent on provision of opportunities to reduce reliance on plastic-packaging, and increased awareness of options and impacts (Marazzi et al., 2020; HM Treasury, 2018). The general public seems willing to accept public policy, including bans on plastic items, to reduce plastic consumption (e.g. Statista, 2018b). Behaviour change research focused on the intention-behaviour gap indicates that there is a disparity between what people say they would like to do to be more sustainable, and what they actually do (Sheeran and Webb,

2016). This points to the need for further encouragement, alongside increasing the ease and convenience of sustainable choices, which requires more direction (including incentives and deterrents) from government. Our results show there is high potential for government to influence the use of single-use food-related plastic consumption either indirectly or directly through fees, taxes and bans on single-use plastics (Liu et al., 2021a). On the other hand, businesses, individuals, and communities can directly reduce excessive plastic use and encourage or demand improved regulations.

From the results of recent research and those of the present study, we recommend the following actions:

- Support for fully sustainable packaging (based on full life-cycle analysis) in eat-in and takeaway establishments, including reusable options alongside single-use alternatives, to replace single-use plastic containers, straws, stirrers, cutlery, condiment sachets;
- Acceptance by food retailers and takeaway establishments of reusable bottles, cups and food containers, supported by effective, well communicated hygiene safeguarding processes;
- Increased provision of public water refill stations / drinking fountains, with particular responsibility taken up by local governments and public service providers.

Better waste management also needs to be implemented to prevent plastic from becoming pollution. Mass awareness among citizens of their responsibility to ensure appropriate plastic waste disposal and of the environmental consequences of littering and mismanagement of plastic waste can also be tackled at governmental level, for example by including teaching on the environmental impact of plastic pollution into school curricula (Parashar and Hait, 2021).

Academia and government (at local and national levels) need to work together to promote sustainable attitudes towards use of plastic, and identify the valuable role that participatory citizen science can play, as well as that of knowledge exchange and communication forums (Silva et al., 2020a, 2020b). Citizen science has proved a valuable tool for data collection on plastic use and pollution (Nelms et al., 2020; Syberg et al., 2020; Ammendolia and Walker, 2022). Our plastic footprint calculator tool demonstrates the potential for wider application to reducing plastic use by consumers, as well as for businesses. Footprinting for plastic consumption and waste can be an effective tool for decision-making, policy creation and public engagement (Klemeš et al., 2020).

Recent studies have highlighted the prevalence of consumer takeaway items in the world's oceans, with Morales-Caselles et al. (2021) finding that plastic bags, bottles, food containers and food wrappers make up almost half of total anthropogenic marine (macro) litter. Considering that the UK is one of the top three contributors to marine litter in Europe (González-Fernández et al., 2021), national efforts to reduce single-use plastic consumption - and related plastic pollution - should be made. True reform requires urgent legislation to reduce unnecessary single-use plastic items to be comprehensively enacted and enforced.

CRediT authorship contribution statement

Debbie Winton: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Visualization; Writing – original draft. **Luca Marazzi:** Data curation; Funding acquisition; Investigation; Methodology; Project administration; Writing – review & editing. **Steven Loiseau:** Funding acquisition; Methodology; Supervision; Validation; Writing – review & editing.

Data availability

Data will be made available on request.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Debbie J. Winton reports a relationship with Natural England that includes: employment.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2022.157672>.

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