Understanding and changing the public's behaviour relating to plastic waste

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Declaration

I, Ayşe Lisa Ustaoğlu Allison, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

The following work was carried out at the Department of Clinical, Educational and Health Psychology, University College London (UCL), under the supervision of Professor Susan Michie, Professor Mark Miodownik and Doctor Fabiana Lorencatto. This work formed part of a larger project, the UCL Plastic Waste Innovation Hub's 'Designing-out Plastic Waste' project. This thesis has not been submitted, in whole or in part, for any other degree, diploma or qualification at any other University.

This PhD research was funded by UKRI (UK Research and Innovation) and EPSRC (Environment and Physical Sciences Research Council).

This thesis does not exceed the limit of 100,000 words specified by the Degree Committee.

Signed, 11th September 2023

Abstract

Background: Circular economy transitions are hampered by a paucity of theory- and evidence-based behavioural research; this hinders attempts to design effective waste management interventions.

Aims: This thesis uses behavioural science frameworks to identify key behaviours relating to plastic waste, influences on these behaviours, and design and evaluate a behaviour change intervention.

Method: Study 1 was a systematic review and meta-analysis identifying and categorising behaviours related to plastic waste; identifying, categorising and evaluating variables associated with these behaviours and; identifying, categorising and evaluating components of prior interventions. Studies 2 and 3 identified influences on compostable plastic packaging purchase and household food waste recycling. Study 4 integrated the findings of Studies 1-3 to develop an intervention enabling desired disposal of compostable plastic packaging. The developed intervention consisted of disposal instruction labels. Study 5 evaluated the labels for their effectiveness in changing disposal behaviour.

Results: Most research in this area focuses on shopping bag use and (dry) recycling; there needs to be greater prioritisation of more resource-efficient waste management strategies. Across studies, a combination of capability, opportunity and motivation was required to enact behaviour, suggesting that holistic approaches are needed for intervention design. Generally, citizens wish to behave pro-environmentally, however, their environments are often not set up such that desired behaviours are the more obvious, convenient, or affordable thing to do. Explicit disposal instructions and imagery can improve the disposal of compostable plastics

but cannot be sufficient without congruent improvements to compostable plastic certification, labelling and waste management.

Conclusions: The findings of this thesis can be used to inform the amendment of existing, and design of novel, interventions and policies relevant to these behaviours, including improvements to the implementation of public services relevant to these behaviours.

Impact statement

The work in this thesis has generated requests for talks, research collaborations and industry consultancy. I won UCL Grand Challenge funding (2019) proposing the work in this thesis and the UCL Sully Award for the 'best departmental upgrade' (2020) presenting work from Studies 1-2.

A version of each study has been published in peer-reviewed journals (Studies 1-4) or submitted for publication pending peer-review (Study 5). Details of the publications are provided in the relevant chapters and at the end, in the research paper declarations.

Work from Study 1 was presented at the Plastics Research and Innovation Fund (PRIF) End of Year Award Conference (2020) and PRIF Early Career Researchers Conference (2020). Work from Studies 2-3 was presented at Global Research and Innovation in Plastics Sustainability (GRIPS) Conference (2021) and Materials Research Exchange (MRE) Conference (2022). Findings from both studies were included in a submission of written evidence to a House of Lords Environment and Climate Change Committee Inquiry on mobilising action on climate change and environment via behaviour change. The work from Study 2 has been presented on the *Voices of Grand Challenges* podcast. A policy briefing on the findings of Study 3 has also been published.

Work from Study 4 was presented at MRE (2022) and GRIPS (2023) and led to a talk at DEFRA (March 16th, 2023). The direct policy impacts are evidenced below:

> *"Ayşe presented a useful summary of the BCW in relation to a study she led on looking at compostable plastic package labelling. Her presentation helped Defra colleagues in Resources and Waste understand more about the BCW, and importantly, the ways in which it can be used in a government context to support policymaking…By showing colleagues a step-by step process of how she utilised the BCW / COM-B, colleagues now better understand how they would apply such an approach in-house..."* – Poppy Cooke, Social Researcher in Resources & Waste at DEFRA.

Work from Study 5 was presented at GRIPS (2023). The direct research and industry impacts of this work are evidenced below:

> "*I think you have undertaken a fascinating piece of research that will feed directly into the development of the labels with OPRL. It is an impressively well-structured and undertaken piece of research. Thank you*" – Professor Margaret Bates, Executive Director at On Pack Recycling Label (OPRL) and Visiting Professor of Sustainable Waste Management at University of Northampton.

> "*Ayşe's labelling research has made a valuable impact on our research as it has informed the design of a label we have designed as part of our UKRI funded 'Close the Loop' project… It has been incredibly valuable to discuss research plans with Ayşe and be informed by the important work she has already conducted in this area."* – Doctor Nicola Buckland, Lecturer in Psychology at the University of Sheffield.

I have directly applied skills and insights gained throughout this PhD to other research collaborations leading to additional publications in Nature Energy, Frontiers in Sustainability, UCL Open: Environment and Proceedings of the Institution of Civil Engineers - Municipal Engineer.

Acknowledgements

First, I would like to thank my truly wonderful supervisors: Professor Susan Michie, Professor Mark Miodownik and Doctor Fabiana Lorencatto. I am forever grateful for all your guidance, support and mentorship over the years. I am particularly thankful to Susan for enabling my independence, the many career-building opportunities, and the highly detailed feedback on my written work. It was a privilege to learn from your expertise and resourceful approach to problem solving. I am extremely thankful to Mark for all your patience and guidance navigating the complex world of interdisciplinary research. You have been a constant source of motivation and affirmation whenever I have needed it. I have learnt so much from you about leadership, teamwork and collaboration. I am also thankful to Fabiana for all your support, especially in the early days of the PhD where it all felt so new and daunting. Your guidance, encouragement, and insights have been immensely helpful. I feel very fortunate to have had the opportunity to learn from and work with the three of you.

It takes a village to complete an applied, interdisciplinary PhD and so I would like to thank everyone who contributed to the work outlined in this thesis. I'd like to thank Professor Thomas Webb and Dr Harriet Baird for being the most wonderful collaborators. I am grateful for the many hours spent helping me conceptualise, conduct and write-up my systematic review and meta-analysis. I would also like to thank all members of the UCL Plastic Waste Innovation Hub and UCL Centre for Behaviour Change, especially my fellow PhD students, for creating a truly inclusive

and supportive work environment. I am thankful for the many video calls during lockdown, just to check in with one another, and all your help piloting surveys and experiments. Your support, feedback and insights have greatly improved the quality of this work. In particular, I'd like to thank Danielle Purkiss who has been a great source of friendship, guidance and support throughout this journey. I've learnt so much from you about collaborative working and participatory research. I'm also thankful to Alexandra Băitanu – you were a pleasure to work with and your support in collecting and analysing my experimental data has been invaluable. It has been a deeply meaningful experience to develop as a researcher and scientist alongside others so brilliant, supportive and kind. I am also incredibly grateful to all those who volunteered their time and efforts as participants in my studies. None of this work would have been possible without you.

I would also like to thank all my relations for their love, support and faith in me. I am eternally grateful for my wonderful parents, Robert and Meryem, from whom I learned to value an open, curious mind. Your unconditional support throughout this journey has made everything easier. I'd like to thank my friends and family in Cyprus for their kinship – my Anneanne, aunties, uncles, cousins, Özcan, Derin and Toya. Thank you for providing community, affirming identity and helping me feel connected to home. I'd especially like to thank Florenza and Raks. You are both very dear to me and I will always remember your support, friendship and our time spent together over the last year and a half of my PhD. And last but not least, I'd like to thank my wonderful partner, Lachlan. Your calming presence, love and endless support in life means everything. Thank you.

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List of abbreviations

AACTT – Action-Actor-Context-Target-Time

APEASE – Affordability-Practicability-Effectiveness-Acceptability-Side-effects-Equity

BBIA – Bio-based and Biodegradable Industries Association

BCT – Behaviour Change Technique

BCTTv1 – Behaviour Change Technique Taxonomy Version 1

BCW – Behaviour Change Wheel

COM-B – Capability-Opportunity-Motivation-Behaviour

COVID-19 – Coronavirus disease 2019

DEFRA – Department for Environment, Food and Rural Affairs (UK Government)

EU – European Union

GUIDED – Guidance for the reporting of intervention development

NAWDO – The National Association of Waste Disposal Officers

OPRL – On-pack Recycling Label

OSF – Open Science Framework

PBAT – Polybutylene Adipate Terephthalate

PEESE – Precision-Effect estimates with Standard Error Test

PET – Polyethylene terephthalate / Precision-Effects Test

PLA – Polylactic Acid

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

REA – Renewable Energy Association

REAL – Renewable Energy Assurance Limited

RVE – Robust Variance Estimation

TDF – Theoretical Domains Framework

TIDieR – Template for Intervention Description and Replication

TÜV – Technischer Überwachungsverein (Technical Inspection Association)

UCL – University College London

UN – United Nations

US – United States

UK – United Kingdom

WRAP – The Waste and Resources Action Programme

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Contributions

Study 1 (reported in Chapter 2): I (ALA) conceived of the study with Susan Michie (SM), Fabiana Lorencatto (FL), Thomas Webb (TLW) and Harriet Baird (HMB). Data extraction forms were developed with support from FL. I compiled the studies to include in the review with help from Catherine Lawrence (CL) for title and abstract screening and help from HMB for full-text screening. I conducted the coding, narrative syntheses and meta-analyses with support from HMB. I wrote the chapter with feedback from SM, FL, TLW, HMB.

Study 2 (reported in Chapter 3): I conceived of the study with MM. This study drew on data that was collected as part of another project led by Danielle Purkiss (DP). I curated the data and conducted the thematic data analysis. Themes were reviewed and refined with input from FL, SM. I wrote the chapter with feedback from SM, FL, MM.

Study 3 (reported in Chapter 4): I conceived of the study with SM, FL and MM. I collected the qualitative and quantitative data and conducted the thematic and statistical data analyses. I wrote the chapter with feedback from SM, FL, MM.

Study 4 (reported in Chapter 5): I conceived of the study with SM, DP and MM. I integrated the evidence and developed the intervention with support from DP. I wrote the chapter with feedback from SM, FL, DP and MM.

Study 5 (reported in Chapter 6): I conceived of the study with SM, FL, MM and DP. I generated the experimental stimuli with support Alexandra Băitanu (AB) and DP. I built the online survey, including the experiment, with support from AB. I conducted the thematic analyses with support from Jakob Kiessling (JK) and the statistical analyses with support from AB. I wrote the chapter with feedback from SM, FL, MM, DP and AB.

1. Chapter 1 – General Introduction

1.1. The problem of plastic waste: a linear plastics economy

The global plastic waste crisis represents a threat to environmental and public well-being. Over the last six decades, 8,300 million metric tonnes of plastic have been produced (1). As a result of excess production and inefficient waste management, plastic waste has become a leading cause of pollution. The harm to wildlife is well-documented, including the risk of entanglement and ingestion of plastic by fish, birds and turtles (2-5). Microplastics, from the breakdown of plastic waste, have also entered into human food systems where the potential harm to human health is unclear (6, 7).

Plastic pollution is also associated with inequity. Global plastic waste is largely exported from higher-income countries to lower-income countries for processing; this 'offloading' of the problem to poorer nations only serves to exacerbate existing social inequalities as plastic waste disproportionately pollutes these coastlines (8). Plastic pollution impacts the viability and security of fishing and aquaculture industries. Many populations in lower-income countries have a high dependency on seafood for nutrition and their livelihoods leaving them highly vulnerable to changes in the quantity, quality and safety of marine life (9).

Marine pollution also undermines the potential restorative psychological benefits that coastlines may provide. Marine animals, such as seabirds, whales and turtles, hold important cultural and emotional importance to many communities - witnessing their harm (whether through personal experience, stories or media) can cause negative impacts on mental health (10). Plastic pollution also marginalises

recreational users of coastlines who may avoid these places to escape visually distressing scenes of pollution (11, 12). The negative health impacts of this include reduced access to the benefits coastlines typically offer, e.g., promoting physical activity, facilitating important social and culturally significant interactions, and improving physical and mental health (13, 14). If current trends continue, it is estimated that by 2050 an additional 12,000 million metric tonnes of plastic waste will be in landfills or littered, contributing to considerable environmental and social harm and injustice (1). As such, eliminating plastic waste is a high global priority for sustainable development efforts (15, 16).

Though public perceptions of plastic are mostly negative (17), plastic, as material, is not itself inherently problematic. Despite there needing to be a dramatic reduction in the amount produced, there can be many beneficial applications. For instance, plastic packaging has several health and environmental benefits within global supply chains e.g., facilitating clean drinking water and food safety, reducing food waste, and reducing packaging weight during transportation (18-20). The issue is not plastic per se but plastic *waste;* this is the result of the system within which the majority of plastic is produced, applied and managed.

Most plastics are produced and circulated within a 'linear economy' which functions on a premise of extraction and exploitation i.e., a 'take-make-use-dispose' approach. This involves the collection of raw materials (e.g., water, air and non-renewable energy sources) and transforming them into products which get used (often single-use) until they are discarded. With the global population growing and demand for raw materials increasing, this linear approach of production, consumption and waste management is not sustainable. It threatens essential life

support systems leading to biodiversity loss, resource depletion and excessive land use (21-23). A more sustainable approach to plastic production, use and waste management is required to reach sustainable development targets such as those outlined by the UN Sustainable Development Goals (15).

1.2. The solution to plastic waste: a circular plastics economy

A circular plastics economy offers a more sustainable alternative to the mainstream linear model. A definition of circular economy is: "*A regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."* (24). In this, the life cycle of plastics can be extended through waste management processes such as sharing, leasing, reusing, repairing, refurbishing and recycling. The goal of the circular economy is to reduce waste to a minimum and keep materials flowing around a 'closed loop' where they retain value by being recycled in some way or repeatedly used rather than end up as waste. Circulating materials in this way reduce the overall demand for production.

Within the circular economy framework, a distinction can be drawn between waste prevention and waste recovery. As shown in Figure 1.1, this is depicted by the EU's waste hierarchy which prioritises waste management options in terms of resource efficiency (25). Waste prevention strategies are prioritised over waste recovery strategies. Both types of strategies reduce waste, just in different ways. In the former, the idea is to reduce waste by not generating it in the first instance. In the

latter, though 'waste' might technically be generated (e.g., in the form of recyclate[1]), waste is reduced insofar as materials are diverted from landfills through recovery processes such as recycling and composting (i.e., kept in the 'loop').

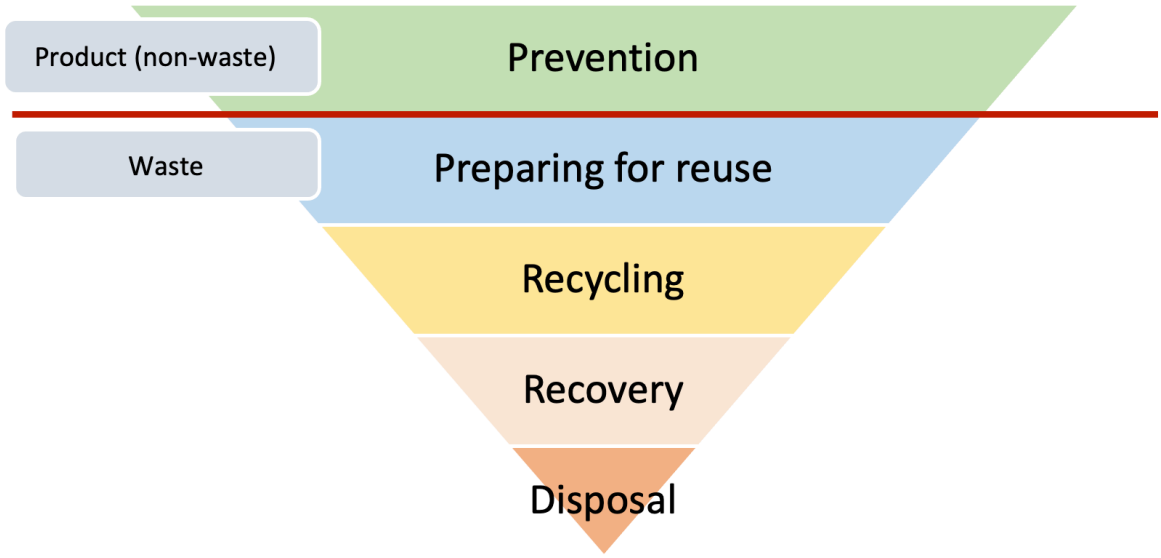

Figure 1.1 The EU's waste hierarchy prioritises waste management options from most desirable to least desirable (reproduced with permission from (26)).

In addition to the environmental benefits of enhancing resource efficiency, the broader social benefits include improving the security of resources, improving working conditions, encouraging behaviours and structures that foster community (e.g., sharing), and, providing people with more innovative products and services that are increasingly cost-efficient in the long-term (27). The circular economy can therefore be thought of as a holistic system that is "*restorative and regenerative by intention and design*" (28).

Nonetheless, regardless of whether the circular strategy prioritised is waste prevention (e.g., reduction) or waste recovery (e.g., recycling), transitioning towards

[1] The quality of the raw material transported to a recycling facility for processing into a new material or product.

a circular plastics economy is complex with many challenges. It is reliant on changing the behaviour of many groups of people across all levels of the plastics system (e.g., the general public, producers, suppliers, and people responsible for managing waste post-use) operating at various organisational levels (e.g., individual, community, industry, government). For example, producers and suppliers will need to offer reusable and recyclable alternatives to single-use plastics, and citizens will need to be willing to use (and reuse) these alternatives and ensure that they are dealt with appropriately at end-of-life. People who are responsible for the collection and sorting of waste post-use will need to ensure that the waste gets directed to the appropriate channels for recovery. Such widescale changes in behaviour also depend on developments in technological innovation and infrastructure.

Nonetheless, while technological innovation and changes in infrastructure are often necessary, they are not sufficient to solve the plastic waste issue. People will need to interact appropriately with these technologies and systems to enable their environmental benefits. Understanding the public's behaviour and enacting behaviour change is therefore a fundamental part of any solution aimed at reducing plastic waste. To generate the high-quality evidence required to transition towards a circular plastics economy, it is important to understand key behaviours relating to the production, supply, purchasing, use and disposal of plastics. Then, based on this knowledge, interventions can be designed to promote desirable behaviours that reduce waste and minimise undesirable ones that create waste.

Enabling behaviour change, however, is not easy, as evidenced by the number of societal problems that would be improved by groups of people changing their behaviour, along with a large scientific community investigating how to do this more

effectively. As well as drawing on relevant evidence and theory to inform efforts to change behaviour, a variety of frameworks have been developed, and widely used, to assist the process.

1.3. A behaviour change approach: theoretical frameworks

Guidance for developing and evaluating the kinds of 'complex' interventions needed to achieve such behaviour change argues for theoretically grounded and evidence-informed approaches (29-31). The behavioural sciences offer a range of models, theories and frameworks that can be used for this purpose. While many frameworks for understanding behaviour (32) and developing interventions exist (33), the Behaviour Change Wheel (BCW) (34, 35), which is widely used and advocated by UK Government (36), was selected to underpin the work in this thesis.

Using behaviour change theory and the available evidence, the main purpose of the BCW is to provide a systematic and comprehensive analysis of available intervention and policy options for a given behaviour change challenge. It is a flexible framework that can be used to design interventions at the individual, community or population level and can be applied in combination with various research methodologies (e.g., evidence synthesis, qualitative research, quantitative research, systems mapping). Although developed as a universal behaviour change framework, to date, the BCW has been used most frequently to understand and change behaviours relating to public health and clinical practice (37-41). To the author's knowledge, it has had minimal application within research examining behaviours associated with plastic waste. Nonetheless, the Behaviour Change Wheel's versatility, evidence-based approach, and comprehensive understanding of behaviour make it a fitting tool for addressing behaviour change in this context.

Further reasons for selecting the BCW include it being an integrative framework, synthesising 19 other behavioural and behaviour change frameworks (34, 35). Assumptions about what drives behaviour will often influence the types of interventions that are used to change behaviour. If the assumptions made by certain theories are limited, this can impact the effectiveness of interventions based on them. The benefits of integrative frameworks therefore include combining the strengths and overcoming the limitations of the original theories, models and framework they are comprised of. This can lead to an improved understanding of the factors that encourage, hinder and/or maintain behaviour and, by extension, the design of interventions more likely to be effective.

Another benefit of the BCW is that it offers a method for systematically progressing from an understanding of the influences on behaviour to clearly defined intervention and policy strategies including the selection of specific behaviour change techniques. While other intervention development frameworks outlining a range of potential intervention strategies exist (e.g., MINDSPACE (42)), there may be little guidance on which ones to select based on a comprehensive behavioural analysis of the problem. Similarly, while other theories of behaviour exist (e.g., the Theory of Planned Behaviour (43)), they can be limited in terms of how comprehensively they consider the wide range of potential influences on behaviour and provide little guidance on how to move from an understanding of the determinants of behaviour to intervention design.

The BCW and associated frameworks used in the research reported in this thesis are outlined in more detail below.

1.3.1. Behaviour Change Wheel (BCW)

Shown in Figure 1.2, the BCW supports intervention design by depicting a process with three broad stages, starting from the inner hub of the wheel and working outwards: 1) Select and precisely specify the target behaviour targeted by the intervention; 2) 'Diagnose' the behaviour i.e., identify what would need to change for the behaviour to change; and 3) Design the intervention by using the behavioural diagnosis as a basis for selecting intervention and policy options.

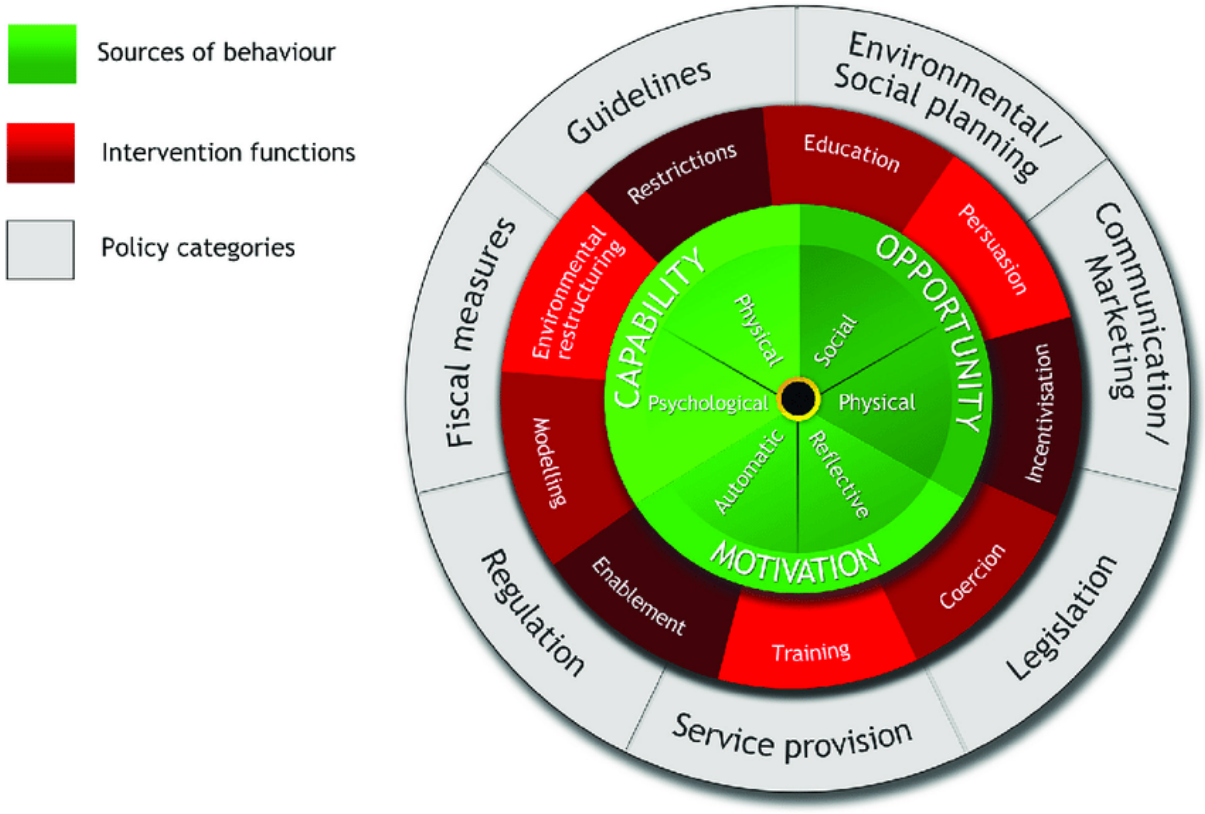

Figure 1.2 The Behaviour Change Wheel (reproduced with permission from (34, 35)).

Behavioural target selection involves narrowing down a target behaviour from an array of possible behaviours that are related to achieving the desired outcome. Behavioural target specification involves precisely operationalising the target

behaviour in terms of who does what, where when in which context etc. so that it is clear and explicit what is being targeted (and likely measured) for change. Behavioural diagnosis includes identifying behavioural influences to understand what would need to change for the behaviour to change. Additional frameworks can be used to facilitate specifying and diagnosing the target behaviour. They are detailed in Section 1.3.2, Section 1.3.3 and Section 1.3.4 of this chapter.

Designing the intervention involves a series of smaller steps including identifying intervention types (i.e., broad types of behaviour change strategies) and policy options (i.e., implementation strategy selections to help deliver/leverage the intervention). Table 1.1, depicts definitions of each intervention type and policy option. Intervention types can be mapped to more specific component behaviour change techniques (BCTs) from the Behaviour Change Techniques Taxonomy (BCTTv1), comprising 93 hierarchically clustered BCTs (44). BCTs are the elementary components of interventions such as 'goalsetting', 'action planning' or 'instructions on how to perform the behaviour'. A detailed intervention plan may then be developed by selecting BCTs that bring about the desired intervention strategy. The BCW Guide to Designing Interventions (34) offers guidance regarding the selection of BCTs that are best suited and most commonly used for each intervention type and which intervention type is most suited for which type of behavioural problem (as analysed using COM-B). Definitions of each BCT can be found in the original article (44). A detailed intervention specification covering both the content (BCTs) and delivery of the intervention can be created, based on the selected BCTs and their delivery e.g., modes of delivery (e.g., via an online app, training programme, advertisement etc), and source, schedule and style of delivery.

Table 1.1 Definitions of BCW intervention types and policy options.

Intervention type	**Definition**
Education	Increasing knowledge and understanding
Persuasion	Getting people to change behaviour by generating 'cognitive dissonance' – an uncomfortable state of having contradictory beliefs, thoughts or values towards something (45)
Incentivisation	Changing the attractiveness of a behaviour by creating the expectation of reward
Coercion	Changing the attractiveness of a behaviour by creating the expectation of punishment
Training	Increasing psychological or physical skills; Restriction: constraining behaviour by setting boundaries
Environmental restructuring	Altering the physical or social environment
Modelling	Showing examples of the behaviour for people to imitate
Enablement	Providing support to change behaviour in ways not covered by other intervention functions e.g., through encouragement, moral support
Policy options	**Definition**
Guidelines	Development and dissemination of documents that make recommendations for desired behaviour
Environmental and social planning	Changing the physical and social environment people inhabit
Communications and marketing	Use of marketing channels and tools to communicate a message e.g. can include mass media campaigns and digital marketing campaigns
Legislation	Using laws and other similar instruments to set restrictions on behaviour with penalties for breaching
Service provision	Providing a service, material resources and aids
Regulation	Development and implementation of rules regarding behaviour that instruct the behaviour and possibly provide rewards and punishments for conforming
Fiscal measures	Use of taxation and tax relief. The aim here is to incentivise and disincentivise behaviours where one has the authority to levy taxes

1.3.2. COM-B model (Capability-Opportunity-Motivation-Behaviour)

Shown in Figure 1.3, is the hub of the BCW Wheel, the COM-B (Capability-Opportunity-Motivation-Behaviour) model. The COM-B model provides a framework for identifying the various modifiable influences on a behaviour and thus can be used to identify behavioural targets for interventions. The model posits that for a behaviour to occur, there must be: Capability, Opportunity and Motivation to enact the behaviour. Capability can refer to people's physical or psychological capability such as their physique and stamina or knowledge, intellectual capacity, memory and decision-making processes. Opportunity can refer to social or physical opportunity such as the social environment of cultures and norms or the physical environment of objects and events with which people interact. Motivation can be automatic or reflective motivation and refers to the intentions, desires, evaluations, habits and instincts that direct human behaviour.

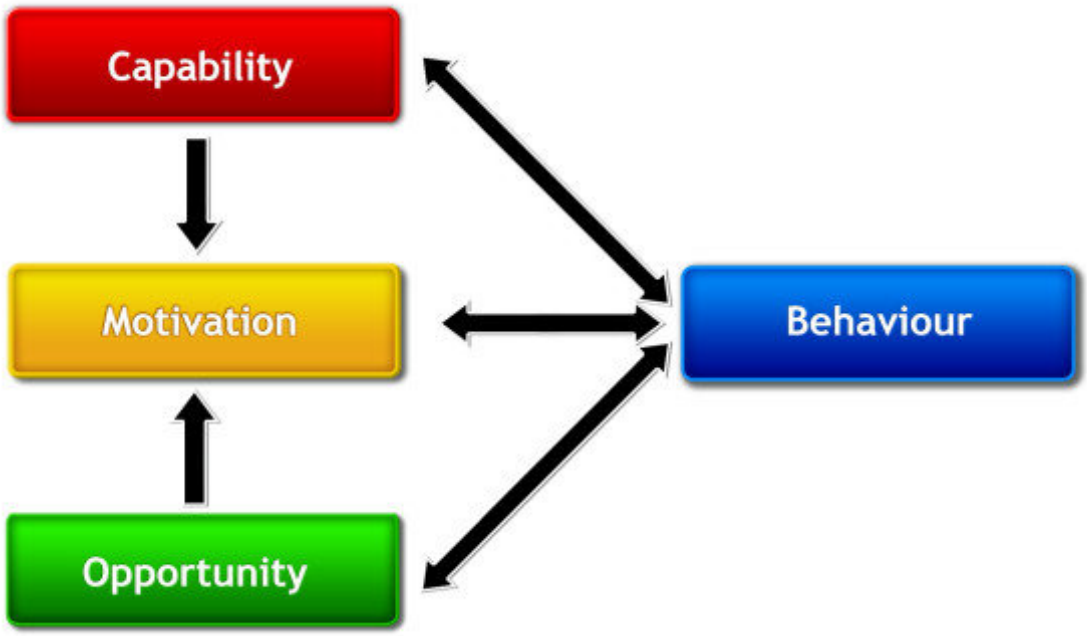

Figure 1.3 COM-B model (reproduced with permission from (34, 35)).

1.3.3. Theoretical Domains Framework (TDF)

Shown in Table 1.2, an elaboration of the COM-B model is the Theoretical Domains Framework (TDF) (46). The TDF includes 14 Theoretical Domains, representing individual, socio-cultural and environmental factors influencing behaviour. These include people's knowledge and skills, memory, attention and decision-making processes, beliefs about capabilities and consequences, goals and emotions as well as physical and social environmental factors.

Table 1.2 Definitions of the 14 TDF domains.

TDF domain	Explanation
Knowledge	An awareness of the existence of something
Skills	An ability or proficiency acquired through practice
Social/Professional role and identity	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting
Beliefs about capabilities	Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use
Optimism	The confidence that things will happen for the best or that desired goals will be attained
Beliefs about consequences	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation
Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus
Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way
Goals	Mental representations of outcomes or end states that an individual wants to achieve
Memory, attention and decision processes	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives
Environmental context and resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour
Social influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours
Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event
Behavioural Regulation	Anything aimed at managing or changing objectively observed or measured actions

Figure 1.4 shows the relationship between COM-B categories and TDF domains. COM-B and TDF may be considered as part of the 'toolbox' of behavioural science frameworks that can be used to conduct a behavioural diagnosis (34, 47).

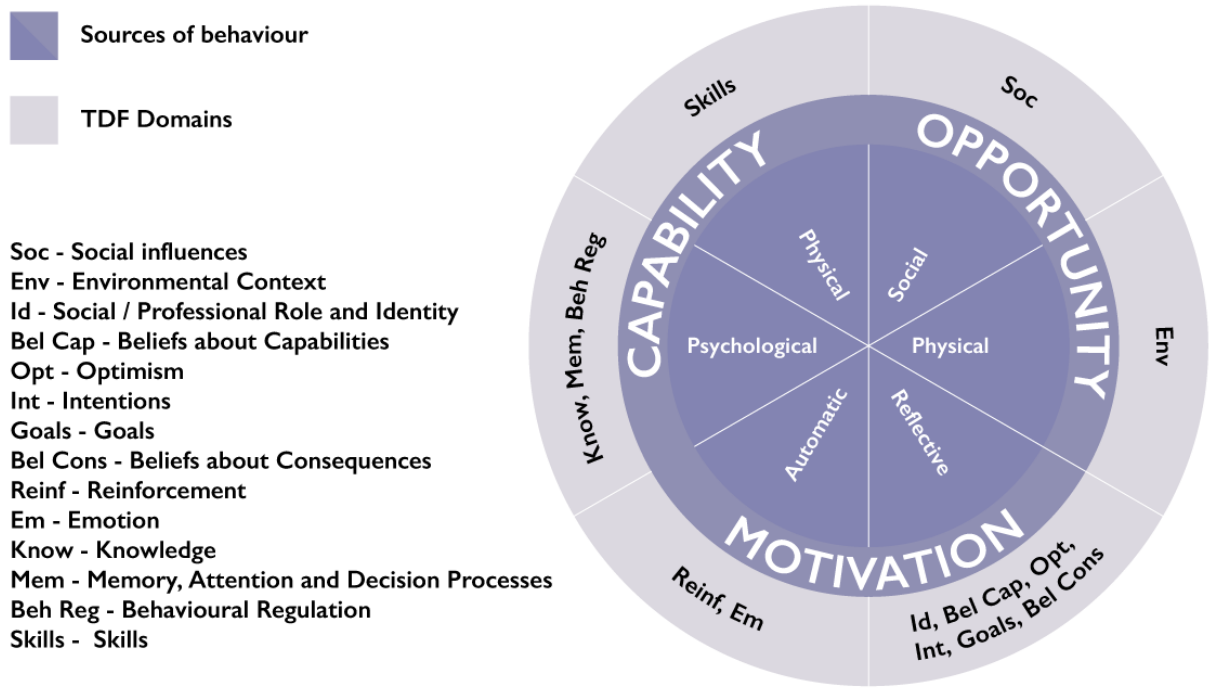

Figure 1.4 Link between TDF and COM-B categories (reproduced with permission from (26)).

Interventions do not occur in social vacuums so contextual factors must be taken into consideration during the design process to maximise likely effectiveness. A framework to structure this process, created by the authors of the Behaviour Change Wheel Guide, is known as APEASE.

1.3.4. APEASE framework

APEASE stands for Acceptability, Practicability, Effectiveness/cost-effectiveness, Affordability, Safety/side-effects and Equity. These are criteria to consider at every

stage of the intervention development process. The overall purpose of APEASE is to enhance the relevance, utility, justness and practicability of an intervention. The definitions of the criteria are:

- Affordability; how costly the proposed intervention is going to be
- Practicability; how feasibly the intervention can be delivered in the intended setting
- Effectiveness; how effective the intervention is going at changing the target behaviour
- Acceptability; how appropriate the intervention is deemed by key stakeholders and those receiving the intervention
- Side effects; a consideration of what potential unwanted side effects there might be from delivering this intervention
- Equity; a consideration of whether the intervention instigates disparities between different sectors of society

Intervention designers should consider these criteria at every stage of the intervention development process using available evidence combined with expert and stakeholder judgment. A further benefit of the BCW approach then is that it allows for the engagement of stakeholders throughout the intervention development process. For instance, APEASE criteria when used with the appropriate study design (e.g., focus group discussions, workshops, interviews and surveys etc.), may be used to aid the process of selecting an appropriate target behaviour to achieve the desired outcome, narrowing down on appropriate intervention strategies and selecting a mode of delivery that is suitable for the given intervention context and population. By systematically applying the APEASE criteria, stakeholders can

provide their views about the types of behaviour change strategies, policies and techniques they believe are most likely to be successful, sustainable, and equitable thereby enhancing the likely effectiveness of the intervention in practice. The BCW is therefore a useful behaviour change framework for tackling 'real-world' behaviour change problems requiring engagement from stakeholders with local, context-specific expertise.

1.4. The present thesis

Drawing on the theories, models and frameworks introduced above, this thesis addresses the problem of plastic waste by advancing the understanding of the role of behaviour.

The evidence relating to behaviour in the area of plastic waste is varied and crosses multiple scientific disciplines. To collate and synthesise the available scientific evidence, the first step in this thesis was a systematic review and meta-analysis (reported in Chapter 2). The value of this included identifying what is already known and the key knowledge gaps in this area. As the problem of plastic waste was found to be a result of various waste items, behaviours, actors and contexts, meaningfully investigating this problem further necessitated the selection of appropriate use cases.

The case study selected for this thesis was the waste management of compostable plastic packaging in the UK. Compostable plastic packaging represents a potential solution to the issue of plastic waste by reducing the amount of plastic packaging sent to landfills and incineration. The idea is that through composting plastic waste, whether that's through industrial, home or community composting processes, the materials will retain value as they are recycled into a nutritional

compost that can be useful in other applications (e.g., as fertiliser). Compostable plastics have, nonetheless, become the 'wild west' of the packaging sector in that the materials are largely unregulated. This means that there are issues with standards and certification, with limited rules around how they are labelled and marketed; manufacturers and suppliers are, therefore, at liberty to market them as they please. At the time of writing this thesis in 2023, there is also no reliable system for collecting, sorting and processing compostable plastics in the UK which means these materials often do not end up composted as they were designed to. Taken together, this means that the claims made of compostable plastics' environmental credentials are often exaggerated to the public leading to confusion and mistrust of these materials (48). Compostable plastics could be part of a circular UK packaging system; however, this would require UK citizens to adopt the appropriate waste management behaviours that lead to the materials being composted i.e., putting them in the right bin for composting as incorrect disposal (which leads to them being sent to landfill or incineration) offsets the potential environmental benefits of compostable plastic packaging (49, 50). Figure 1.5 highlights some of the current challenges around the management of compostable plastic and what a circular economy for these materials, enabled by the correct behaviours, could look like.

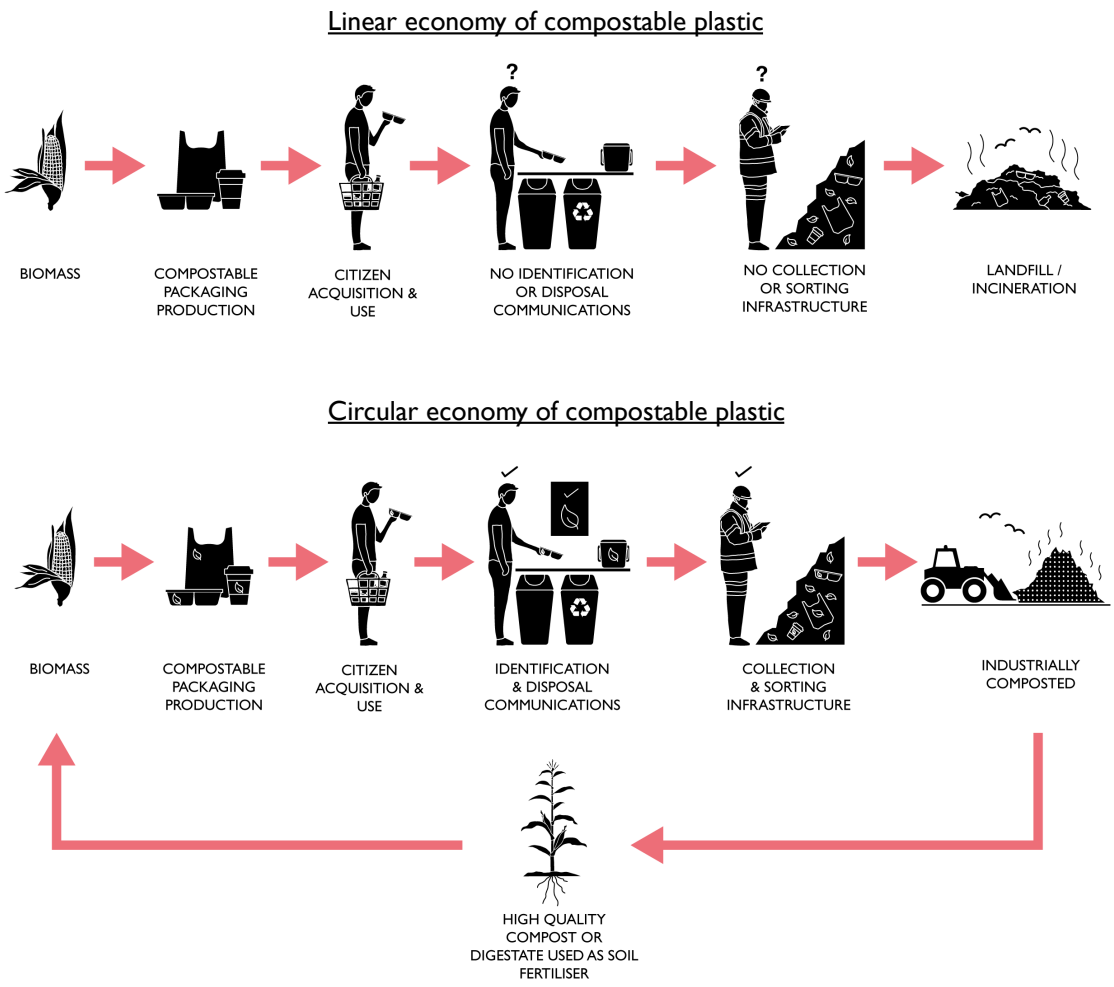

Figure 1.5 Challenges and potential solutions to a circular economy of compostable plastics (reproduced with permission from (51)).

As compostable plastics are relatively new in terms of an integrated UK waste management strategy, there is little research conducted that could inform the design of effective behaviour change interventions to increase appropriate waste management of these materials. Recognising the complexity within the wider system of compostable waste management and that circular transitions will require concurrent improvements to the wider technical aspects of the system (e.g., the manufacture of compostable plastics and waste processing infrastructure) including behaviour change across other key groups of people implicated (e.g., compostable

plastic suppliers, waste collectors and waste processors, local authorities and policy-makers), the present thesis focuses specifically on the behaviour of end-users who play a key role in sorting the material into the correct bin at end-of-life. Furthermore, it is recognised that in the UK, local household food waste collection services provide the most likely context for the management of compostable plastics, en masse. For this reason, it is behaviour concerning this waste management route that is prioritised and investigated over other potential routes such as home-composting or disposal of compostable plastic packaging in 'closed' scenarios e.g., festivals, office buildings.

To this end, the subsequent two studies in this thesis aim to advance scientific understanding in this area by identifying influences on citizens' compostable plastic packaging purchase (Study 2 reported in Chapter 3) and recycling of household food waste via local household food waste collections (Study 3 reported in Chapter 4). The findings of these studies can inform behaviour change strategies to promote the desired disposal of compostable plastic packaging. Recognising the distinction between waste prevention and waste recovery within a circular economy agenda (Figure 1.1), the terminology 'reduce waste' is used throughout this thesis as a range of circular behaviours relating to the reduction, reuse and recycling of plastic waste are investigated (e.g., in Study 1). Where references are made to 'waste reduction' in the context of behaviours relating to waste recovery, i.e., Studies 2-5, the author clarifies that this is in reference to reducing waste by keeping materials 'in the loop' rather than reducing waste via source reduction.

Accordingly, by applying the Behaviour Change Wheel, the findings of all the previous empirical studies in this thesis (Studies 1-3) were subsequently integrated

to develop an intervention promoting the disposal of compostable plastics (Study 4 reported in Chapter 5). The developed intervention consisted of a series of disposal instruction labels consisting of various wording and imagery. The final study in this thesis reports the evaluation of the disposal instruction labels, for effectiveness in promoting the desired disposal of compostable plastic packaging (Study 5 reported in Chapter 6).

The present thesis' key contributions to knowledge include the identification of the range of behaviours that have been investigated empirically concerning plastic waste; the identification of the key challenges the general public faces with the purchase of compostable plastic packaging and disposal of compostable waste; and, the identification of the disposal instructions on labelling that most effectively divert compostable plastic packaging into the desired bin.

The present thesis' key contributions to theory and methodology include the application of the Behaviour Change Wheel and associated frameworks to understanding and changing behaviour within the context of the circular economy. As previously mentioned, these frameworks have predominantly been applied within health contexts. Human behaviour is implicated in a wide range of societal problems and so applications of behavioural science are required in many areas beyond health. Documenting applications of behavioural science theories, methods and frameworks within novel, interdisciplinary implementation contexts not only advance behavioural science as a discipline but also demonstrates the value of behavioural science amongst other fields of study, such as environmental engineering. This, in turn, helps to explore the universal utility and relevance of these frameworks

meanwhile generating case studies that disseminate learning across disciplinary boundaries.

1.5. Aims of the current thesis

This thesis aimed to advance scientific understanding of the public's behaviour concerning plastic waste. Specifically, the objectives of this thesis are to:

1. Identify key behaviours related to plastic waste;
2. Identify influences on key behaviours related to the purchase and disposal of compostable plastic packaging;
3. Design and evaluate an intervention aimed at enabling the desired disposal of compostable plastic packaging.

2. Chapter 2 – Reducing plastic waste: a systematic review and meta-analysis of behavioural influences and interventions (Study 1)

2.1. Abstract

Background: Eliminating plastic waste relies, in part, on changing human behaviour.

Aims: This review aimed to use theoretical frameworks and models of behaviour (i.e., AACTT (Action-Actor-Context-Target-Time) and COM-B (Capability-Opportunity-Motivation-Behaviour)) and behaviour change (i.e., Behaviour Change Wheel and the Behaviour Change Techniques Taxonomy) to: a) identify and categorise behaviours, b) identify, categorise and evaluate factors that might be associated with behaviour, c) identify, categorise and evaluate components of interventions.

Method: A systematic literature search was conducted. Results were narratively synthesised. Sub-group meta-analyses were used to quantify (i) the strength and direction of the relationship between COM-B variables and behaviour and (ii) the effectiveness of intervention components in changing behaviour.

Results: 60 studies of behaviour relating to plastic waste were identified. Studies focused predominantly on the general public (actors; $n = 48$), recycling (action; $n = 25$), shopping (context; $n = 19$), and a limited range of plastic waste items – mostly relating to packaging e.g., shopping bags, bottles, cups. Variables reflecting capability, opportunity, and motivation all had medium-strength associations with behaviour ($r+$ range from .22 to .41). The intervention types associated with the

strongest changes in behaviour were ‘persuasion’, ‘enablement’ and ‘environmental restructuring’ (*d*+ range from 1.15 to 1.69). The policy options associated with strongest changes in behaviour were ‘communications and marketing’, ‘environmental and social planning’ and ‘service provision’ (*d*+ range from 1.00 to 1.64). Interventions targeting ‘psychological capability’ (*d*+ = -0.28) had an overall negative effect on plastic waste reducing behaviours while targeting ‘physical opportunity’ (*d*+ = 1.08) and ‘reflective motivation’ (*d*+ = 1.34) had the strongest positive effects. All identified BCTs had medium to large effects at changing behaviour (*d*+ range from 0.58 to 1.33).

Conclusion: A wider range of ‘higher priority’ resource-efficient behaviours warrant scientific investigation. A combination of capability, opportunity and motivation is needed to promote behaviours that reduce plastic waste and prevent behaviours that generate plastic waste. Targeting knowledge and awareness is a necessary but not sufficient behaviour change strategy in this area.

2.2. Background

Behaviour change is critical in the transition towards a plastic economy yet there is a dearth of theory and evidence-based behaviour change research within this area. This meta-analytic systematic review is the first study of this thesis and aims to examine the role of behaviour by identifying key behaviours relating to plastic waste, influences on those behaviours and interventions aimed at reducing plastic waste. A version of this work has been published in the Journal of Cleaner Production (52).

As described in Chapter 1, as well as informing the design of interventions, the Behaviour Change Wheel can be used in systematic reviews and other types of evidence syntheses to integrate research findings on influences relating to a target behaviour and contents of interventions (e.g., (53-59)). The importance of evidence synthesis includes delivering a clear and comprehensive overview of the available evidence on a given topic (60). Since, the evidence on citizens' behaviour relating to plastic waste is methodologically varied and multi-disciplinary, including evidence from economics (61), marketing (62), psychology (63), and anthropology (64), an evidence synthesis in this area may be useful to consolidate existing knowledge and identify understudied areas.

Different types of evidence syntheses could be useful for advancing the understanding of behaviour concerning plastic waste. Some might synthesise evidence on what interventions have been done before and what works, others may be more qualitative syntheses on influences on a behaviour. This study synthesises the available scientific evidence on prior interventions and behavioural influences using both qualitative and quantitative techniques to provide a comprehensive overview of this topic.

Prior efforts to synthesise the psychological and behavioural evidence concerning plastic waste have been made. A narrative review of factors associated with behaviours leading to citizens' plastic waste and interventions to tackle plastic waste was conducted by Heidbreder and colleagues in 2019 (65). The review found that habits, norms, and situational factors predicted citizens' plastic consumption and that political and psychological interventions were the most common types of interventions aimed at curbing plastic consumption. However, this review was not systematic meaning that evidence may have been missed; nor was the evidence structured within a behavioural framework, meaning that it is difficult to categorise and conceptualise the various influences on behaviour and components of the interventions. Aside from the benefits of lending structure to evidence synthesis, using behavioural frameworks can also facilitate the subsequent step-wise progression to designing interventions (future or refinement of existing) which, in turn, facilitates the uptake of scientific evidence to practice. Furthermore, since the Heidbreder et al. review was narrative, it was not possible to compute the magnitude of the effects of factors on behaviour and/or the interventions.

Thus, a systematic review with meta-analysis is needed to provide high-quality, quantitative evidence to inform modelling, future research and implementation efforts and policy (60). Conducting such a review within theory- and evidence-based behavioural frameworks, such as those identified in Chapter 1, would help to identify and conceptualise the factors associated with behaviour, providing targets for interventions. It would help to identify the types of interventions that are most likely to be effective at reducing plastic waste (30). Finally, such a

review would be valuable in helping to identify the key knowledge gaps in this research area.

In the present study, a systematic review and meta-analysis are conducted using the Behaviour Change Wheel framework and associated COM-B model and BCTTv1 outlined in Chapter 1. An additional framework is also used in this study to specify the key behaviours studied. This is because there are several different behaviours that people can engage in to reduce plastic waste e.g. those involved in reducing, reusing and recycling (25). Interventions are more likely to be effective if they target specific behaviours following a detailed and comprehensive analysis of behaviours and their influences in their contexts (66). Specifying the behaviours studied can also help to improve understanding of how diverse the current behavioural evidence relating to plastic waste is. The framework used is the Action, Actor, Context, Target, Time framework (AACTT) (67). Action refers to what is being targeted for change (e.g., selling hot drinks in reusable cups over single-use cups); Actor refers to the person(s) who are part of the intervention (e.g., café staff that sell takeaway coffee); Context refers to where the behaviour is performed (e.g. in cafes); Target refers to whom the behaviour effects (e.g. people who buy takeaway coffee); and Time refers to when and for how long the behaviour is performed (e.g. when people are 'on the go' and want coffee).

To this end, the aims of this review were three-fold. First, this study aimed to identify and describe the key behaviours that contribute to plastic waste. Second, it aimed to describe the factors that are potentially associated with these behaviours and conduct meta-analyses to identify which factors are most strongly associated with behaviour. Finally, it aimed to describe which intervention types, policy options,

targeted behavioural antecedents and BCTs have been used to modify these behaviours and conduct meta-analyses to identify the effectiveness of different behavioural change strategies on behaviours relevant to plastic waste.

2.3. Method

A protocol was published before conducting the review on the Open Science Framework (OSF) along with the study materials, including the raw data files and R code used for the meta-analysis (https://osf.io/53mtu/). This study follows Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (68, 69) and recommendations for meta-analyses (70, 71).

Eligible papers were identified via a systematic search of the peer-reviewed scientific literature. Data (i.e., text and/or numbers) were extracted from the manuscripts and coded for analysis. All papers contributed towards the narrative syntheses. A sub-group of these papers was included in quantitative meta-analyses if they met additional eligibility criteria. Evidence was synthesised within behaviour change frameworks for analysis. Figure 2.1 provides an overview of the method, and directs the reader to the sections of the manuscript that provide more detailed information.

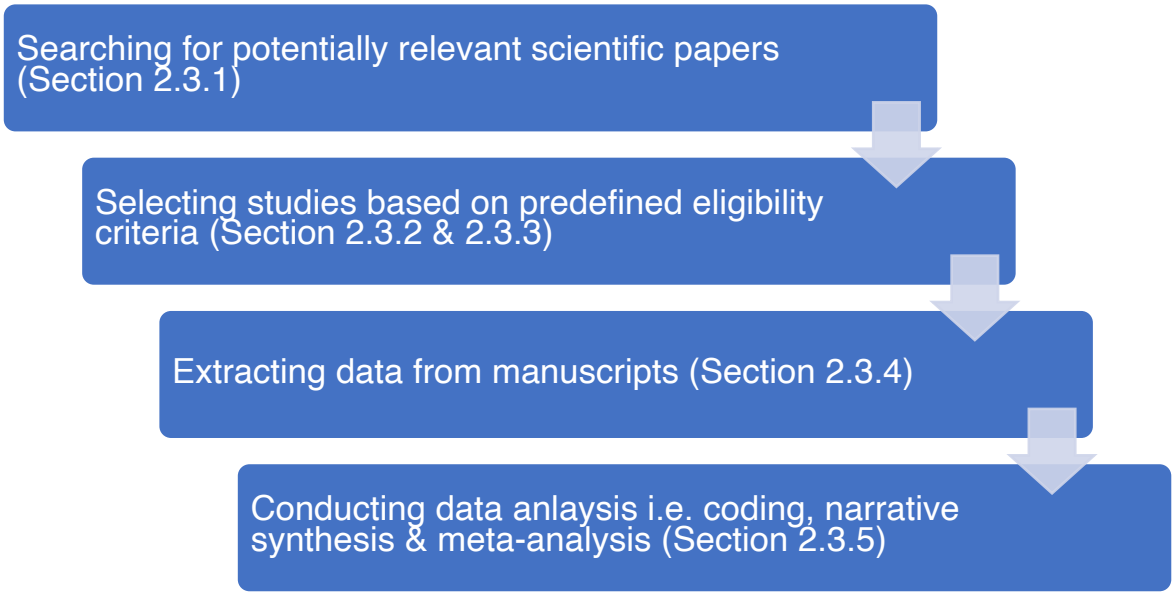

Figure 2.1 Overview of review methodology (reproduced with permission from (52)).

2.3.1. Search strategy

Two strategies were used to identify papers. First, an electronic search of three databases was conducted in February 2020: a) PsychINFO (due to its focus on psychological and behavioural science), b) GreenFILE (due to its focus on sustainability), and c) SCOPUS (due to it being a large database of varied, multidisciplinary peer-reviewed articles). The search was restricted to English-language and peer-reviewed, published journal articles. This is because English is the only language shared by all members of the research team and non-peer-reviewed studies may be of lower methodological quality than published studies (72). Each database was searched using terms relating to three filters: (i) plastic (e.g., plastic*, OR microplastic*); (ii) behaviour (e.g., behavio?r*, recycle*, reus*) and; (iii) influences or interventions (e.g., impact*, predictor*, influence*). Studies had to include at least one search term from each of the three filters in the title, abstract, or keywords. A detailed description of the electronic database search strategy is openly available via OSF (https://osf.io/kerwt). The electronic database search was supplemented by forward and backwards searching the studies cited by and citing Heidbreder et al's review (65) in July 2020.

2.3.2. Study eligibility

Three types of studies were of interest in this review: a) studies that explored variables associated with behaviour(s) relating to plastic waste e.g., (73), b) studies that reported an intervention aimed at changing behaviour relating to plastic waste e.g., (74), or c) studies that did both e.g., (75). Studies were eligible for inclusion in the review if they were: a) empirical (i.e., not reviews), b) addressed plastic as a

waste material in the manuscript[2] and, c) investigated behaviours, defined as: "*Anything that a person does in response to internal or external events. Actions may be overt (motor or verbal) and directly measurable or, covert (activities not viewable but involving voluntary muscles) and indirectly measurable; behaviours are physical events that occur in the body and are controlled by the brain*" (32)[3]. Both qualitative and quantitative studies were considered.

2.3.3. Study screening and selection

The process of identifying eligible studies was conducted in two stages. First, the titles and abstracts of articles identified via the search strategies were screened to identify potentially relevant studies. A random 10% of studies were double-screened by a second reviewer (CL) to assess for reliability. Rayyan software was used to support the title and abstract screening process (76). Any discrepancies were discussed until both researchers came to a consensus. Finally, the full texts of articles describing potentially relevant studies were reviewed against the study inclusion and exclusion criteria to determine eligibility. A random 38% of studies were double-screened by a second reviewer (HMB) to assess reliability at the full-text screening stage.

2.3.4. Data extraction

Data from individual studies was extracted using a form developed for the current review. The data extraction form is openly available via OSF (https://osf.io/t5ake). The form was piloted with five studies (75, 77-80) by the thesis author (ALA) and reviewed by a co-investigator (FL) to ensure that all relevant information was

[2] Studies on plastic surgery or plastic used within artistic contexts were therefore excluded.
[3] Studies, therefore, investigating variables associated with and interventions aimed at changing behavioural intentions/willingness were not eligible for inclusion.

captured before formal data extraction. Initial data extraction was then conducted by the thesis author (ALA), and a random 10% of studies were independently coded by another co-investigator (HMB) using the data extraction form. The extracted data included publication details (e.g., study title, first three authors, publication year, publication journal) and methodological details (e.g., study type [i.e., reporting factors associated with behaviour, reporting the effects of an intervention or reporting both], study design, country in which the study was conducted, mean age of the sample, gender composition of the sample [i.e., percentage female]). A data extraction 'crib sheet' depicting additional criteria that were used to support data extraction can be found via OSF (https://osf.io/wfjdk).

To identify the behaviours studied within the scientific literature, the extracted data included: a) the measure of behaviour (e.g., self-reported recycling behaviour) or associated outcome (e.g., volume of plastic waste in a bin), b) whether behaviour was measured using self-report or and objective measure, c) if self-report, then the reliability of the measure (if applicable) and, d) the written description of the target behaviour from the manuscript.

To identify which variables have been identified as potentially associated with these behaviours, the written description of the variable potentially associated with behaviour from the manuscript (e.g., attitudes, social norms etc.) and the reliability of the measure of this variable (if applicable) were extracted.

To identify which variables are most strongly associated with behaviours related to plastic waste, data extracted included: a) effect size *r*, representing the strength of the relationship between the variable and the behaviour, b) how the effect size was

calculated (i.e., reported in text, authors provided on contact or converted using Psychometrica (81)), c) the sample size for the reported effect size.

To identify what interventions have been used to try and change these behaviours, the written description of the intervention was extracted from the manuscript.

To identify which interventions are most effective at changing these behaviours related to plastic waste, data extracted included: a) effect size *d*, representing the difference between the intervention conditions on the measure of behaviour and/or associated outcomes, b) how the effect size was calculated (i.e., reported in text, authors provided on contact or converted using Psychometrica (81)), c) the sample size of the control group for the reported effect size, d) the sample size of the intervention group for the reported effect size and e) the standard error of the effect size which was calculated manually using MAVIS (v1.1.3) (82) or the effect size calculator provided by the Campbell Collaboration (83).

2.3.5. Data analysis

Coding of extracted data was conducted using Excel. Descriptive statistics were conducted using SPSS (84). The meta-analytic approach taken is detailed in Section 2.3.5.1.

To identify the behaviours studied within the scientific literature, the written description of the behaviour extracted from the manuscript was dummy coded to clarify the presence or absence of an Action, Actor, Context, Target and Time, aspects of the AACTT framework (i.e., 1 = present, 0 = absent). These were then quantified using frequencies.

To identify which variables have been identified as potentially associated with these behaviours, this description of these variables extracted from the manuscripts was deductively dummy-coded to clarify the presence or absence of each of the six COM-B components (i.e., 1 = present, 0 = absent). These were then quantified using frequencies.

To identify what interventions have been used to try and change these behaviours, the written description of the intervention extracted was dummy-coded to clarify the presence or absence of each BCW intervention type, policy option, targeted COM-B component and BCT(s) from the BCTTv1 (i.e., 1 = present, 0 = absent). These were then quantified using frequencies.

2.3.5.1. Meta-analytic approach

Additional sub-group analyses were run, for eligible quantitative studies, to identify which of the COM-B variables were most strongly associated with behaviours related to plastic waste and which BCW intervention types, policy options, targeted COM-B variables and BCTs were most effective at changing behaviour.

2.3.5.1.1. Additional eligibility criteria for inclusion of studies in meta-analyses

To be eligible for inclusion in the meta-analyses of association between predictive variables and behaviour, these studies had to measure at least one component of the COM-B model, that is, a capability (e.g., memory or knowledge), an opportunity (e.g., access to council waste collection or social norms) or a motivation (e.g., beliefs or pro-environmental values) and at least one behaviour relating to plastic waste. Studies needed to report, or provide sufficient information for the author to calculate, effect size *r* representing the strength and direction of the relationship between the measure of the COM-B construct and the measure of behaviour.

To be eligible for inclusion in the meta-analyses of intervention effectiveness, these studies had to investigate the effect of an experimental manipulation or intervention designed to modify behaviours. Studies needed to be designed in a way that isolated the effect of the intervention (e.g., via a pre- and post-intervention assessment or a control/comparator group). The evaluation had to be in the context of the intervention's effectiveness in changing behaviour[4]. Studies that measured changes in behaviour (e.g., asking people how often they recycle before and after a behavioural manipulation) and studies that measured changes in an outcome of behaviour (e.g., measuring the volume of plastic waste produced in a waste bin before and after a behavioural intervention) were included where this was clearly an indicator of actual behaviour change e.g., (79, 85). The study also had to report or provide sufficient information for the author to calculate, effect size *d* representing the difference between the intervention conditions on the measure of behaviour and/or associated outcomes.

If the required information was not reported, attempts were made to contact the study authors. If the required information could not be obtained after contacting the author, the study was excluded from the meta-analysis and incorporated within the narrative synthesis.

2.3.5.1.2. Effect size index

Two different effect size metrics were used to conduct the subsequent meta-analyses: (i) effect size *r* and, (ii) effect size *d*. Effect size *r* was used to represent the strength and direction of the relationship between factors potentially associated with

[4] Other types of intervention evaluations (e.g., acceptability or cost effectiveness) were therefore excluded.

behaviour and Cohen's *d* was used to represent the impact of the interventions on behaviour. Where Pearson's *r* or Cohen's *d* was not available, Psychometrica (81) was used to convert other statistics (e.g., means and standard deviations, Odds Ratios) into *r* or *d*. As some studies investigated behaviours that contribute to plastic waste while others investigated behaviours that reduce plastic waste, some effect sizes were transformed to ensure that effect sizes reflected the relationship between factors or effects of interventions on reductions in plastic waste.

2.3.5.1.3. Meta-analytic procedures

Random-effects meta-analyses with Robust Variance Estimation (RVE) (71) were conducted using the 'robumeta' and 'metafor' packages in R (86, 87). RVE was used to address statistical dependencies at the within-study level as multiple studies contributed multiple effect sizes[5].

As Pearson's *r* is not normally distributed**,** Fisher's z-transformed correlation coefficients were used to represent the relationship between COM-B variables and behaviour. Results were converted back to Pearson's *r* for reporting. Cohen's *d* was used to represent the impact of the interventions on behaviour. In line with meta-analytic guidance, some study samples were windsorized – this is a data transformation strategy that involves limiting extreme values to prevent them from biasing results (88). One study (89) had a sample size (n = 46,755) that exceeded three standard deviations from the mean sample size (M = 1,572, SD = 2,393) and

[5] This estimation method permits clustered data (i.e., effect sizes nested within samples) to be meta-analysed by correcting the within-study standard errors for correlations between effect sizes. This is done by estimating the average correlation between all pairs of within-study effect sizes (ρ), which is then used to correct the between-study sampling variance (τ^2) for these statistical dependencies. The author set ρ = .80 because sensitivity analyses revealed that findings were invariant across different reasonable estimates of ρ. Alongside τ^2, I^2 was also reported, which quantifies the proportion of effect size variance due to between-sample heterogeneity.

so it was windsorized by making it equal to the next largest sample size (n = 8,162) (80) which was within three standard deviations of the mean sample size. So as not to lose data, the same winsorized sample size (i.e., n = 8,162) was used for two other population-level studies as the sample size was not reported (79, 85).

Moderation analyses were conducted. Continuous moderators were entered into a regression equation as a predictor using the RVE approach. Categorical moderators which had two levels were dummy-coded and entered into the meta-regression equation using RVE[6].

Although, the method of moments estimator used by the 'robumeta' package to estimate τ^2 (90) and its degrees of freedom are adjusted for a small sample size, this robust standard error estimation with small sample adjustment remains biased (i.e., increased type I error rate) if the adjusted degrees of freedom are < 4 (70, 91). Therefore, results with less than 4 degrees of freedom were not interpreted.

Finally, for each meta-analysis, the potential for publication bias was assessed using a multimethod approach. The fail-safe N statistic was calculated using Rosenberg's method (92). If this value is greater than the critical value, 5n + 10 (where n equals the number of effect sizes), then the probability of publication bias is low. Contour-enhanced funnel plots (93) were created which aggregated effect sizes at the study level to assess for signs of asymmetry and then formally tested the presence of asymmetry using Egger's regression (94). Whether effect sizes could be predicted by their standard errors (i.e., using the Precision-Effect Test, PET (95)) was investigated using RVE methods. Whereas Egger's regression considers the

[6] The significance of the regression coefficient for the predictor variable in these models tests whether the variable significantly moderates the respective relationship.

intercept of the regression, PET considers the slope of the regression. Significant Egger's and PET tests are suggestive of publication bias. If results failed the fail-safe N, Egger's and PET publication bias tests, publication bias was corrected for via calculating PEESE (95) (i.e., using the Precision-Effect estimates with Standard Error Test to test whether effect sizes can be predicted by their variances) and running Trim-and-Fill analyses (96).

2.4. Results

2.4.1. PRISMA Diagram

The literature search identified 4,904 papers, of which 60 met the inclusion criteria. Figure 2.2 shows the flow of studies through each phase of the review.

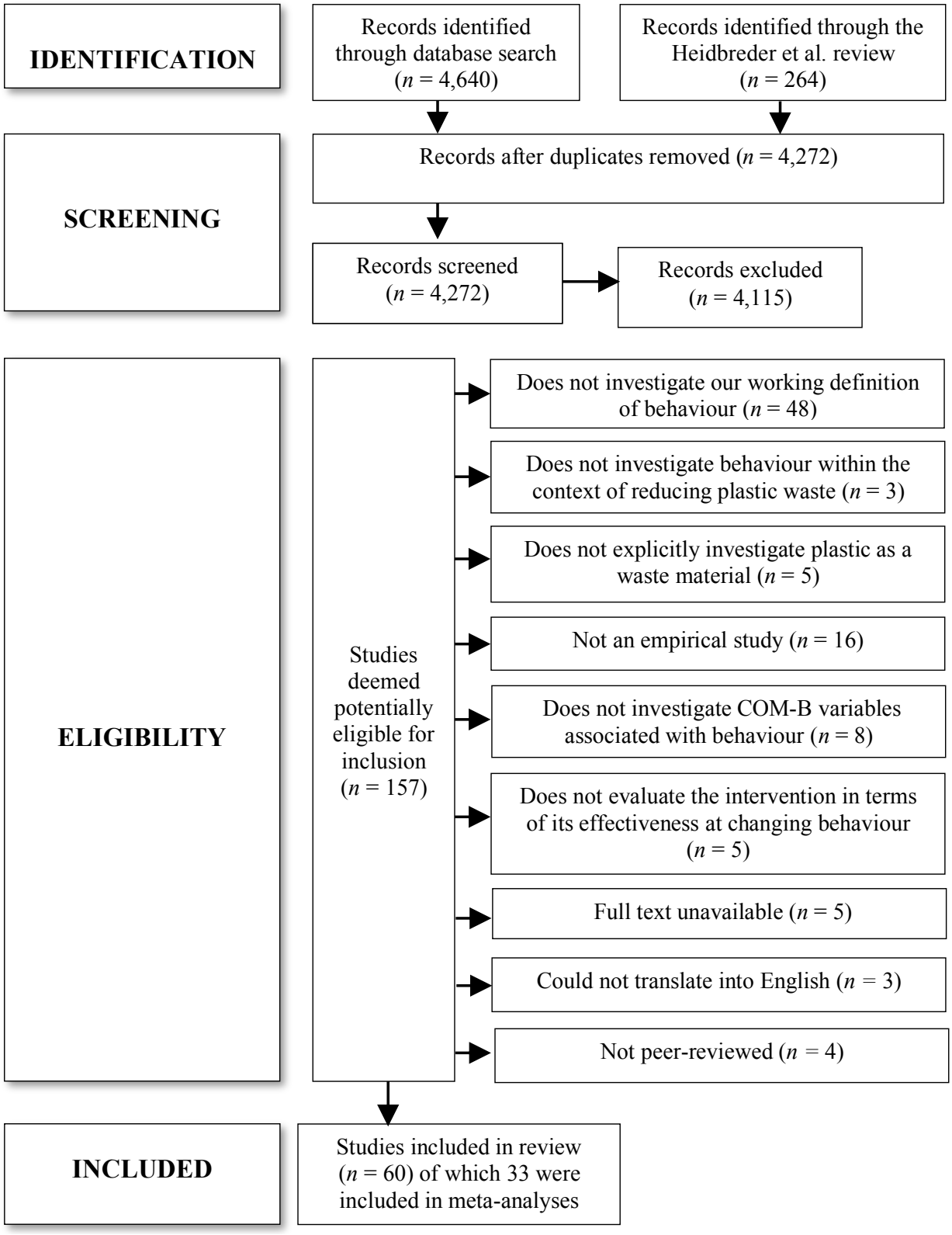

Figure 2.2 PRISMA diagram depicting the study flow (reproduced with permission from [52]).

2.4.2. Inter-rater reliability for data screening and data extraction

2.4.2.1. Inter-rater reliability for data screening

For title and abstract screening Cohen's kappa was 0.69. Thus, there was a substantial level of agreement between the two reviewers. Any discrepancies were discussed until resolved.

For full text screening, Cohen's kappa was 0.71 and percentage reliability was 87%. Thus, there was a substantial level of agreement between the two reviewers. Any discrepancies were discussed until resolved.

2.4.2.2. Inter-rater reliability for data extraction

For continuous variables, reliability between the two coders ranged from $r = 0.95$ to 1.00. For categorical variables, Cohen's kappa ranged from 0.49 to 1.00 and percentage agreement ranged from 83% to 100%. Thus, there was generally a high level of agreement between the two coders. Any discrepancies were discussed until resolved. Full details of the reliability analyses at data extraction level can be found in openly available via OSF (https://osf.io/q5nhu).

2.4.3. Study characteristics

Twenty-three studies reported factors potentially associated with behaviour (8, 50, 61, 64, 73, 97-114) - an overview of these studies is openly available via OSF (https://osf.io/6w8nq). Twenty-seven studies reported interventions aimed at changing behaviour (74, 77-79, 85, 89, 115-135) - an overview of these studies is openly available via OSF (https://osf.io/amqwd). Ten studies reported both (62, 63, 75, 80, 136-141) - an overview of these studies is openly available via OSF (https://osf.io/mucpy). As shown in Figure 2.3, the majority of studies were conducted in mainland Europe ($n = 17$) and Asia ($n = 14$) followed by North America

(*n* = 12) and the United Kingdom (*n* = 6). The studies were published between 1996 and 2020, with the majority of studies (53.4%) published between 2017 and 2020.

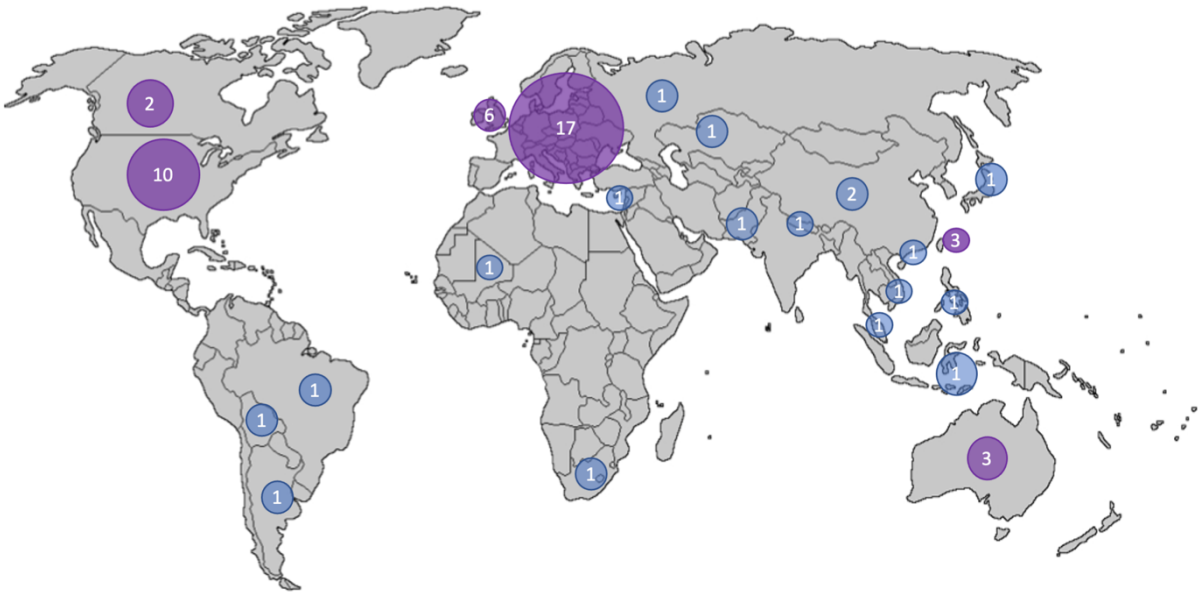

Figure 2.3 Global distribution of study samples (reproduced with permission from (52)). Barnes et al (8) used a global dataset of data from 63 countries and so is not represented in this diagram. Romero et al (98) is represented twice in this figure as they used two different samples: one from Brazil and one from Canada. Mainland Europe (*n* = 17) consists of Germany (*n* = 4), Portugal (*n* = 3), Sweden (*n* = 3), Italy (*n* = 2), Belgium (*n* = 1), France (*n* = 1) and The Netherlands (*n* = 1).

2.4.4. Behaviours relating to plastic waste

Table 2.1 summarises the behaviours investigated by the primary studies, according to the AACTT framework (67). In total, 19 different types of actions (behaviours) were identified, the most common being recycling (*n* = 25) which included recycling of unspecified plastic waste items (*n* = 19) and recycling of plastic water bottles/cups (*n* = 6). Six different actors were investigated across studies; although the majority focussed on the general public (*n* = 48). Six different contexts were investigated, including shopping (*n* = 19) or a university environment (*n* = 6).

The target of the behaviour was only specified by one study; the customer being served by the retailer at the checkout (140). Six different timeframes were investigated across studies, the most common being a single shopping trip (*n* = 14).

Table 2.1 Behaviours investigated summarised according to AACTT framework.

Action	***n***	**Actor**	***n***	**Context**	***n***	**Target**	***n***	**Timeframe**	***n***
Recycling plastic (unspecified)	19	General public	48	Shopping	19	Customer	1	During a single shopping trip	14
Using reusable shopping bags	15	University students/ staff and/or visitors	10	University campus	6			During the past week	2
Recycling plastic water bottles/cups	6	Employees	2	Home	5			During a working day	1
Taking free single-use plastic shopping bags	6	School students and/or personnel	2	School	2			During the past fortnight	1
Buying single-use plastic shopping bags	4	Retailers	1	Work	1			Over an unspecified four-week period	1
Using plastic bags (unspecified)	4			Cafe	1			The last five instances	1
Other[a]	19			Riverside	1			Daily	1

Notes: *n* = number of studies; [a] Other = using no shopping bags, *n* = 3; reusing plastic items (unspecified), *n*= 2; plastic packaging consumption (unspecified), *n* = 2; separating plastic waste items for recycling, *n*= 2; sorting plastic waste items for recycling, *n* = 2; refilling water bottles, *n* = 1; cleaning plastic waste items for recycling, *n* = 1; reselling plastic items (unspecified), *n* = 1; littering plastic waste items, *n* = 1; upcycling plastic waste items, *n* = 1; donating plastic items (unspecified), *n* = 1; compressing plastic waste items for recycling, *n* = 1, composting plastic water bottles, *n* = 1.

2.4.5. Variables associated with behaviour relating to plastic waste

Thirty-three studies explored 24 variables that are potentially associated with behaviour. These variables were coded as reflecting: reflective motivation (*n* = 23); physical opportunity (*n* =16); social opportunity (*n* = 10) and automatic motivation (*n* = 8). None of the primary studies examined variables related to physical capability. In the subsequent sections, the letter '*n*' is used to denote the number of primary studies while the letter '*k*' is used to denote the number of independent samples contributing the reported sample-weighted average effect size.

2.4.5.1. Psychological capability

Psychological capability was often measured in terms of awareness of the likely outcomes of behaviour (*n* = 7). For example, awareness of the environmental impact of plastic pollution was identified as an enabler of a range of behaviours related to reducing plastic waste, including recycling plastic waste (103, 105, 106, 141), reducing consumption of plastic packaging (100, 136) and donating, reselling, and reusing plastic items (73). Several studies (*n* = 4) also considered participants knowledge. For example, knowledge about recycling emerged as both a barrier (if knowledge was lacking) and enabler (if knowledge was present) to reducing plastic waste. This included knowledge of how to prepare waste for recycling (e.g., cleaning and sorting into the correct bin) (105, 108) and also being able to identify whether the waste is recyclable in the first place (112, 142). Two studies considered memory. For example, participants across studies reported finding it difficult to remember to save plastic containers for recycling (102) and forgetting to take reusable shopping bags with them when they went shopping (108). Finally, one study considered

participants' skills and training: specifically, education and training in sorting and recycling waste conducted by local government (105).

On average, psychological capability had a small-to-medium sized relationship with behaviours related to plastic waste ($r_+ = 0.24$, $k = 6$, see Table 2.3).

2.4.5.2. Physical opportunity

Physical opportunity was typically considered in terms of the convenience of the respective behaviours ($n = 9$). For example, inconvenience was considered as a barrier to enacting behaviours that reduce plastic waste including recycling (105, 108, 110, 112) and using reusable shopping bags (98). Similarly, using single-use plastic shopping bags was considered to be convenient (64, 102, 113); thereby enabling their use. For example, vendors identifying as women in Mali spoke of how plastic bags offer easy and convenient packaging for sensitive products like medicines: "Plastic bags are very convenient for me. Before we had a lot of concerns about where to put the local medicinal products we sell; now we have the plastic bags" (64). Physical opportunity also encompassed consideration of the environmental context ($n = 2$) and availability of waste management facilities ($n = 7$). For example, certain activities and situations such as social gatherings (e.g., weddings, parties etc.) and going to outdoor spaces (e.g., parks) and entertainment venues presented a barrier to reducing plastic consumption (100). Lack of bins was also considered as a barrier to recycling (101), while access to recycling facilities such as bring banks and drop-off waste collection sites were considered enablers to recycling (105, 108, 109, 111, 112, 139).

Physical opportunity also included consideration of resources ($n = 4$), both as a barrier and enabler to reducing plastic waste. For example, the profits gained from

selling upcycled goods enabled upcycling of plastic waste items, whereas lack of time and space were identified as barriers to upcycling (105). While some studies reported the cheap cost of plastic bags as an enabler to buying them (113), other studies found that the charge for plastic shopping bags deterred people from buying them (138). Another study found that the potential profits gained from selling recyclable waste onwards promoted recycling, while the costs of excess waste generation acted as a barrier to producing waste (110). Physical opportunity also included consideration of institutional quality (i.e., the capacity of the state to protect and support its citizens) ($n = 2$). Low institutional quality was identified as a barrier to reducing citizens' plastic waste. This included corruption by those performing public functions, poor ability of the government to promote and formulate effective regulatory interventions and low freedom of press in a community (61). Lack of supportive and codified laws to reduce the production, supply, distribution and waste management of single-use plastics was also mentioned as a barrier to reducing plastic waste (100). Finally, physical opportunity was also reflected in the availability (or not) of single-use plastic. The ubiquity of plastic packaging was typically found to be a barrier to reducing waste. For example, participants in some studies mentioned the futility of bringing reusable bags when the grocery item is still wrapped in layers of plastic wrapping (64, 113).

On average, physical opportunity had a medium-to-large sized relationship with behaviours related to plastic waste ($r_+ = 0.41$, $k = 3$) (see Table 2.3).

2.4.5.3. Social opportunity

Social opportunity included consideration of social and cultural norms ($n = 11$), manifested as both injunctive (i.e., perceptions of what behaviours are approved or

disapproved by others) and descriptive norms (i.e., perceptions of which behaviours are typically performed). This included pressure to maintain traditional customs (e.g., using woven baskets at the market instead of plastic shopping bags (64)) and pressure to conform to internalised pro-environmental standards for recycling plastic waste items (99, 103, 104, 106, 110, 111), using reusable shopping bags (98), taking single-use shopping bags at checkouts (80) and donating, reusing and reselling plastic items (73). A culture of high plastic consumption and littering posed a barrier to reducing plastic waste (100), while the perception that others recycle prompted recycling (111). The way that the media represents plastic has also been considered ($n = 2$). For example, a lack of media coverage of plastic may influence knowledge and awareness of the outcomes of behaviour (100). Alternatively, modelling how to classify, segregate and handle different types of household waste may increase behaviours that reduce plastic waste (105). Finally, social opportunity includes consideration of social support. For example, the presence of cadres in the community providing counselling in household solid waste reduction were found to promote desirable plastic waste management behaviours such as recycling and upcycling (105).

On average, social opportunity had a small-to-medium sized relationship with behaviours related to plastic waste ($r_+ = 0.22$, $k = 6$, see Table 2.3).

2.4.5.4. Automatic motivation

Automatic motivation included consideration of habit ($n = 6$), both as a barrier and enabler to a range of behaviours related to reducing plastic waste, including using plastic shopping bags (113), recycling plastic items (75, 103, 106), and consumption of plastic packaging (100, 136). Negative affect was also considered to reflect

automatic motivation. For example, people associated guilt with not using reusable shopping bags (137) and sadness with seeing others not recycling their plastic waste (99).

On average, automatic motivation had a medium sized relationship with behaviours related to plastic waste ($r_+ = 0.33$, $k = 6$, see Table 2.3).

2.4.5.5. Reflective motivation

Reflective motivation encompassed a wide range of beliefs, including consideration of attitudes ($n = 6$). For example, positive attitudes towards recycling were associated with subsequent recycling (103, 106, 108) while negative attitudes towards single-use plastic bags were associated with being less likely to use them (80). Positive attitudes towards plastic-waste-management behaviours were also associated with increased donation, reuse and reselling of plastic items (73). Another study found that negative attitudes towards recyclable items and multiple-use carrier bags was associated with great consumption of single-use plastic (100). Six studies also considered participants beliefs about plastic as a material. For example, the perception that recycling is unnecessary (112), and that single use plastic is more hygienic than reusable materials (100) were associated with being more likely to use single-use plastic items. Being less likely to use single-use plastic items was associated with the beliefs that excess waste burdens waste management systems (104) and leads to environmental degradation (107, 111, 139), and that plastic packaging poses health risks (e.g., cancer, chromosomal mutations) and changes the taste of food and drink (100).

Reflective motivation also included perceptions of the difficulty of enacting a behaviour. For example, studies investigated the relationship between perceived

behavioural control and recycling plastic waste items (103, 106), plastic bag use amongst shoppers (62, 80) and reselling, reusing and donating plastic items (73). Other studies did not refer to perceived difficulty as perceived behavioural control but still investigated its relationship with behaviour. For example, perceived obstacles to recycling were found to make it harder to recycle in one study (139), whereas perceived ease made it easier to recycle in another (104). Another study found that participants found it rather difficult to buy products without plastic packaging (136).

Reflective motivation also included consideration of personal moral norms ($n = 7$) – i.e., a sense of obligation based on the individual's personal values – and identity ($n = 3$). In one study, individualistic values were shown to be associated with increased use of plastic single-use shopping bags (97). In other studies, pro-environmental personal moral norms were found to be associated with using less plastic packaging (63) and recycling (103, 104, 106, 111, 139). With respect to identity, studies have found that pro-environmental identity was related to increased recycling (99) and reduced purchase of plastic packaging (136). Reflective motivation also included consideration of perceived sanctions ($n = 3$) and beliefs about responsibility ($n = 3$). For example, if people believe that they will not be heavily sanctioned during a plastic bag ban, then they are more likely to continue using plastic bags (140). They are also less likely to abide by certain behaviours if there are no or minimal sanctions (61, 111). Beliefs regarding whose responsibility it is to reduce plastic waste was also associated with behaviours related to plastic waste. The more people believed that it is corporations' responsibility to reduce plastic waste, the less likely they were to recycle (104) or use reusable bags (98).

Believing that individual households should not be to blame for the waste created by the many was also associated with reduced recycling (139).

Finally, reflective motivation included consideration of people's intentions to engage in behaviours relevant to plastic waste and plans to enact these intentions (n = 8). For example, the strength of participants' intentions to bring their own bags and to reuse bags (114), not to take plastic bags at supermarket checkouts (62, 80, 114), making plans to renounce plastic packaging (63), and having an active interest in recycling (103, 104, 106, 112). The higher the intention, the more likely they were to enact that behaviour.

On average, reflective motivation had a medium sized relationship with behaviours related to plastic waste (r_+ = 0.34, k = 15, see Table 2.3).

2.4.5.6. Publication biases and moderation effects

Contour-enhanced funnel plots for COM-B variables can be found openly available via OSF (https://osf.io/usp8y). Publication biases were not identified (see Table 2.8). Results from moderation analyses can be found openly available via OSF (https://osf.io/9dty4). Age or gender of the sample, year of publication, or the nature of the measure of behaviour (i.e., objective or self-report) was not found to moderate the size of the association between variables associated with plastic waste and behaviour.

2.4.6. Interventions targeting behaviours relating to plastic waste

An overview of the range and frequencies for the intervention types, policy options, targeted COM-B components and BCTs in the primary studies can be found via OSF (https://osf.io/9zcah). The sample weighted average effect size for each intervention type, policy category, BCT and targeted COM-B component can be

found in Table 2.4, Table 2.5, Table 2.6 and Table 2.7 respectively. In the subsequent sections, the letter '*n*' is used to denote the number of primary studies while the letter '*k*' is used to denote the number of independent samples contributing the reported sample-weighted average effect size.

2.4.6.1. Intervention types

The studies used eight of the nine potential types of intervention (i.e., the only type of intervention that was absent was 'training'). The most common types of intervention were 'environmental restructuring' ($n = 16$) and 'coercion' ($n = 14$), followed by 'persuasion' ($n = 7$), 'enablement' ($n = 6$), 'education' / 'incentivisation' ($n = 5$), 'restriction' ($n = 4$) and 'modelling' ($n = 1$).

2.4.6.1.1. Environmental restructuring

These interventions included stocking reusable cups for sale to reduce the number of hot beverages bought in single-use cups in cafes (74); adding bins to promote recycling (79, 85, 115, 118, 129); adding water refill stations to reduce plastic water bottle pollution (77) and implementing recycling schemes/policies (119, 121, 123-125, 133, 135, 139, 141). On average, interventions involving environmental restructuring had a very large effect on behaviours related to plastic waste ($d_+ = 1.31$, $k = 23$, see Table 2.4).

2.4.6.1.2. Coercion

Interventions involving coercion included plastic bag charges (89, 116, 117, 126-128, 131, 134, 138); a 'latte levy (i.e., charging for drinks bought in single-use cups) (74); mandatory recycling policies (117, 135, 139) and; waste handling fees based on volume and/or weight (117, 124, 133, 139). On average, interventions involving

coercion had a large effect on behaviours related to plastic waste ($d_+ = 0.76$, $k = 23$, see Table 2.4).

2.4.6.1.3. Persuasion

Interventions involving persuasion included emotive texts/images depicting plastic pollution (63, 136); motivational/inspirational posters advocating desired behaviour (74); inducing guilt (137); inducing positive or negative attitudes towards a plastic bag policy (78); inducing cognitive dissonance (130); prompting people to commit to the desired target behaviour (130) and; advertising messages framed as 'losses' or 'gains' (62). On average, interventions involving persuasion had a very large effect on behaviours related to plastic waste ($d_+ = 1.15$, $k = 18$, see Table 2.4).

2.4.6.1.4. Enablement

Interventions that provided enablement included distributing free reusable cups/bottles to primary school (132) and university students (74); voice prompts to reduce plastic bag use at supermarkets (80) and visual prompts to promote recycling (85) and; prompting employees to form if-then plans (or implementation intentions (143)) to increase recycling at work (75). On average, interventions involving enablement had a very large effect on behaviours related to plastic waste ($d_+ = 1.69$, $k = 8$, see Table 2.4).

2.4.6.1.5. Education

Interventions classed as 'education' included providing information about the environmental impacts of plastic pollution (132, 136, 141) and information to assist use of a recycling bin (e.g., the types of items that can be placed in the recycling bin) (85, 129). On average, interventions involving education had a very large effect on behaviours related to plastic waste ($d_+ = 1.69$, $k = 8$, see Table 2.4).

2.4.6.1.6. Incentivisation

Interventions involving incentivisation included a 'bottle bill' (i.e., a container deposit law) (135, 139); posters providing feedback on recycling behaviour to boost a student initiative to participate in plastic recycling (129); signs thanking people for recycling (115) and; discounts for buying drinks in reusable cups (74). On average, interventions involving incentivisation had a very large effect on behaviours related to plastic waste ($d_+ = 0.97$, $k = 8$, see Table 2.4).

2.4.6.1.7. Restriction

Interventions involving restriction included plastic bag bans (complete or partial) (120, 122, 126, 140). On average, interventions involving restriction had a small effect on behaviours related to plastic waste ($d_+ = 0.26$, $k = 7$, see Table 2.4).

2.4.6.1.8. Modelling

Interventions involving modelling included providing feedback on desirable recycling behaviour for students to aspire to and imitate (129). On average, interventions involving modelling had a medium-sized effect on behaviours related to plastic waste ($d_+ = 0.54$, $k = 2$, see Table 2.4).

2.4.6.2. Policy options

The interventions developed by the primary studies reflected six of the seven potential policy options identified by the Behaviour Change Wheel (i.e., all except guidelines). 'Fiscal measures', and 'legislation' were the most commonly used ($n =$ 15, $n = 13$ respectively), followed by 'Communications and marketing' ($n = 12$) 'service provision' ($n = 11$), 'environmental and social planning' ($n = 8$), and 'regulation' ($n = 2$).

2.4.6.2.1. Fiscal measures

Fiscal measures included levies for taking bags at supermarket checkouts (89, 116, 117, 126-128, 131, 134, 138); a 'late levy' for buying drinks in a single-use cup (74); a discount for buying drinks in reusable cups (74); a 'bottle bill' (135, 139) and; volume/weight based waste handling fees (117, 124, 133, 139). On average, interventions employing fiscal measures had a large effect on behaviours related to plastic waste ($d_+ = 0.89$, $k = 26$, see Table 2.5).

2.4.6.2.2. Legislation

Legislation included mandatory recycling policies (117, 135, 139); 'bottle bills'(135, 139); laws banning plastic carrier bags (120, 122, 126, 140) and; laws mandating a charge for plastic carrier bags (89, 116, 117, 126, 131, 134, 137, 138). On average, interventions employing legislation had a medium-sized effect on behaviours related to plastic waste ($d_+ = 0.55$, $k = 27$, see Table 2.5).

2.4.6.2.3. Communications and marketing

Communications and marketing included using print media such as motivational posters/signs advocating the desired behaviour (74); educational information on a campaign to reduce plastic waste (132, 136, 141); persuasive/emotive messaging (62, 63, 78, 130, 137); educational information on the types of items that can be recycled (85, 129) and rewarding signs to promote desired behaviour (115). On average, interventions employing legislation had a large effect on behaviours related to plastic waste ($d_+ = 1.00$, $k = 24$, see Table 2.5).

2.4.6.2.4. Service provision

Service provision included implementation of waste management and recycling services (119, 121, 123-125, 133, 139, 141); support for recycling in the

workplace (75) and the distribution of free reusable cups to university students (74) and; reusable water bottles to primary school students (132). On average, interventions providing services had a large effect on behaviours related to plastic waste ($d_+ = 1.64$, $k = 7$, see Table 2.5).

2.4.6.2.5. Environmental and social planning

Environmental and social planning included stocking reusable cups for purchase in cafés (74); implementing water refill stations (77); adding recycling bins within the environment (79, 85, 115, 118, 129) and adding behavioural voice prompts within the environment (80). On average, interventions employing environmental and social planning had a large effect on behaviours related to plastic waste ($d_+ = 1.41$, $k = 21$, see Table 2.5).

2.4.6.2.6. Regulation

Regulation included voluntary plastic bag charges at retailer checkouts without support from legislative frameworks (127, 128). Only one study had quantitative data that could be used for the meta-analysis so the sample weighted average effect size for the effectiveness of interventions employing 'regulation' as a policy category could not reliably be calculated.

2.4.6.3. The effect of specific Behaviour Change Techniques on behaviour

Fifteen of the 93 BCTs in the BCTTv1 (44) were identified at least once in the studies reporting interventions. 'Restructuring the physical environment' and 'punishment' and were the most commonly used BCTs ($n = 16$ and $n = 15$ respectively), followed by 'adding objects to the environment' ($n = 9$), 'information about social and environmental consequences' ($n = 7$) and 'prompts/cues' ($n = 6$). 'Instruction on how to perform the behaviour' was delivered in five studies while

'material incentive (behaviour)' was delivered in four. 'Future punishment' was delivered twice while the other seven BCTs that were employed were each used in just one study each. Table 2.2 depicts examples of how the BCTs were employed within the context of this review. Table 2.6 summarises the results of the meta-analyses examining the effect of the BCTs that were used in two or more studies on behaviours related to plastic waste. Below, only results where the degrees of freedom were greater than four are reported on in text (70).

Table 2.2 Examples of how BCTs were operationalised across the primary studies.

BCTs	***n***	**Examples**
Restructuring the physical environment	16	Plastic bag bans (140)
Punishment	15	Implementing a levy or fee at the point of purchase for plastic shopping bags (89)
Adding objects to the environment	9	Implementing a filtered water refill station (77)
Information about social and environmental consequences	7	Provision of showcards and/or posters with environmental messages about the number of cups ending up in landfill (74)
Prompts/cues	6	"Feel Good for Doing Good" sign affixed to garbage cans to serve as a positive cue to remind individuals to recycle (115)
Instruction on how to perform the behaviour	5	Informative poster aimed at assisting the use of the new eight-compartment plastic recycling bin (129)
Material incentive (behaviour)	4	Bottle deposit laws providing explicit financial incentives to return plastic water bottles in exchange for money (135)
Future punishment	2	Mandatory kerbside recycling policies with risk of fines for non-compliance (139)
Goal setting (behaviour)	1	People in a Parisian supermarket were asked to commit themselves by signing a poster advocating the target behaviour: no use of plastic bags (130)
Action planning	1	Employees of a company had to make implementation intentions where they were asked to plan when, where and how to recycle their old paper and used plastic cups (75)
Commitment	1	People in a Parisian supermarket were asked to commit themselves by signing a poster advocating the target behaviour: no use of plastic bags (130)

Feedback on behaviour	1	A feedback poster showing the recycling rates of all student halls in the intervention to boost student initiative to participate in plastic recycling (129)
Social support (practical)	1	Distribution of free reusable cups to university students and staff (74)
Non-specific incentive	1	A rewarding sign, "Thank You", was also attached to all the recycling bins to reward individuals (115)
Incompatible beliefs	1	People asked to remember past transgressions relating to plastic bag use to arouse cognitive dissonance (130)

Notes: *n* = number of studies.

BCTs with medium-to-large effects included: Providing instructions on how to perform a behaviour (e.g., participants receiving ten pieces of advice on how to reduce their plastic consumption presented with photos (136)) (d_+ = 0.58, k = 7, see Table 2.6), restructuring the physical environment (e.g., plastic bag bans (140)) (d_+ = 0.73, k = 16, see Table 2.6) and punishment (e.g., implementing a levy or fee at the point of purchase for plastic shopping bags (89)) (d_+ = 0.75, k = 23, see Table 2.6). BCTs with very large effects included: Providing a material incentive to change behaviour (e.g., bottle deposit laws providing explicit financial incentives to return plastic water bottles in exchange for money (135)) (d_+ = 1.16, k = 6, see Table 2.6), information on social and environmental consequences (e.g., provision of showcards and/or posters with environmental messages about the number of cups ending up in landfill (74)) (d_+ = 1.17, k = 17, see Table 2.6), prompts/cues (e.g., "Feel Good for Doing Good" sign affixed to garbage cans to serve as a positive cue to remind individuals to recycle (115)) (d_+ = 1.17, k = 20, see Table 2.6) and adding objects to the environment (e.g., implementing a filtered water refill station (77)) (d_+ = 1.33, k = 24, see Table 2.6).

2.4.6.4. Targeted COM-B components

Interventions targeted five of the six components of the COM-B (i.e., all except physical capability). Physical opportunity and automatic motivation were the most commonly targeted components ($n = 20$, $n = 18$ respectively), followed by psychological capability ($n = 8$) and reflective motivation ($n = 6$). Social opportunity was only targeted by one study.

2.4.6.4.1. Targeting psychological capability

Interventions targeting psychological capability included reminders directing attention towards the desired behaviour (e.g. via visual/auditory prompts (80, 115, 129) and colourful recycling bins to increase their saliency (118)); increasing procedural knowledge on how to perform the target behaviour (e.g., providing information on what items can be recycled (85)) and; increasing awareness of campaigns (e.g., via highlighting the consequences of plastic pollution (132, 136, 141)). On average, interventions targeting psychological capability had a small negative effect on behaviours related to plastic waste ($d_+ = -0.28$, $k = 10$, see Table 2.7).

2.4.6.4.2. Targeting physical opportunity

Interventions targeting physical opportunity included increasing the availability of resources (both objects and services) within the physical environment to reduce barriers to the desired target behaviour; for example, distributing free reusable cups/bottles and making them available for purchase (74, 132), adding water refill stations (77) and recycling bins within the environment (79, 85, 115, 118, 129) and increasing availability of local waste management and recycling services (119, 121, 123-125, 133, 139, 141). Interventions targeting physical opportunity also manifested

as decreasing the availability of resources that promote undesired behaviour (e.g., plastic carrier bag bans (120, 122, 126, 140)). On average, interventions targeting physical opportunity had a large effect on behaviours related to plastic waste (d_+ = 1.08, k = 30, see Table 2.7).

2.4.6.4.3. Targeting automatic motivation

Interventions targeting automatic motivation included inducing feelings of guilt (137); reinforcement via feedback on behaviour (129); incentivisation (e.g., via discounts (74) and deposit-return schemes (135, 139)); the prospect of punishment (e.g., additional charges, levies and taxes (74, 89, 116, 117, 124, 126-128, 131, 133, 134, 138, 139)) and sanctions (e.g., a threatened penalty for disobeying the law (117, 120, 126, 140)). On average, interventions targeting automatic motivation opportunity had a large effect on behaviours related to plastic waste (d_+ = 0.77, k = 32, see Table 2.7).

2.4.6.4.4. Targeting reflective motivation

Interventions targeting reflective motivation included arousing cognitive dissonance and encouraging people to commit to the target behaviour (130); increasing pro-environmental attitudes and values (e.g., via motivational posters/messaging (74, 78)) and increasing self-efficacy (e.g., via setting implementation intentions to recycle (75)) and being invited to participate in a challenge to reduce plastic waste (136). Interventions targeting reflective motivation also manifested as targeting personal moral norms and perceived behavioural control (63). On average, interventions targeting reflective motivation had a large effect on behaviours related to plastic waste (d_+ = 1.34, k = 17, see Table 2.7).

2.4.6.4.5. Targeting social opportunity

Interventions targeting social opportunity included targeting people's perceptions of descriptive social norms (i.e., perceptions about how others are recycling to promote recycling behaviour (129)). On average, interventions targeting social opportunity had a medium-sized effect on behaviours related to plastic waste (d_+ = 0.54, k = 2, see Table 2.7). However, the effect size should be interpreted with caution as only two interventions targeted social opportunity.

2.4.6.5. Publication biases and moderation effects

Contour-enhanced funnel plots for each intervention type, policy category, targeted COM-B component and BCT can be found openly via OSF (https://osf.io/avwuq). There was risk publication bias for all intervention types except for 'coercion' and 'enablement', all policy options except for 'legislation' and service provision', all targeted COM-B components and all BCTs except for 'punishment' and 'instruction on how to perform the behaviour' (see Table 2.8). Bias adjusted effect sizes from trim-and-fill analyses ranged from -0.79 to +0.18 (see Table 2.9).

The only variable found to significantly moderate (some) of the effects of interventions on behaviours related to plastic waste, was how the behaviour was measured. The nature of the measure of behaviour significantly and positively impacted effect sizes for interventions targeting 'physical opportunity', the intervention type 'persuasion' and the policy category 'communications and marketing' such that effect sizes were higher when behaviour was objectively measured vs self-reported. Full details on all moderation analyses are available via OSF (https://osf.io/9dty4).

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Table 2.3 Relationships between COM-B factors and plastic waste reducing behaviour.

COM-B factor					95% CI			Heterogeneity	
	k	***o***	***r+***	***SE***	***LL***	***UL***	***t(df)***	**τ^2**	**I^2**
Physical capability									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-
Psychological capability									
Intercept only									
Constant	6	10	0.24	0.05	0.12	0.36	5.18 (4.94)	0.01	80.97
Social opportunity									
Intercept only									
Constant	6	9	0.22	0.06	0.07	0.37	3.88 (4.87)	0.01	81.26
Physical opportunity									
Intercept only									
Constant	3	3	0.41	0.08	0.09	0.79	5.62 (1.91)	0.01	74.09
Automatic motivation									
Intercept only									
Constant	6	6	0.33	0.04	0.23	0.46	8.25 (4.28)	0.01	59.18
Reflective motivation									
Intercept only									
Constant	15	42	0.34	0.04	0.27	0.43	9.10 (14.00)	0.09	97.62

Notes: k = number of independent samples*; o* = number of effect sizes; *r+* = weighted average effect size *r*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of t-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (70), - = insufficient number of effect sizes to conduct meta-analysis.

Table 2.4 Effects of interventions on behaviours related to reducing plastic waste by BCW intervention type.

BCW Intervention Type					95% CI			Heterogeneity	
	k	***o***	***d+***	***SE***	***LL***	***UL***	***t(df)***	**τ^2**	**I^2**
Education									
Intercept only									
Constant	6	13	0.68	0.39	-0.33	1.69	1.72 (5.00)	1.01	94.87
Persuasion									
Intercept only									
Constant	18	21	1.15	0.36	0.38	1.91	3.18 (16.90)	1.46	85.73
Incentivisation									
Intercept only									
Constant	8	15	0.97	0.35	0.13	1.8	2.76 (6.71)	0.53	85.08
Coercion									
Intercept only									
Constant	23	30	0.76	0.15	0.46	1.06	5.20 (21.20)	0.49	86.48
Restriction									
Intercept only									
Constant	7	14	0.26	0.18	-0.19	0.70	1.43 (5.98)	0.19	75.15
Environmental Restructuring									
Intercept only									
Constant	23	37	1.31	0.26	0.78	1.85	5.11 (21.50)	0.82	92.36
Modelling									
Intercept only									
Constant	2	9	0.54	0.42	-4.82	5.90	1.27 (1.00)	0.77	91.24
Enablement									
Intercept only									
Constant	8	8	1.69	0.44	0.64	2.74	3.82 (6.88)	1.19	94.98
Training									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-

Notes: k = number of independent samples*; o* = number of effect sizes; *d+* = weighted average effect size *d*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of t-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (70), - = insufficient number of effect sizes to conduct meta-analysis.

Table 2.5 Effects of interventions on behaviours related to reducing plastic waste by BCW policy options.

BCW Policy Option					95% CI			Heterogeneity	
	k	***o***	d_+	***SE***	***LL***	***UL***	***t(df)***	τ^2	I^2
Fiscal Measures									
Intercept only									
Constant	26	32	0.89	0.16	0.55	1.22	5.70 (24.30)	0.51	87.12
Legislation									
Intercept only									
Constant	27	36	0.55	0.11	0.32	0.78	4.88 (25.20)	0.29	81.82
Communications and marketing									
Intercept only									
Constant	24	34	1.00	.028	0.43	1.56	3.63 (22.70)	1.09	89.84
Service provision									
Intercept only									
Constant	7	7	1.64	0.61	0.14	3.14	2.68 (5.92)	2.08	91.67
Environmental and social planning									
Intercept only									
Constant	21	34	1.41	0.27	0.84	1.97	5.19 (19.50)	0.87	94.06
Regulation									
Intercept only									
Constant	1	3	-	-	-	-	-	-	-
Guidelines									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-

*Note*s: *k* = number of independent samples*; o* = number of effect sizes; d_+ = weighted average effect size *d*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of t-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (70), - = insufficient number of effect sizes to conduct meta-analysis.

Table 2.6 Effects of interventions on behaviours related to reducing plastic waste by Behaviour Change Techniques (BCTs) from the BCTTv1.

Behaviour Change Techniques					**95% CI**			**Heterogeneity**	
	k	***o***	***d_+***	***SE***	***LL***	***UL***	***t(df)***	**τ^2**	**I^2**
Goal setting (behaviour)									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-
Action planning									
Intercept only									
Constant	2	2	0.95	0.53	-5.83	7.72	1.77 (1.00)	0.42	72.73
Commitment									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-
Feedback on behaviour									
Intercept only									
Constant	2	9	0.54	0.42	-4.82	5.90	1.27 (1.00)	0.77	91.24
Social support (practical)									
Intercept only									
Constant	4	4	2.30	0.83	-0.33	4.93	2.7 9 (3.00)	2.22	85.72
Instruction on how to perform behaviour									
Intercept only									
Constant	7	14	0.58	0.34	-0.29	1.45	1.63 (5.98)	1.00	94.19
Info. about social and environmental consequences									
Intercept only Constant	17	17	1.17	0.39	0.33	2.00	2.97 (15.9)	1.71	88.08
Prompts/cues									
Intercept only									
Constant	20	27	1.19	0.31	0.55	1.84	3.88 (18.6)	0.98	91.70

Material incentive (behaviour)									
Intercept only									
Constant	6	6	1.16	0.54	-0.24	2.56	2.14 (4.89)	0.84	85.43
Non-specific incentive									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-
Future punishment									
Intercept only									
Constant	2	2	0.54	0.05	-0.08	1.16	11.00(1.00)	0	0
Restructuring the physical environment									
Intercept only									
Constant	16	24	0.73	0.21	0.28	1.18	3.45(15.00)	0.77	93.87
Adding objects to the environment									
Intercept only									
Constant	24	35	1.33	0.25	0.81	1.85	5.33(22.40)	0.82	91.61
Incompatible beliefs									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-
Punishment									
Intercept only									
Constant	23	29	0.75	0.15	0.44	1.05	5.03(21.50)	0.45	86.87

Notes: k = number of independent samples*; o* = number of effect sizes; *d+* = weighted average effect size *d*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of t-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (70) , - = insufficient number of effect sizes to conduct meta-analysis.

Table 2.7 Effects of interventions on behaviours related to reducing plastic waste by targeted COM-B variables.

Targeted COM-B factor					**95% CI**			**Heterogeneity**	
	k	***o***	***d+***	***SE***	***LL***	***UL***	***t(df)***	**τ^2**	**I^2**
Physical capability									
Intercept only									
Constant	-	-	-	-	-	-	-	-	-
Psychological capability									
Intercept only									
Constant	10	17	-0.28	0.28	-0.92	0.35	-1.01 (9.00)	0.82	94.77
Social opportunity									
Intercept only									
Constant	2	9	0.54	0.42	-4.82	5.90	1.27 (1.00)	0.77	91.24
Physical opportunity									
Intercept only									
Constant	30	48	1.08	0.22	0.64	1.53	4.99 (28.50)	0.91	92.76
Automatic motivation									
Intercept only									
Constant	32	48	0.77	0.14	0.49	1.05	5.66 (30.10)	0.45	85.72
Reflective motivation									
Intercept only									
Constant	17	19	1.34	0.37	0.55	2.12	3.61 (15.90)	1.53	85.49

Notes: k = number of independent samples*; o* = number of effect sizes; *d+* = weighted average effect size *d*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of t-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (70), - = insufficient number of effect sizes to conduct meta-analysis.

Table 2.8 Results from tests of publication bias.

	Failsafe N	Egger's regression		PET using RVE		
COM-B factor	(5n +10)	*z*	*p*	*B*	95% CI	*df*
Psychological capability	544	1.06	.29	6.15	-80.16-92.47	2.64
Social opportunity	480	0.06	.95	-10.87	-65.96-44.23	2.43
Physical opportunity	406	-0.37	.71	-12.56	-278.53-253.40	1.00
Automatic motivation	338	-0.53	.59	-6.59	-73.48-60.30	2.13
Reflective motivation	45,954	-0.59	.56	-15.34	-49.14-18.45	9.48
BCW intervention type						
Education	335	-2.26	**.02***	-24.84	-72.78-23.10	2.37
Persuasion	169	5.50	**<.001*****	**10.2****	5.85-14.62	6.37
Incentivisation	161	3.72	**<.001*****	6.14	-2.84-15.13	2.49
Coercion	1413	1.17	.24	1.67	-1.94-5.28	3.57
Restriction	**29**[a]	1.85	.06	15.30	-43.34-73.95	1.84
Environmental restructuring	7279	2.13	**.03***	**4.34***	0.72-7.96	9.02
Modelling	**40**[a]	2.05	**.04***	160.13	-304.3-625	1.00
Enablement	255	1.95	.05	4.67	-1.67-11.00	3.90
BCW policy option						
Fiscal measures	1688	2.45	**.01***	4.07	-0.05-8.18	8.79
Legislation	968	0.98	.33	1.32	-1.43-4.062	10.8

Communications & marketing	1160	3.42	**<.001*** **	**6.09****	1.94-10.236	10.9
Service provision	93	1.20	.23	2.03	-12.41-16.47	1.91
Environmental & social planning	5850	2.23	**.03***	**4.3***	0.78-7.72	2.75
Regulation	-	-	-	-	-	-
Targeted COM-B variable						
Psychological capability	**39[a]**	0.92	.36	3.37	-18.60-25.35	1.90
Social opportunity	**40[a]**	2.06	**.04***	160.13	-304.30-625.00	1.00
Physical opportunity	7294	3.12	**.002****	**4.31***	0.84-7.79	10.00
Automatic motivation	2708	2.76	**.006****	3.97	-0.01-7.94	9.41
Reflective motivation	256	4.91	**<.001*** **	**10.50****	5.26-15.73	5.15
Behaviour Change Technique						
Goal setting (behaviour)	-	-	-	-	-	-
Action planning	**3[a]**	-	-	-	-	-
Commitment	-	-	-	-	-	-
Feedback on behaviour	40	2.06	**.04***	160.13	-304.30-625.00	1.00
Social support (practical)	44	4.56	**<.001*** **	**16.52***	7.96-25.07	1.69
Instruction on how to perform the behaviour	351	-1.88	.06	-9.58	-48.47-29.30	1.66
Information about social and environmental consequences	114	5.50	**<.001*** **	**10.37*****	6.49-14.24	6.25
Prompts/cues	966	3.42	**<.001*** **	**5.45***	1.57-9.33	10.07

Material incentive (behaviour)	35	2.51	**0.01***	7.03	-4.31-18.37	2.38
Non-specific incentive	-	-	-	-	-	-
Future punishment	**3[a]**	-	**-**	**-**	-	-
Restructuring the physical environment	1617	-2.22	**0.03***	-15.91	-34.70-2.88	6.62
Adding objects to the environment	6769	2.08	**0.04***	**3.82***	0.24-7.39	12.00
Incompatible beliefs	-	-	-	-	-	-
Punishment	1308	1.10	0.27	2.51	-2.17-7.19	8.09

Notes: a = Failsafe N does not exceed Rosenberg's critical value; significance codes: $p < .001$ ***, $p < .01$ **, $p < .05$ *; *B* = unstandardized beta coefficient; 95% CI = the 95% confidence intervals; PET = Precision Effect Test; RVE = robust variance estimation. A significant PET and/or *z*-value in the Egger's regression test indicates risk of bias (Egger et al., 1997). Tests of Failsafe N and Egger's regression were conducted using meta-analytic random/mixed-effects models, whereas PET was conducted using RVE; *df* = degrees of freedom, *df*s < 4 should be treated with caution (70), - = insufficient number of effect sizes to conduct meta-analysis.

Table 2.9 Effect sizes as a function of different interventions following correction for publication bias.

	Trim-and-fill					PEESE using RVE		
BCW intervention type	Observed *o*	Unadj. *d+*	Imputed *o*	Adj. *d+*	Change	*B*	95% CI	*df*
Education	13	0.68	0	0.51	-0.17	-170.02	-674.83-334.79	2.06
Persuasion	21	1.15	0	1.01	-0.14	**17.40*** **	13.55-21.25	5.22
Incentivisation	15	0.97	0	0.69	-0.28	13.31	-2.89-29.50	1.65
Coercion	30	0.76	0	0.78	+0.02	2.51	-17.48-22.70	1.37
Restriction	14	0.26	2	0.17	-0.09	98.51	-355.74-552.76	1.72
Environmental restructuring	37	1.31	0	1.14	-0.17	**11.06** **	6.23-15.89	5.15
Modelling	9	0.54	0	0.40	-0.14	1195.40	-2271.3-4662.1	1.00
Enablement	8	1.69	0	1.71	+0.02	11.31	-1.20-23.82	2.38
BCW policy option								
Fiscal measures	32	0.89	0	0.90	+0.01	**11.54***	2.54-20.54	3.13
Legislation	36	0.55	9	0.27	-0.28	5.09	-4.44-14.62	8.72
Comms & marketing	34	1.00	0	0.21	-0.79	**14.31*** **	9.23-19.38	6.00
Service provision	7	1.64	0	1.65	+0.01	0.95	-24.53-26.43	1.41
Env & social planning	34	1.41	0	1.18	-0.23	**10.82** **	6.03-15.61	5.72
Regulation	-	-	-	-	-	-	-	-
Targeted COM-B variable								

Psychological capability	17	-0.28	5	-0.39	-0.11	6.91	-142.51-156.34	0.78
Social opportunity	9	0.54	0	0.40	-0.14	1195.40	-2271.3-4662.1	1.00
Physical opportunity	48	1.08	0	0.93	-015	**9.84***	3.00-16.69	6.36
Automatic motivation	48	0.77	0	0.70	-0.07	**11.60***	2.92-20.29	3.24
Reflective motivation	19	1.34	0	1.22	-0.12	**17.43*****	13.26-21.60	4.67
Behaviour Change Technique								
Feedback on behaviour	9	0.54	0	0.40	-0.14	1195.40	-2271.3-4662.1	1.00
Social support (practical)	4	2.30	0	2.31	+0.01	**20.50***	2.87-38.13	1.65
Instruction on how to perform the behaviour	14	0.58	0	0.47	-0.11	-29.65	-263.78-204.48	1.38
Information about social and environmental consequences	17	1.17	0	1.19	-0.02	**18.05*****	14.46-21.64	5.26
Prompts/cues	27	1.19	0	0.99	-0.20	**13.48*****	8.10-18.85	5.95
Material incentive (behaviour)	6	1.16	0	1.23	+0.07	13.97	-3.02-30.96	1.69
Restructuring the physical environment	24	0.73	0	0.91	+0.18	-95.27	-257.18-66.64	4.78
Adding objects to the environment	35	1.33	0	1.21	-0.12	**10.58****	5.17-16.03	6.06
Punishment	29	0.75	0	0.78	+0.03	9.29	-7.86-26.45	3.18

Notes: Significance codes: $p < .001$ ***, $p < .01$ **, $p < .05$ * Observed *o* = number of aggregated effect sizes included in analyses; Unadj. *d+* = unadjusted effect size estimate; Imputed *o* = number of additional effect sizes added by trim-and-fill analyses; effect sizes added by trim-and-fill analyses; Adj. *d+* = adjusted effect size estimate (i.e., including imputed studies); PEESE = precision effect estimates with standard error; *B* = unstandardized beta coefficient; 95% CI = the 95% confidence intervals. Tests of Trim-and-fill were conducted using meta-analytic random/mixed-effects models, whereas PEESE was conducted using RVE), - = insufficient number of effect sizes to conduct meta-analysis.

2.5. Discussion

This review aimed to identify behaviours associated with plastic waste (either contributing to waste or reducing waste) that have been investigated within the scientific literature, along with the variables that are associated with these behaviours, and the interventions that are most effective at changing these behaviours. To achieve these aims, the review organised and synthesised existing research relating to plastic waste using the AACTT (i.e., action, actor, context, target, time) framework to describe the behaviours that have been investigated, the COM-B model to describe the factors that have been investigated as potentially associated with behaviour, and the BCW to identify the types of intervention and policy options along with the COM-B components that the interventions targeted. BCTs that have been used to modify these behaviours were identified using BCTTv1. Meta-analysis was used to estimate: a) the strength and direction of the association between COM-B variables and behaviour and; b) the effect of different interventions and intervention components on behaviour. The review identified 60 studies, of which 33 were eligible for inclusion in the meta-analyses. The subsequent sections discuss the main findings, their theoretical and practical significance, and identify further avenues for research.

2.5.1. Behaviours related to plastic waste

Recycling was the most commonly specified action for reducing plastic waste, the general public was the most commonly specified actor, and in-person shopping was the most commonly studied context. The only plastic waste-related items specified in the primary studies were related to packaging i.e., shopping bags, cups and water bottles; otherwise, studies focused on unspecified, generic plastic waste.

As plastic waste is the result of multiple behaviours from multiple actors across various contexts, empirical investigation into a wider range of actions, actors and contexts is likely to be needed to make progress in this space. For example, while recycling is important, there is a consensus that focusing on waste prevention strategies is more optimal than waste processing strategies, exemplified by the EU waste hierarchy, which prioritises waste management options in terms of resource efficiency (25). For example, repair can prevent waste (144) as can reuse (145). They represent some of the most energy-efficient ways to reduce waste from single-use packaging materials, after eliminating their use (25). However, behaviours relating to reuse or repair are rarely studied and so less is known about peoples' engagement with them or interventions to promote them (146).

'Individualising' behaviour, through a focus on the general public's consumption, can also shift focus away from the socioeconomic and commercial drivers of plastic waste behaviours. Because the actions of businesses and governments shape the social, economic and environmental contexts within which citizens interact (147), behaviour change research should explore the behaviour of a wider range of actors including those of government and industry.

In addition, behaviour is involved across all stages of the plastic lifecycle; there is a missed opportunity to understand the behaviours of people who are involved with managing plastic post-use. For instance, no studies investigating the behaviour of waste collectors were identified when this group of people play a critical role in ensuring plastic waste gets appropriately managed and diverted to recycling facilities. There is also a need for research investigating plastic waste-related

behaviours in the context of online environments. This is particularly important given the rise in the use of online shopping and food delivery services (148, 149).

2.5.2. Variables associated with behaviours related to plastic waste

All identified COM-B variables had medium-strength associations with behaviour, although more data is required to draw conclusions about the impact of 'physical opportunity'. 'Reflective motivation' had the strongest association with behaviour followed by 'automatic motivation'. This is unsurprising as waste management behaviours, and specifically recycling (which constituted the majority of the target behaviours studied), are often habitual and emotionally- and morally-significant behaviours (150-154). 'Psychological capability' and 'social opportunity' had the weakest associations with behaviour. This could be explained by waste management behaviours, and particularly recycling, being comparatively less socially influenced behaviours than other environmentally-significant behaviours, such as dietary behaviours (155, 156). The study findings support the notion that while knowledge and awareness are associated with behaviour, they are neither sufficient nor the strongest drivers of behaviour. The findings also demonstrate that a combination of capability, opportunity and motivation are required to enact behaviour, suggesting that holistic approaches are needed for intervention design.

2.5.3. Interventions targeting behaviours related to plastic waste

The intervention types associated with the strongest changes in behaviour were 'persuasion', 'enablement' and 'environmental restructuring'. The policy options associated with the strongest changes in behaviour were 'communications and marketing', 'environmental and social planning' and 'service provision'. Interventions targeting 'psychological capability' had an overall negative effect on plastic waste-

reducing behaviours while targeting ‘physical opportunity’ and ‘reflective motivation’ had the strongest positive effects. All identified BCTs had medium to large effects on changing behaviour.

The approach that behaviour change is about ‘getting the message across’ or providing knowledge and information has been identified as two of the main errors that policymakers make (147). The findings show that citizens must have not only the capability but also the motivation and opportunity to adopt behaviours that reduce plastic waste – indeed, interventions targeting psychological capability typically had a negative effect on behaviours that reduce plastic waste. This further suggests that interventions should consider all of these factors simultaneously, rather than focusing only on providing information.

It may be more effective to provide information in tandem with persuading people to identify with and feel part of a pro-environmental movement (e.g., by creating positive feelings, attitudes and norms towards behaviours that reduce plastic waste and vice versa for behaviours that produce plastic waste). Strategies that restructure physical and social environments to make desirable behaviours easier and more enjoyable are also likely to be effective (e.g., by restricting access to single-use products through levies and bans and providing efficient, convenient, attractive and affordable (ideally free) products and services). Indeed, the intervention types and policy options that were associated with the strongest changes in behaviour were related to providing support, persuasion and changing physical contexts.

While all identified BCTs were associated with positive changes in behaviour, it is important to note that only a narrow number were employed across the interventions;

future efforts may wish to explore a wider range of intervention strategies following a detailed analysis of that behaviour in its context.

2.5.4. Strengths and limitations

This review's global scope strengthens the potential for generalising findings across national contexts. However, the limited range of behaviours examined in the primary studies suggests that their findings may not apply to all types of plastic waste-related behaviours (e.g., reuse) and products (e.g., absorbent hygiene products).

While prior evidence reviews have been conducted (65), this is the first review to use behaviour change theory to categorise the nature of interventions designed to reduce plastic waste and use meta-analysis to quantify the effect of intervention types, components, and strategies on behaviours related to plastic waste. In many cases, however, this approach represents a 'post-hoc' application of theory to understand interventions that were not informed by theory. Evidence suggests that explicit application of theory can improve intervention design, facilitate the evaluation of intervention effectiveness, and enhance learning within health behaviour change contexts (157); for a review see (158). It is therefore suggested that behaviour change theory could be used to inform the design of interventions targeting plastic waste. This study also highlights clear evidence gaps which, alongside the development of open-access coding manuals, can be used to guide future research efforts.

Potential issues relating to the breadth of the COM-B model as a meta-analytic framework were identified. 'Reflective motivation' refers to a broad category of behavioural influences that could pertain to beliefs, identity, goals or intentions.

While the complimentary narrative synthesis provided richness and context to the meta-analytic findings, using a more granular framework, such as TDF, as a meta-analytic framework may have allowed for conclusions about factors associated with behaviour being made at a more specific level. This is potentially more useful for intervention design, giving clearer instruction to intervention designers on what to target. Particularly for the broader COM-B categories e.g., 'reflective motivation', an option could be to also code data to TDF domains and include them in analyses as potential moderators of the influence of COM-B variables. Although this was not possible in the present study due to a lack of data, it is something to consider in future studies where there is more evidence available.

Many target behaviours and interventions were poorly described which hindered the ability to extract and code study components. This is an issue that has been raised by other behavioural scientists (159-162). Poor behavioural specification is problematic as it prevents understanding exactly what is being targeted, investigated and measured. To improve evidence synthesis, better reporting of target behaviours is required.

Some sub-group meta-analyses were also not able to be computed due to a lack of data, limiting the conclusiveness of study findings. For example, no data on the potential effectiveness of some of the BCW policy options (i.e., guidelines), intervention types (i.e., training) and most BCTs from the BCTTv1were identified as they have not yet been studied concerning their effects on behaviours related to plastic waste. In addition, many interventions were multi-faceted, involving multiple intervention types and policy options and targeting several COM-B components.

Factorial designs would help to disentangle the effect of intervention components from each other.

Another limitation is that the effects of some of the interventions may have been confounded with the target behaviour being investigated. For example, the sample-weighted average effect size for the intervention type 'restriction', which consisted of partial or complete plastic bag bans, was unexpectedly low when compared with the other types of intervention. The bans were likely more effective at changing single-use plastic bag use, but less effective at changing behaviour relating to bringing one's bags to the supermarket. Restriction laws are also only as effective as their perceived enforcement (140). The meta-analysis was unable to take these potential contextual moderating variables into account.

2.5.5. Recommendations

Recommendations for research include investigating a broader range of actors, actions and contexts in line with real-world circular economy transition needs e.g., focussing research efforts on higher-priority resource-efficient behaviours such as reuse and repair (over recycling). Behavioural science research in this area is also likely to benefit from taking a more 'systems' approach i.e., approaching the issue of waste as a complex behavioural system involving multiple actors interacting with plastic across the material lifecycle. Behavioural systems mapping, an emerging behaviour change science methodology (163), may be an effective tool for this exercise as it allows researchers to visualise the relevant actors, contexts and actions to a behavioural problem. Visualising a problem in this way may help to identify actors and their behaviours that might not otherwise have been prioritised for

research. It is also recommended that behaviours and interventions are better reported to allow for better evidence synthesis.

Policy recommendations include taking into account the influence people's material and social environments have in directing their behaviours. It is important to ensure that policies provide structural (and material) support so that the desired behaviour is as attractive, easy, affordable and accessible as possible. It is important to minimise the risks of isolating people and widening existing inequalities during circular transitions.

Recommendations for practice include taking systematic approaches to intervention design e.g., by using frameworks such as the BCW which allows designers to consider a wide range of possible intervention options before settling on a strategy. Doing so may result in evidence on a wider range specific BCTs becoming available which, in turn, advances behaviour change science.

2.6. Conclusion

Human behaviour is at the heart of the plastic waste problem. This review provides a first step towards identifying relevant behaviours, the factors associated with these behaviours, and interventions that are most likely to be effective at changing behaviour. The headline conclusions are that a wider range of 'higher priority' resource-efficient behaviours warrant scientific investigation. A combination of capability, opportunity and motivation is needed to promote behaviours that reduce plastic waste and prevent behaviours that generate plastic waste. Targeting knowledge and awareness is not sufficient as a behaviour change strategy in this area. Interventions involving 'persuasion', 'enablement' and 'environmental restructuring' are likely to promote behaviours that reduce plastic waste with techniques such as 'information about social and environmental consequences'; 'prompts and cues', 'material incentive (behaviour)' and 'adding objects to the environment'. These findings can inform the design of future and refinement of current interventions and policies in this context. It is also suggested that future research investigate a wider range of actions, actors and contexts to advance scientific understanding and effective applications to reduce plastic waste and echo calls for systematic, transparent and specific reporting of target behaviours and interventions to strengthen evidence in this area.

3. Chapter 3 – Barriers and enablers to compostable plastic packaging purchase: a qualitative study amongst UK citizens (Study 2)

3.1. Abstract

Background: Compostable plastics have the potential to reduce plastic waste. However, as a relatively new option on the market, people's views, attitudes and current behaviour relating to this packaging type remain under-investigated.

Aims: This study aims to identify the barriers and enablers to compostable plastic purchase amongst UK citizens.

Method: Using data from The Big Compost Experiment citizen science project, 610 open-ended survey responses to a question exploring reasons for compostable plastic packaging purchase were thematically analysed. Themes were categorised as barriers and enablers and according to the components of the Capability, Opportunity, Motivation, and Behaviour (COM-B) model of behaviour.

Results: Key barriers to purchase concerned: psychological capability (not understanding terminology used to label packaging, not taking notice of packaging, and preferring other types of packaging and product qualities); reflective motivation (negative beliefs about compostable plastic packaging's environmental impacts and scepticism over decomposition claims), and physical opportunity (no access to appropriate waste management). Key enablers to purchase concerned: reflective motivation (positive beliefs about compostable plastic packaging's environmental impact and resolve to behave pro-environmentally) and physical opportunity (access to appropriate waste management).

Conclusions: Reducing ambiguity concerning the labels used to describe compostable plastic packaging is likely to promote their purchase. Interventions should therefore improve information about the source of the packaging material, how the packaging waste is processed, and how to dispose of the packaging. This is also likely to promote correct disposal of these items via increasing knowledge of disposal instructions, provided the correct waste management infrastructure is available.

3.2. Background

Packaging represents the largest end-use market of plastic and is the dominant generator of plastic waste (1, 164). Innovations within the packaging industry are, therefore, an avenue to reducing waste from single-use plastics. Compostable plastic packaging is one such example. This qualitative study is the second study in this thesis and aims to investigate the influences on buying compostable plastic packaging. A version of the work presented in this chapter has been published in the journal Sustainability (48).

Chapters 1 and 2 mention how reusable alternatives represent the most energy-efficient way to reduce waste from single-use packaging materials after eliminating their use (25). However, reducing or reusing materials is not always feasible, especially for products that require flexible and semi-flexible plastic packaging (e.g., bags, pouches and films, tubes), which makes up approximately 17% of all plastic packaging placed on the market (165). Chapter 1 highlights how plastic packaging enables food safety (e.g., facilitating clean drinking water), hygiene (e.g., keeping medical equipment sanitary) and reducing the emissions associated with other types of waste (e.g., food waste) or transport (e.g., reducing packaging weight during transportation). An additional challenge with conventional flexible and semi-flexible plastic packaging is that it is currently technically difficult to recycle mechanically, and therefore not economically viable (166). Compostable plastics offer a potential solution to minimising waste from single-use plastic packaging, particularly where reusable or mechanically recyclable materials are impractical. This is important within flexible plastic packaging applications, as compostable plastic packaging

represents an opportunity to reduce plastic waste without compromising on safety or the operations of supply chains.

While there is a growing body of technical research concerning compostable plastics, including investigations into their degradation processes (167, 168) and life cycle assessments (169, 170), little is known about people's *behaviours* concerning this material. As highlighted in Chapter 1, human behaviour is an integral part of 'closing the loop' in the circular economy of plastics, as people interact with plastic packaging through buying, using, reusing and initiating its disposal pathway at end-of-life. To improve policies and intervention efforts to promote the adoption (i.e., purchase) and recycling (e.g., via local food waste collection services) of compostable plastics, it is necessary to understand the patterning of these behaviours in the variety of contexts in which they occur, and the influences on these behaviours.

A study in Italy showed that people preferred plastic water bottles derived from 'biobased' products to traditional fossil-based polyethylene terephthalate (PET) plastic bottles, and were willing to pay a premium for them (171). A subsequent international study partially contradicted these findings; while participants were shown to generally have positive attitudes towards bio-based plastic products, they were unsure whether they would buy these products if they were expensive (172). A UK study found that while people felt positively towards biodegradable and compostable plastics, they had little knowledge of them (173). Similar results were reported by a more recent survey of Australian citizens, who also demonstrated a lack of knowledge relating to biodegradable plastic and incorrect disposal of them in the recycling bin (174). These findings are consistent with an experimental study in

Germany investigating the rate of correct disposal for ‘biobased’ plastic water bottles (which were also compostable) vs. traditional fossil-based plastic water bottles (50). German citizens reported positive attitudes towards bio-based plastic water bottles, but frequently disposed of them incorrectly (i.e., in the recycling bin, which was the wrong bin in that context), thus undermining their environmental benefits. Similar results were reported in a study in the Netherlands comparing disposal decisions for ‘bioplastic’ cups and traditional fossil-based plastic cups; people tended to dispose of the ‘bioplastic’ cups in the recycling bin meant for traditional fossil-based plastic materials (49). While these studies provide important information about the potential opportunities and challenges posed by biodegradable and compostable plastics, they do not draw on behavioural theory, thus limiting their utility for designing interventions.

The terms ‘bioplastic’, ‘compostable’, ‘bio-based’ and ‘biodegradable’ are often used interchangeably making it challenging to make sense of and accumulate the evidence. The terms have distinct meanings and nuanced differences. The present thesis defines these terms in line with European Bioplastic’s definition of bioplastics (175) and the EU’s definitions of compostable, biobased and biodegradable plastics (176, 177). As summarised in Table 3.1. ‘bioplastic’ comprises a whole family of materials with different properties and applications.

Table 3.1 Definitions for bioplastic, biobased, biodegradable and compostable plastic.

Term	Definition	Source
Bioplastic	Plastic material is defined as bioplastic if it is either biobased, biodegradable, or features both properties.	(175)
Biobased	Biobased plastics are fully or partially made from biological resources, rather than fossil raw materials. They are not necessarily biodegradable or compostable.	(177)
Biodegradable	Biodegradable plastics biodegrade in certain conditions at their end of life. Biodegradable plastics may be made from biological resources or fossil raw materials.	(177)
Compostable	Compostable plastics are a subset of biodegradable ones and typically decompose in industrial composting facilities, and first need to be collected. Compostable plastics may be made from biological resources or fossil raw materials.	(177)

The term ‘biobased’ is a descriptor relating to the start of the lifecycle – how the materials for making the plastic were sourced. Bio-based plastics are fully or partially made from biological resources, rather than fossil raw materials. Bio-based plastics

are not necessarily biodegradable or compostable, terms which refer to how the material degrades at its end of life. The main difference between 'biodegradable' and 'compostable' in the context of plastic is that biodegradable plastic can take an undetermined time to break down. In contrast, compostable plastic must degrade, within a given timeframe, under specified composting conditions. There exist various nationally and internationally accredited certifications assessing the credentials of compostable packaging (see Section 5.2.2 of Chapter 5).

As highlighted in Chapter 1, this thesis is underpinned by a multi-faceted 'systems' approach to investigating behaviour concerning plastic waste. As such, the studies reported in this thesis are concerned with behaviour relating to 'compostable' plastic packaging and this term is used throughout; the term 'compostable' refers to a specific type of material that needs to be managed through specific routes and thus allocates a clearer role to UK citizens as people responsible for sorting and disposing of waste through specific compostable waste management routes e.g., local food waste collection services.

As a first step towards better understanding UK citizens' behaviour in relation to compostable plastic packaging, Study 2 aims to identify the barriers and enablers to compostable plastic packaging purchase, the initial behaviour in a chain of behaviours of people interacting with this type of packaging. Disposal of compostable plastic packaging is investigated in Studies 3, 4 and 5 of this thesis. This study addressed the research question: what are the barriers and enablers, in terms of capability, opportunity, and motivation (components of the COM-B model outlined in Chapter 1), to buying compostable plastic packaging?

3.3. Method

3.3.1. Design

This was a cross-sectional survey study.

3.3.2. Dataset: The Big Compost Experiment

The dataset for this study came from a wider UK citizen science project, The Big Compost Experiment (178). This citizen science project aims to assess the performance of plastics currently marketed in the UK as home-compostable within home-composts. Describing citizen science as a research method is beyond the scope of this thesis; details on this can be found elsewhere (179, 180).

The Big Compost Experiment was designed by researchers at UCL's Plastic Waste Innovation Hub (181) and was launched on November 7th, 2019. It consists of a publicly accessible website containing a short online survey regarding current composting practices, compostable plastic purchasing behaviour, and an optional compostable plastic home composting experiment. Further details and the two-year results from the Big Compost Experiment have been published in the journal Frontiers in Sustainability (182). The author of this thesis (ALA) led the qualitative analysis of survey data.

3.3.3. Participants and recruitment

Study participants consisted of adults, aged 18 and above, within the general UK population, across all regions. Demographic information about survey respondents was not collected to protect anonymity. The project was advertised via the following channels: email (including UCL-affiliated mailing lists), social media (including the UCL Plastic Waste Innovation Hub's professional social media networks), interviews on national and regional radio (including BBC Radio 4 Inside Science, Cambridge

105), articles in national charity and organisation magazines (including Science World, National Allotment Society, and Garden Organic), and public outreach events within London (including the 2019 Bloomsbury Festival). Prospective participants were directed to The Big Compost Experiment website containing the survey link.

3.3.4. Measures

The survey is openly available via OSF (https://osf.io/y9uwt). For the present study, the responses to the first question within the larger survey were of interest: "Are you more likely to buy products with packaging marked 'compostable' or 'biodegradable'?". Participants had options of answering 'yes', 'no', or 'I don't know', and were asked to provide a reason for their answer in free text form.

The term 'biodegradable' was included in the survey question as this is a common term used to label compostable plastic packaging in the UK. A decision to engage the UK public and canvas the widest range of views, thoughts and perceptions was prioritised over technical accuracy.

3.3.5. Procedure

Ethical approval was received from UCL (Project ID/Title: 16747/001: Big Compost Experiment). The survey was accessed via an online web link and took approximately five minutes to complete. Participants were asked to provide informed consent before completing the survey and were given a link to the study information sheet. They were then invited to take part in an optional home composting experiment, where they could create a profile and upload photos tracking the degradation process of compostable plastic packaging in their composters.

3.3.6. Data analysis

The Big Compost Experiment ran from November 2019 to August 2023. The study reported in this chapter analyses pre-COVID-19, cross-sectional survey responses collected from November 2019 to March 2020. The dataset analysed in this study is openly available via OSF at https://osf.io/smzh9. Data were analysed within Excel.

An inductive approach to analysis was first taken, followed by deductive theory-based analysis as a second step. For the inductive analysis, a thematic analysis (183) on 200 random free text responses from 'yes' responders, 205 free text responses from 'no' responders, and 205 free text responses from 'I don't know' responders to the question: "Are you more likely to buy products with packaging marked 'compostable' or 'biodegradable'?" was conducted. Respondents who did not provide a complete answer to this item were excluded from the analysis.

For the deductive theory-based analysis, the COM-B model, outlined in Chapter 1, was used as a data analysis framework to organise emergent themes as behavioural influences related to capability, opportunity, and motivation. As shown in Figure 3.1, the analysis was conducted in the following steps:

1. **Familiarisation with the data.** This involved reading all survey responses and noting any recurring patterns.
2. **Generation of initial codes to indicate themes**. As responses were assigned codes, a coding framework detailing code labels and definitions was developed and revised iteratively to help guide subsequent coding.
3. **Search for themes.** This involved organising codes into a tentative set of candidate themes.

4. **Review of themes.** This step involved a back-and-forth process of revisiting the raw survey responses and coding framework to update the names, descriptions, and definitions of candidate themes.
5. **Mapping of emergent themes onto COM-B categories of barriers and enablers.** A theme qualified as a barrier if it deterred the purchasing of compostable plastics, as an enabler if it promoted it, and as mixed if it could do both. Theme labels and their categorisation into COM-B components were reviewed by the lead author's tertiary supervisor (FL), upon which the appropriate revisions were made.
6. **Assignation of names and definitions for themes**. This involved finalising the name, definition, description, and example quotes for each theme. The coding framework, available via OSF (https://osf.io/bk9sh), shows each theme's names, definitions, descriptions, and example quotes grouped according to those who said they were more likely, unlikely, or unsure whether they would buy compostable plastic packaging.
7. **Production of the report**. This involved writing up the analysis with feedback from the author's supervisory team.

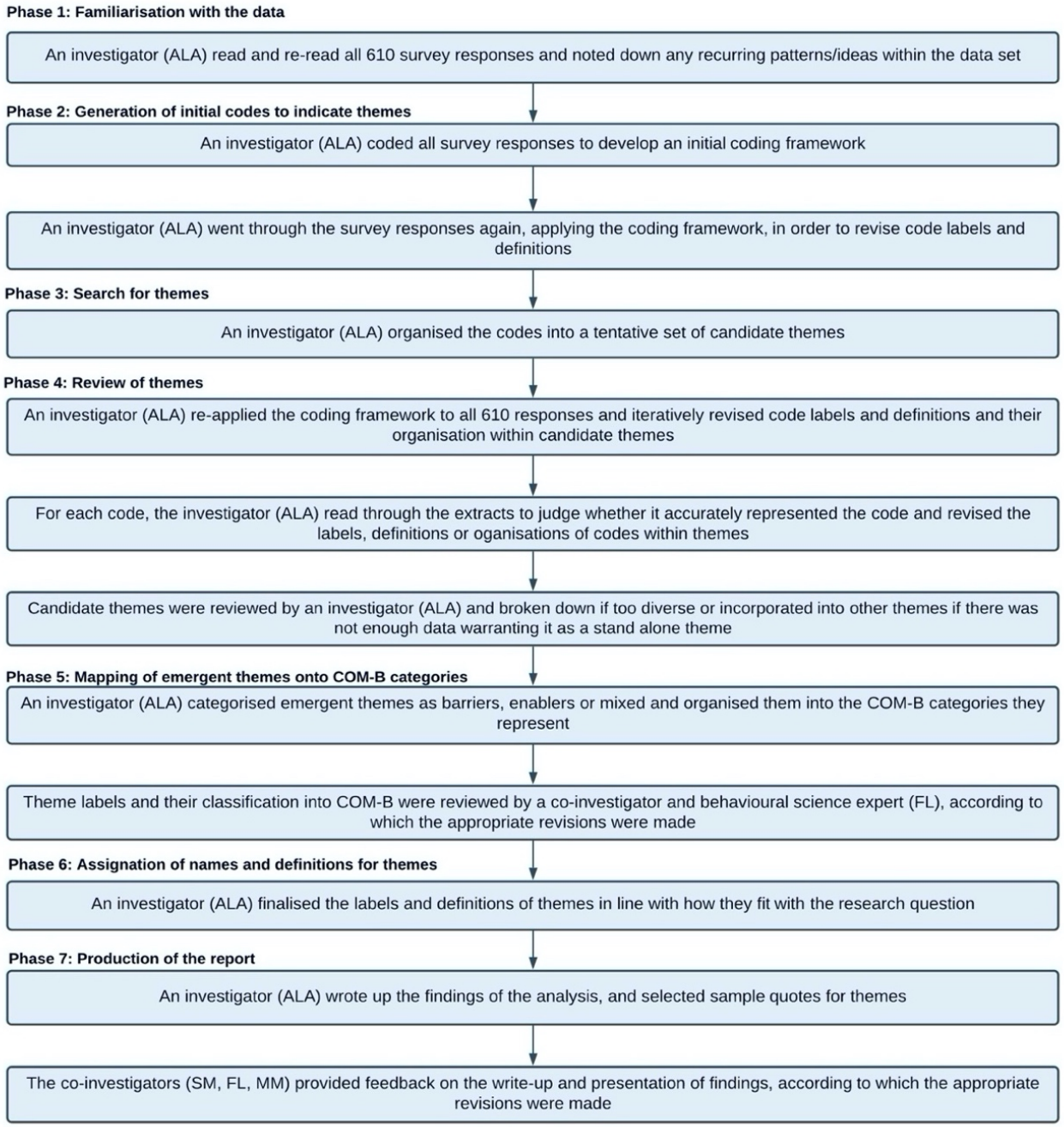

Figure 3.1 Steps undertaken to conduct the thematic analysis (reproduced with permission from (48)).

The Thematic Codebook is openly available via OSF (https://osf.io/bk9sh) and shows each theme's name, definition, description, and example quotes grouped according to those who said they were more likely, unlikely, or unsure whether they would buy compostable plastics. Thematic saturation was deemed reached when no new themes were emerging from the dataset (184-188).

3.4. Results

A total of 6523 participants responded to the survey. After removing participants who did not provide a reason for their answer to the question “Are you more likely to buy products with packaging marked ‘compostable’ or ‘biodegradable’?”, 5176 participant responses remained. Of these, the majority of the respondents indicated that they were more likely to buy products in compostable plastic packaging (84.1%), 8.1% said they were not, and 7.8% said they were unsure (Table 3.2).

Table 3.2 Frequency and percentage of respondents indicating whether they were more likely to purchase compostable plastic packaging.

Answer	**Frequency (total n = 5176)**	**Percentage (%)**
Yes	4353	84.1
No	419	8.1
I don’t know	403	7.8

No new themes were emerging from the dataset after the 610th participant and so data saturation was deemed reached (see Data Saturation Table, openly available via OSF: https://osf.io/wbdvf). Enablers were reported only by those who indicated that they were likely to buy compostable plastic packaging. Barriers were reported by those who said they were likely, unlikely, and unsure whether they would buy compostable plastic packaging, with some barriers (i.e., understanding terminology and labels, packaging preferences) reported across all groups. Table 3.3 depicts frequencies and illustrative quotes for barriers and enablers identified. Quotes from participants are included alongside their survey IDs.

Table 3.3. Emergent themes mapped to COM-B with illustrative quotes.

COM-B domain	Theme (*n* = 16)	No. (max *n* = 112)	Barrier/ enabler	Example quote(s)
Psych. Cap.	1. Understanding terminology/labels	61	Barrier	"I am not sure what these terms really mean." ID 17551 "These terms are confusing and can misleading." ID 13113
	2. Awareness of the plastic waste problem	4	Enabler	"I am aware of the crisis with plastic around the world. . ." ID 21563
	3. Attention to product packaging and labelling	55	Barrier	"I don't always notice the compostable/biodegradable signs amongst other text, images, and symbols on packaging." ID 18872 "Don't read labels when shopping." ID 21986 "Partly forget to check. Only look at the packaging when I come to put it in the bin." ID 15122
	4. Packaging preferences	71	Barrier	"I would prefer to buy products in reusable or recyclable packaging, I believe this is more resource efficient." ID 14967
	5. Other product qualities take precedence	71	Barrier	"The item is more important than the packaging." ID 19231 "We buy the products we like, without looking at the packaging." ID 18664 "There are too many considerations when buying products. A clothes item with biodegradable packaging might be manufactured in a less sustainable way or using a poorly looked-after/paid workforce, or just be significantly more expensive. It's impossible to be sure of the best ethical choice within a given budget. Even professional advice can vary: e.g., is it better to recycle paper or send it to energy from waste plant, and indeed are there sufficient processing facilities for either?" ID 17816
Phys. Opp.	6. Access to compostable plastic packaging waste management	64	Both	"I have a compost heap therefore I can dispose of the material safely instead of it going to landfill." ID 21421 "Our authority does not accept food waste for recycling, and it is inconvenient put packaging in the green bin as all other green bin content comes from the garden." ID 13262
	7. Aspects of the shopping environment	14	Barrier	"Most of our household shopping is done online and we can't tell what the packaging is." ID 18153 "No time to check all these while shopping." ID 21857
	8. Availability of compostable plastic packaging	27	Both	"Comes from work and church as [they're] already using." ID 21783 "Not always on offer as a choice." ID 14709

Soc. Opp.	9.	Social norms	3	Both	"It is much more acceptable." ID 21451 "But also have a flat so only access to a shared compost heap, and neighbours have complained in the past when I've put compostable plastic in, as it just looks like the wrong thing has been put in. When I explained, they still complained that it takes too long to compost." ID 15122
Aut. Mot.	10.	Environmental concerns	20	Enabler	"I am concerned about the environmental impact and climate change." ID 21453
Ref. Mot.	11.	Beliefs about environmental impact of compostable plastic packaging	112	Both	"Perceived lower environmental impact. Spend less time in the ground before breaking down." ID 21832 "The fuss about single use plastic is massively over hyped. The total amount of plastic used for this is, in relative term[s], miniscule…" ID 12080 "There is still an impact in producing the packaging (land use/carbon emissions etc.), whether it is biodegradable or not." ID 14269 "Not convinced they are better." ID 18432
	12.	Resolve to behave pro-environmentally	74	Enabler	"I'm always looking for ways to minimise my footprint." ID 21956 "I object to non-compostable throw-away plastic." ID 21440 "The companies that are going to the bother of using biodegradable wrapping should be supported." ID 21329 "…knowing that I can reduce the amount of waste going to landfill or even to a recycling stream means a lot." ID 21650
	13.	Hope that compostable plastic packaging will be beneficial	9	Enabler	"In the hope they will deteriorate quicker and completely, unlike much plastic packaging." ID 21725
	14.	Scepticism over decomposition claims	112	Barrier	"I would buy if the compostability was deliverable—not just greenwashing as it is at present." ID 21167 "Having put 'biodegradable' stuff in my compost bins in the past they don't seem to break down very effectively." ID 18820
	15.	No intention to buy compostable plastic packaging	33	Barrier	"I try to buy products with absolutely minimal packaging or better none at all." ID 18164 "I would be unlikely to purchase them and remain with taking my own bags to fill with my fruit and veg and re-useable coffee cup." ID 14267 "Because I can't be bothered to read every bit of packaging." ID 12288
	16.	Beliefs about capability	4	Barrier	"All manufacturers should be using these types of packaging. It should not be the consumer who has to check." ID 18714 "I'm not the primary purch[aser]." ID 18381

3.4.1. Barriers

3.4.1.1. Psychological Capability

3.4.1.1.1. Understanding terminology and labels

Participants reported issues with understanding the terminology used to label compostable plastic packaging, for instance, not knowing what the terms 'biodegradable' and 'compostable' mean (e.g., "I would need a convincing explanation of what these terms meant if I were to be influenced by them…" ID 11866), the environmental implications of the terms being vague (e.g., "I don't think it's clear whether there are lower or higher carbon emissions associated with these products." ID 18000), and a lack of knowledge regarding end-of-life instructions, including not knowing where to put the waste, not knowing what waste collection options are offered by the council, and a lack of awareness of composting as a plastic waste disposal strategy (e.g., "…although I understand what compostable means, had not thought of it as an option…" ID 16827). Even amongst participants who indicated that they were likely to purchase compostable plastic packaging, there was a misunderstanding regarding end-of-life instructions and the environmental benefits conveyed by the labels 'biodegradable' and 'compostable' (e.g., "It needs to be made clearer if hot composting is required though…" ID 21608; "Although I'm not sure which is better for the environment, I think it is the former, especially as there seems to be so many questions about what actually happens to recycled plastic…" ID 21520).

3.4.1.1.2. Packaging preferences

Preference for other types of packaging was also a barrier and was reported by those who said they would buy, would not buy, and were unsure about whether they

would buy compostable plastic packaging. Preferences for packaging varied; some expressed preference for no packaging, others for recyclable and reusable materials, such as paper and glass, and others for packaging labelled as compostable over biodegradable and, more specifically, preferred home compostable over industrially compostable.

3.4.1.1.3. Other product qualities taking precedence

For some participants, other aspects of a purchase were deemed more important than packaging. These included: the product itself (e.g., “It is the product that I buy, not the wrapping.” ID 17563), price (e.g., “My main incentive is price.” ID 19429), other ethical attributes (e.g., “…I try to buy fair-trade, organic, and local…” ID 19076), and functionality (e.g., “Compostable plastic is the worst of both worlds. . .it falls apart if you make it useful as a bag to hold stuff in. . .” ID 20899).

3.4.1.1.4. Attention to product packaging and labelling

Those who were unsure and unlikely to buy this packaging reported not noticing or considering packaging labels, labels not being obvious, and packaging being considered at the point of disposal as opposed to the point of purchase.

3.4.1.2. Physical Opportunity

3.4.1.2.1. Aspects of the shopping environment

For those who said they would not buy or were unsure about buying compostable plastic packaging, barriers related to the physical commercial environment, for instance, the lack of packaging information when shopping online and time constraints while shopping.

3.4.1.2.2. Access to compostable plastic packaging waste management

For those who would not buy or were unsure about buying compostable plastic packaging, access was a barrier, either because their council did not offer collection or they could not compost at home.

3.4.1.2.3. Availability of compostable plastic packaging

This was a barrier for those without access to compostable plastic packaging in their environment.

3.4.1.3. Social Opportunity

3.4.1.3.1. Social norms

Social influence discouraging the purchase of compostable plastic packaging was a barrier. For instance, participants mentioned tensions arising with neighbours if they put plastic in a communal compost heap (e.g., “But [I] also have a flat so only access to a shared compost heap, and neighbours have complained in the past when I’ve put compostable plastic in, as it just looks like the wrong thing has been put in. When I explained, they still complained that it takes to[o] long to compost.” ID 15122).

3.4.1.4. Reflective Motivation

3.4.1.4.1. Beliefs about the environmental impact of compostable plastic packaging

This was a barrier for those who said they were unlikely to buy and unsure about buying compostable plastic packaging. This theme included beliefs that the impact of single-use plastic is exaggerated, that biodegradable and compostable plastics have a higher carbon footprint than non-biodegradable and non-compostable plastics, and

that biodegradable and compostable plastics, like traditional plastic, will also only break down into harmful microplastics.

3.4.1.4.2. Scepticism over decomposition claims

This was a barrier for those who said they were unlikely to buy and not sure they would buy compostable plastic packaging. For instance, some reported a general mistrust of compostable plastic packaging degradation claims, while others had unsuccessfully tried to compost compostable plastic packaging at home.

3.4.1.4.3. No intention to buy compostable plastic packaging

This theme emerged for those who said they were unsure about buying or unlikely to buy compostable plastic packaging, and included: avoiding packaging altogether, preferring to engage in other behaviours to reduce waste, and having competing priorities.

3.4.1.4.4. Beliefs about capability

This emerged for those who said they were unsure whether they would buy compostable plastic packaging. They perceived the producer to have responsibility for reducing plastic waste, rather than the general public, and reported not having control over household shopping e.g., because one's partner was the primary shopper.

3.4.2. Enablers

3.4.2.1. Psychological Capability

3.4.2.1.1. Awareness of the plastic waste problem

An awareness of issues with plastic waste enabled the purchase of compostable plastic packaging.

3.4.2.2. Physical Opportunity

3.4.2.2.1. Access to compostable plastic packaging waste management

This was an enabler for those who said they would buy compostable plastic packaging, either because they already compost or their council offers a collection of compostable plastic packaging.

3.4.2.2.2. Availability of compostable plastic packaging

Having compostable plastic packaging available within the commercial environment was an enabler.

3.4.2.3. Social Opportunity

3.4.2.3.1. Social norms

Social norms encouraging the purchase of compostable plastic packaging were an enabler. For instance, participants mentioned it being more 'civilized' and socially acceptable to buy compostable plastic packaging (e.g., "More civilised to do so." ID 21834).

3.4.2.4. Automatic Motivation

3.4.2.4.1. Environmental concern

Enablers included concerns about environmental well-being, the accumulation of waste in the natural environment, and the build-up of plastic waste in particular.

3.4.2.5. Reflective Motivation

3.4.2.5.1. Beliefs about the environmental impact of compostable plastic packaging

This was an enabler for those who said they were likely to buy compostable plastic packaging. For instance, this included beliefs that compostable plastic packaging is more resource efficient, reduces the amount of waste sent to landfills

and incineration, improves soil quality, prevents the build-up of plastic in the environment, and degrades faster than non-biodegradable plastic.

3.4.2.5.2. Hope that compostable plastic packaging will be beneficial

The theme of hope/optimism that compostable plastic packaging will have positive environmental consequences emerged as an enabler. Here, we refer to an optimistic desire for a specific outcome that emerged distinctly from beliefs about the truth regarding compostable plastic packaging's impact.

3.4.2.5.3. Resolve to behave pro-environmentally

This resolve included an intention to support businesses that use compostable plastic packaging and desire to buy compostable plastic packaging, as it aligns with one's ethos or values.

3.5. Discussion

This study aimed to identify the barriers and enablers to buying compostable plastic packaging amongst UK citizens. Key reasons for not buying compostable plastic packaging concerned psychological capability (not understanding the terminology used to label packaging, not taking notice of packaging, and preferring other types of packaging and product qualities), reflective motivation (negative beliefs about compostable plastic packaging's environmental impacts and scepticism over decomposition claims), and physical opportunity (no access to the appropriate waste management). The main reasons for people buying compostable plastic packaging concerned reflective motivation (positive beliefs about compostable plastic packaging's environmental impact and resolve to behave pro-environmentally) and physical opportunity (access to the appropriate waste management).

3.5.1. Barriers to buying compostable plastic packaging

The results support and extend prior findings. Previous data show that people may not understand 'eco' labels as intended, or be aware that they exist (189, 190). This is consistent with the findings of this study that packaging labels often go unnoticed, and that people do not know what 'biodegradable' and 'compostable' mean in terms of their environmental impact and disposal instructions, even amongst those who are willing and motivated to purchase compostable plastic packaging.

People's reported mistrust of labels is likely related to not understanding the terminologies used to label compostable plastic packaging. Misunderstanding the terminology on labels can negatively influence people's perceptions of sustainable products, preventing their purchase (190, 191). It is understandable why people

might not understand these labels as the term ‘biodegradable’ is often misused when describing packaging (192), despite definitions being available (177). In addition, data from a UK-wide citizen science project has shown that plastic products marketed as home-compostable do not degrade in home-composts likely adding to confusion (182).

The findings of this study also suggest that factoring in the disposal of an item after use is important when making purchasing decisions; many reported the lack of appropriate waste management infrastructure as a barrier to buying compostable plastic packaging. While lack of waste management infrastructure is consistently found as a barrier to the disposal of waste e.g., littering (193, 194) and recycling (195), it is seldom investigated or reported as a barrier to the purchase of items.

As mentioned in Section 3.2, purchasing is one of the earlier behaviours enacted, in a chain of interconnected behaviours, when people interact with compostable plastic packaging. The findings of this study suggest that barriers directly related to later behaviours (e.g., disposal) may also influence behaviours earlier on in the chain (i.e., purchase). This emphasises the importance of multi-dimensional appraisals of behavioural problems as behaviours are not static or occur in isolation from one another.

An alternative explanation for the influence of waste management access could be a potential relationship between environmental context, knowledge and environmental intentions; if people are aware and believe that compostable plastic packaging is the ‘greener’ option only when appropriately managed after use, they are unlikely to purchase this material in a context where there is no appropriate waste management.

The influence of packaging preferences on compostable plastic packaging purchases may also be linked to waste management access and pro-environmental intentions. Not only have similar packaging preferences for no packaging or non-plastic packaging materials, such as paper and glass, been identified in other studies (196), but it is possible that no packaging, or recyclable packaging, is preferred because they have more obvious or established disposal routes (in the case of no packaging, there is no disposal to think about).

3.5.2. Enablers to buying compostable plastic packaging

Having pro-environmental values, concerns and intentions increases the purchase of products marketed as sustainable, therefore, it is consistent that they also positively influence compostable plastic packaging purchase (197, 198).

In the previous sub-section, it was speculated that access to waste management infrastructure likely influenced compostable plastic packaging purchases by providing the necessary context to act out their pro-environmental intentions. In the case of limited access to the appropriate waste management infrastructure, i.e., not having a home compost or access to local food waste collection services, not buying the packaging was likely perceived as the 'greener' option. In cases where waste infrastructure was available, buying this type of packaging was likely deemed as the 'greener' option and so enabled purchase.

3.5.3. Implications and recommendations

This has been the first application of the COM-B model in this context and no subject-specific issues were found using the model to understand the purchase of compostable plastic packaging. As highlighted by others using COM-B in implementation research, there were minor challenges with coding behavioural

influences to COM-B domains - the descriptions provided in the Behaviour Change Wheel guide (34) were not always sufficient to make solid judgments on how to categorise influences. This was overcome by creating and applying a thematic codebook during analysis to ensure clarity in what the themes were meant to represent. Where inconsistencies arose, rationale and possibilities were discussed amongst the thesis author (ALA) and their supervisor (FL) until a solution was found.

Irrespective of the different levels of knowledge or views and beliefs held about compostable plastic packaging, the findings of this study suggest that UK citizens are, on the whole, motivated to behave pro-environmentally as demonstrated by the high proportion of survey respondents who indicated they were more likely to buy this type of packaging. This motivation to 'do the right thing' could be effectively leveraged by the appropriate intervention efforts.

The study findings highlight that the labelling system around compostable plastic packaging is limited, preventing the UK public from engaging with this material. The current system is hindering people's abilities to behave in a manner that aligns with their intentions, eroding trust in industry claims and preventing the potential environmental benefits promised by this packaging, as it is often mismanaged at the point of disposal. Building trust in compostable plastic packaging's sustainability credentials will be imperative for promoting its adoption. However, this is not something that a packaging product itself can do because only a functional system of production, distribution, use, reuse, collection and waste processing can deliver sustainability. As such, only a functional system can build and maintain trust.

To promote the adoption of compostable plastic packaging, a labelling system that helps people a) identify packaging, b) trust the environmental claims and c)

understand the disposal requirements is required. This, in turn, will require widescale system changes within industry and governance; gaining the public's trust will rely on a more consistent and transparent method of manufacturing, labelling, testing and certifying compostable plastic packaging.

Developments in infrastructure will be needed to introduce a nationwide collection and processing system for compostable plastic packaging, ensuring that the public can put the right materials in the right bin for the appropriate waste processing. This could, for instance, include adapting current food waste or recycling waste streams so that they can manage compostable plastic packaging waste. The success of these policies would, in turn, rely on effective informational and motivational public campaigns and improved systems of labelling, where disposal instructions are efficiently communicated on packaging.

3.5.4. Limitations and future research

Limits to the present study include taking hypothetical behaviour as a proxy for actual behaviour. Gaps between the reported intention to perform a behaviour and the subsequent performance of that behaviour are well-established (referred to as the intention–behaviour gap) (199, 200).

The demographic information of participants was not collected, which would have helped describe the participant sample and evaluate the likely generalisability of findings to the UK population. The study is likely to show self-selection bias, whereby those who already engage in or are interested in composting were more likely to take part. While the study findings provide insight into behavioural influences, further studies are required to assess the degree of replication of the findings and assess their generalisability to other populations whose views and behaviours relating to

compostable plastic packaging are likely to differ from people who home-compost or engage with citizen science.

More scientific research is needed to identify labelling systems that effectively communicate packaging information. Areas to address include the sustainability information people want on packaging, and whether this influences the extent to which they perceive the packaging to have environmental benefits and/or their purchasing behaviour. Research is needed to clarify which packaging or design features best communicate the correct disposal actions required by people, and whether they increase the correct disposal of compostable plastic packaging.

3.6. Conclusion

Successfully introducing compostable plastic packaging into the market is not without its challenges, relying not only on technological innovation but also on interventions that change human behaviour. The study findings reveal widespread public misunderstanding of the terms used to label compostable plastic packaging, leading to confusion and mistrust towards packaging claims. Interventions will therefore need to increase trust in the environmental claims of packaging and reduce ambiguity concerning the labels used on this packaging. Based on prior research and the present findings, it is suggested that packaging is designed based on the public's needs for transparency and consistency. These include using consistent language, improving information on the source of the packaging material, how the packaging waste is processed and how to dispose of the packaging. These changes, however, will not be sufficient unless improvements to certification are made and facilities for local compostable plastic packaging waste collection and processing are increased. Further research is needed to assess the generalisability of findings to other contexts and to investigate how disposal instruction labels could be used to promote the adoption and correct disposal of compostable plastic packaging amongst citizens. Studies measuring actual behaviour as opposed to behavioural predictors are needed.

4. Chapter 4 – Barriers and enablers to recycling food waste: a mixed methods study amongst UK citizens (Study 3)

4.1. Abstract

Background: A circular economy of compostable plastics requires effective systems for disposing, sorting and recycling of compostable plastic waste. Local food waste collection provides an opportunity for this since compostable plastics are often associated with food packaging and food waste (compostable caddy liners) can be processed by some of the same methods e.g., industrial composting. Understanding the viability of this method of collection of compostable plastics first requires an understanding of the barriers and enablers to the engagement of householders with food waste, its collection and its recycling.

Aims: This study aims to investigate the influences (i.e., barriers and enablers) on household food waste recycling amongst UK citizens.

Method: Participants consisted of members of the UK general public (n = 1801). The COM-B (Capability–Opportunity–Motivation–Behaviour) model was used as a theoretical framework to design a survey exploring barriers and enablers to food waste recycling. Regression analyses and supporting thematic analyses were conducted on survey responses.

Results: Automatic motivation (e.g., emotions and habit) and psychological capability (e.g., knowledge) were found to predict household food waste recycling in regression analyses. The qualitative analyses revealed physical opportunity (i.e., dealing with food waste in other ways such as home-composting or feeding pets/strays, time and financial costs) as the main barrier to recycling food waste.

Participants also reported automatic motivation-related barriers such as concerns over pests, odour, hygiene and local authorities' food waste collection capabilities.

Conclusions: To achieve food recycling behaviour change, strategies for increasing capability might include ensuring clear and consistent messaging about what can and cannot be put in food waste bins; strategies for increasing opportunity might include providing free bins, caddies and liners; strategies for increasing motivation might include ensuring bins, caddies and liners are designed to meet user needs for cleanliness, convenience and hygiene; and ensuring new services are properly resourced to run effectively in the first instance.

4.2. Background

As highlighted in Chapter 1, a circular economy of compostable plastics, in the UK, requires effective systems for disposing, sorting and recycling this material; local food waste collection services provide a potential context for this. Understanding how best to promote the desired disposal of a particular compostable waste item (e.g., compostable plastic packaging), however, first requires a comprehensive understanding of the barriers and enablers to engagement with the waste stream dealing with this item. This chapter aims to do this; this mixed methods study is the third study in this thesis and aims to investigate the influences on household food waste recycling. The findings of this study informed two additional studies reported in Chapter 5 and Chapter 6 which document the design and evaluation of an intervention aimed at promoting disposal of compostable plastics with food waste meant for collection by local authorities. A version of the work presented in this chapter has been published in the journal International Journal of Environmental Research and Public Health (201) and as a policy briefing (202).

To briefly summarise the technical context around compostable waste sorting practices and the desirability of compostable plastics in local food waste collection streams, there are three different routes for processing compostable waste, two of which are commercial services, anaerobic digestion (AD) and In Vessel Composting (IVC), and one of which is home/community composting. In IVC, compostable waste is composted in temperature-controlled aerobic conditions (i.e., in the presence of oxygen) to create a nutrient-rich compost. In AD, compostable waste is broken down by microorganisms in an oxygen-free environment which yields biogas (principally methane) and a liquid digestate. For technical details of different composting

methods, see (203-205). Local home/community composting is an effective compostable waste management option as it reduces demand for separate collection (206) thereby reducing the associated environmental and financial costs of waste transport and management (207). This is particularly relevant in sparsely populated, rural, areas (205). However, it may not be feasible for the majority of urban-dwelling UK citizens who live in densely populated housing often without access to a garden (208). Local home/community is also an aerobic process of composting food waste, however, unlikely IVC, there is little explicit control of the process variables such as temperature, humidity, and security against vermin. It, therefore, may not be appropriate for processing some types of mainstream compostable waste due to the controlled environments required for these materials to degrade safely or without attracting vermin (e.g., compostable plastic packaging, cooked vegetables, meat, dairy, skin and bones). Chapter 2 revealed that one of the key barriers to buying compostable plastic packaging was a lack of appropriate waste infrastructure (i.e., home composting or local compostable waste collection). Even for people who had access to home composting, the materials did not biodegrade in the specified timeframes. Indeed, evidence from the UK has shown that home composting is unlikely to be a viable option for processing compostable plastic waste in the UK as many of the products marketed as compostable do not perform as such in home composts (182). Commercial composting, enabled by household food waste collection services, is therefore the most practicable policy option to ensure that household compostable waste recycling is effective and safe for large and dense populations.

The UK government's impending plan to introduce nationwide food collection services to all households provides the material context necessary to make food waste recycling a viable mass compostable plastic waste management strategy (209). However, to understand and change compostable plastic packaging disposal, it is important to understand UK citizens' behaviour concerning household food waste recycling via local collection services as it is a pre-requisite that people are engaged in this practice before they can recycle compostable plastic via this route.

At the time of writing this thesis, in 2023, many households across the UK did not have access to separate food waste collection services, with low rates of food waste recycling compared to other European countries (210). Food waste collection services are better in the UK's devolved nations. In Wales, weekly food waste collections are offered to 99% of Welsh households (211, 212). However, in England, where local authorities make the decisions on collection and recycling operations, separate food waste collection services are available to fewer than half of all households (213). England is responsible for over three quarters (82%) of UK biodegradable municipal waste (food waste, green waste, cardboard and paper) sent to landfill, generating 5.4 million tonnes of the 6.6 million tonnes UK total in 2019 (210).

Highly successful systems for collecting food waste have been implemented across Europe. Efficient systems based on source separation of food exist in Austria, Slovenia, Belgium and Germany where the bio-waste capture rate is over 60%[7] (205). The success of these systems is owed, in part, to technical factors, i.e., widescale implementation of a simple-to-use, nationally uniform, efficient and reliable

[7] This percentage represents food waste collected as a percentage of food waste generated.

waste collection service. It is also owed to high citizen engagement with food waste recycling schemes which has been achieved through effective behaviour change interventions, including educational and motivational public campaigns to create positive social norms about household food recycling and the provision of free bins and compostable liners (214). As household food waste recycling is a relatively new behaviour in terms of an integrated UK waste management strategy, there is limited scientific research on the topic, in this particular implementation context.

The success of food waste collection services depends on citizens appropriately orienting their behaviour; for the UK, this means population-wide adoption of a new set of household food waste recycling behaviours that are not currently part of most people's routines. To achieve the adoption of this new set of recycling behaviours, knowledge of influences on current and desired food waste recycling behaviour is needed. For instance, this includes understanding why those who currently have access to food waste recycling services do not recycle their food waste. It also requires investigating citizens' use of compostable caddy liners since hygiene concerns and the perceived mess associated with handling food waste have been identified as potential barriers to food waste recycling (215). While some preliminary evidence suggests that compostable bags might be appealing to UK citizens by reducing the 'ick' factor (215), little is known scientifically about current rates of use and what the potential barriers to their adoption might be. It is also increasingly acknowledged that 'acceptability' should be considered when designing, evaluating and implementing interventions; this can be defined as how appropriate intervention recipients find an intervention based on anticipated or experiential cognitive and emotional responses to the intervention (216). However, little is known about how

prepared the UK public may feel about having to adopt a new set of recycling behaviours. Understanding UK citizens' acceptance and readiness for nationwide food waste collection services can therefore increase the likely effectiveness of implementation efforts. To this end, Study 3 aims to identify the barriers and enablers to household food waste recycling amongst UK citizens and addresses the following research questions:

1) What are the barriers and enablers, in terms of capability, opportunity, and motivation (components of the COM-B model outlined in Chapter 1), to recycling food waste via local authority services?
2) For UK citizens with access to council waste collection services, what reasons do they provide for not recycling food waste?
3) For UK citizens with access to council waste collection services, what reasons do they provide for not using compostable plastic caddy liners?
4) What reasons do UK citizens give for feeling unprepared for nationwide food waste collection services?

4.3. Method

4.3.1. Design

This was a mixed methods cross-sectional survey study (217, 218). This approach was chosen to achieve 'triangulation' (i.e., seeking corroboration between quantitative and qualitative data to increase the validity of findings) and 'completeness' (i.e., combining research approaches to provide a more comprehensive picture of the study phenomenon) (219-221).

4.1.1. Participants and recruitment

Study participants consisted of UK citizens, aged 18 and above. Participants were recruited via Prolific – a professional data collection service (222) – and opportunity sampling i.e., advertising the study via a) social media (including Hertfordshire Council's official Twitter page, the UCL Centre for Behaviour Change's official Twitter account and the UCL Environment and Behaviour Hub's professional LinkedIn group); b) email (including the Big Compost Experiment's (178) mailing lists and Hertfordshire Council's mailing lists of residents). Participants recruited via Prolific were compensated for their time at a rate of £10.89/hr. Prolific ensures a representative sample in terms of gender, age and ethnicity for UK participants. Participants recruited via email and social media took part voluntarily.

4.1.2. Questionnaire

A survey, hosted by Qualtrics (223) was developed. It consisted of demographic questions, questions about current food waste recycling behaviour, a series of 5-point Likert-scale items aimed at assessing potential capability, opportunity and motivation-related influences on food waste recycling behaviour and, questions on

participants' awareness of and readiness for the UK government's plan to roll-out nation-wide food waste collection.

To develop the survey, a preliminary set of survey items was cross-referenced with TDF to ensure no likely categories of influence were omitted from the survey. An open-ended question allowed participants to report factors influencing their behaviour that may not have been covered by the set of items in the survey. The survey was piloted for comprehensibility and feasibility with a sample of UCL students and staff including members of the UCL Plastic Waste Innovation Hub and UCL Sustainability network. A digital version of the survey was piloted for usability with a larger group of students and staff. The survey is openly available via OSF at https://osf.io/d5jw7/.

4.1.3. Procedure

Ethical approval was received from UCL (project ID: CEHP/2020/579, data protection: Z6364106/2020/02/86). Participants accessed the survey link via an online web link. The survey took approximately five minutes to complete. Informed consent was obtained before any data collection. Data collection occurred between 11 May 2021 and 21 June 2021.

4.1.4. Data analysis

Statistical analyses were performed in SPSS (84). Data were analysed in a phased approach. First, assumption checks were made. Then, before running the regression, the impact of demographic variables on the dependent variable was investigated. The demographic variables that were significantly associated with the dependent variable were subsequently controlled for in the regression analyses.

Hierarchical multiple linear regression was performed to identify factors associated with recycling food waste. The dependent variable was operationalised as the frequency of food waste recycling (as measured by the survey item “How often do you use the food waste bin when disposing of food waste?”). The following responses were used: always = 5, most of the time = 4, about half the time = 3, sometimes = 2, never = 1. Participants who said no to using a separate food waste bin for recycling food waste were coded as ‘never = 1’ and also entered into the analysis.

The independent variables were psychological capability, physical opportunity, social opportunity, reflective motivation and automatic motivation (components of the COM-B model). Responses to each item were coded so that 1 = disagree, 2 = somewhat disagree, 3 = not sure, 4 = somewhat agree, 5 = agree. Negatively worded items were reverse coded so that a score of 5 always indicated high capability, opportunity or motivation and 1 represented a lack of capability, opportunity or motivation. The mean COM-B scores were calculated for each participant. For example, if three items were measuring social opportunity, the average score of those three items was taken as that person's score for social opportunity. COM-B scales were considered to represent an acceptable level of internal consistency if the Cronbach’s alpha value fell within 0.5 to 0.7 and a good level of consistency if the Cronbach’s alpha value was more than 0.7 (224-226).

Thematic analyses, in line with the approach described by Braun and Clarke (183), were used to identify: a) reasons for not recycling food waste via council collection; b) reasons for not using compostable caddy liners and; c) reasons why participants do not feel ready for nationwide food waste collection. Thematic

analyses were conducted by the author of this thesis (ALA) and in the steps depicted in Figure 4.1.

The raw survey data file exported from Qualtrics and the datasets used for the regression and thematic analyses are openly available via OSF https://osf.io/d5jw7/.

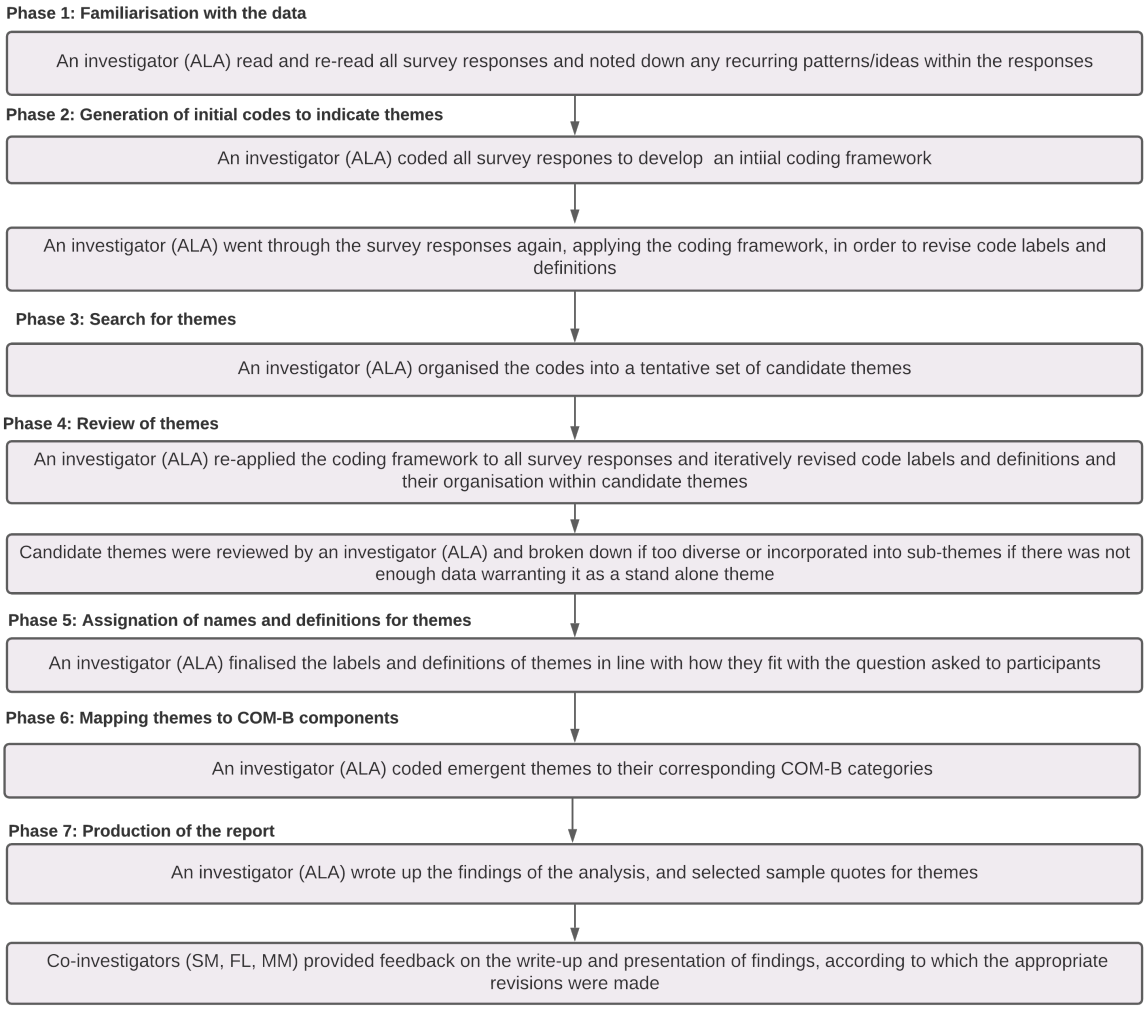

Figure 4.1 Steps taken to analyse survey responses thematically (reproduced with permission from (201)).

4.4. Results

4.4.1. Participant characteristics

In total, 1801 participants completed the survey. Participant demographics are summarised in Table 4.1. Participants (*M* = 56.98; *SD* = 15.49) identified mostly female (65.8%) and White or White British (92.9%). The majority of participants were educated to at least undergraduate level (75.5%), privately owned their homes (86%) and lived in detached (40.1%) housing. The majority of participants were retired (42%) and preferred not to declare their annual pre-tax household income (19.3%). The size of households ranged from one to nine persons (*M* = 2.36; SD = 1.04) and most participants lived within a couple (42.2%) or family unit (28.9%). Our sample is representative of the UK population in terms of ethnicity (227), household annual income[8] (228) and number of people in a household (229), however, our sample is older (230), more educated (231) and has higher levels of home ownership (232) than national averages. Our sample is also more female and retired. Though exact figures of the retired UK population are unknown, with only 18% being over 65 (233), our sample is likely to be more retired than the wider population. Though the proportion is higher in our sample, cohabitation as a couple is also the most common type of relation between household members in the UK (234). Though the proportion is higher in our sample, living in a house (as opposed to a flat) is also the most common dwelling type in the UK (235).

The majority of participants (52.4%) indicated that they were being provided with a separate household food waste collection service at the time of completing the

[8] It is difficult to estimate representativeness in terms of income as the majority of participants preferred not to disclose their income. This interpretation is based on the results of the participants who did disclose annual household income.

survey. This mirrors UK statistics for household food waste collection services; just under half of households are offered such services (213). Of these participants, the majority said that they use a separate food waste bin to recycle their food waste (85.7%). Of the participants who use a separate food waste bin to recycle food waste (n = 809), the majority indicated they use their food waste bin on all of the occasions that they could do so (71.2%). Additional analyses on how participants sourced their food waste bins and where they are kept in the home can be found openly available via OSF (https://osf.io/6zxkc).

Table 4.1 Table summarising participant demographics.

Characteristics	***N (missing)***	***%***	***Mean (SD)***
Gender	1801 (0)		
Male	593	32.9	
Female	1185	65.8	
Non-binary	5	0.3	
Prefer not to say	18	1	
Age (years)	1763 (38)		56.98 (15.49)
Ethnicity	1790 (11)		
White or White British	1674	92.9	
Arab or Arab British	2	0.1	
Asian or Asian British	40	2.1	
Black or Black British	21	1.2	
Mixed	32	1.8	
Any other ethnic background	21	1.2	
Highest level of education	1801 (0)		
Primary education	1	0.1	
Lower secondary education	56	3.1	
Higher secondary education	164	9.1	
Vocational certificate	157	8.7	
Associate degree	59	3.3	
Undergraduate degree	678	37.6	
Postgraduate degree	474	26.3	
PhD/ Doctorate	212	11.8	
Employment status	1801 (0)		
Retired	773	42	
Employed	653	36	
Self-employed	191	10.6	
Homemaker	49	2.7	
Student	44	2.4	
Out of work (looking for work)	24	1.3	
Unable to work	23	1.3	
Out of work (not currently looking)	15	0.8	
Other	29	1.6	
Recruitment Method	1801 (0)		
Social media/email	1501	83.3	
Prolific	300	16.6	
Annual household income pre tax	1801 (0)		
Less than £10,000	61	3.3	
£10,000 to £19,999	207	11.5	
£20,000 to £29,999	255	14.2	
£30,000 to £39,999	224	12.4	
£40,000 to £49,999	163	9.1	
£50,000 to £59,999	137	7.6	
£60,000 to £69,999	98	5.4	
£70,000 to £79,999	80	4.4	
£80,000 to £89,999	58	3.2	
£90,000 to £99,999	32	1.8	
£100,000 to £149,999	97	5.2	
£150,000 or more	41	2.3	
Prefer not to say	348	19.3	
Housing type	1801 (0)		

Owned home	1549	86	
Privately rented	177	9.8	
Council housing	40	2.2	
Student accommodation	6	0.3	
Other	29	1.6	
Dwelling type	1801 (0)		
Detached	738	40.1	
Semi-detached	551	30.6	
Terraced	318	17.6	
Flats non-high rise	152	8.4	
Flats high rise	13	0.7	
Tiny home	7	0.3	
Other (e.g., boat home)	22	1.2	
Number of people in household	1766 (35)		2.36 (1.04)
Household relationships	1801 (0)		
Couple	760	42.2	
Family	701	28.9	
Single person	265	14.7	
Sharing with friends/flatmates	46	2.6	
Other	29	1.6	
Food waste collection services available	1801 (0)		
Yes	944	52.4	
No	830	46.1	
Unsure	27	1.5	
If YES, use of a separate food waste caddy and;	944 (0)	85.7	
Yes	809	14.3	
No	135		
If YES, frequency of caddy use and;	809 (0)	71.2	
Always	577	15.2	
Most of the time	123	2.8	
About half the time	23	9.1	
Sometimes	74	1.5	
Never	12		
If YES, use of compostable caddy liners	809 (0)	68.6	
Yes	555	22.8	
No	185	8.5	
Sometimes	69		
Awareness of UK 2023 food waste scheme	1801 (0)		
Yes	375	20.8	
No	1331	73.9	
Not sure	95	5.3	
Readiness for UK 2023 food waste scheme	1801 (0)		
Yes	1523	84.6	
No	134	7.4	
Not sure	144	7.9	

4.4.2. Factors associated with food waste recycling

4.4.2.1. Internal consistency of survey

As the Cronbach's alpha value for each COM-B domain was 0.61 or above, the items were deemed appropriate for clustering within the regression analysis.

Psychological Capability. Participants answered five items to measure psychological capability (α = 0.768) e.g., "I know what I can and can't put in the food waste bin", "I often forget to dispose of my food waste separately".

Physical Opportunity. Participants answered six items to measure physical opportunity (α = 0.606) e.g., "I have sufficient space in my home for a separate food waste caddy", "I have sufficient time to separate my food waste".

Social Opportunity. Participants answered three items to measure social opportunity (α = 0.708) e.g., "Separating food waste is something that people I know do", "Most people whose opinion I value would approve me of recycling my food waste".

Automatic Motivation. Participants answered four items to measure automatic motivation (α = 0.716) e.g., "I feel guilty if I put food waste in the ordinary bin for landfill", "Disposing of food waste separately is routine practice for me".

Reflective Motivation. Participants answered 15 items to measure reflective motivation (α = 0.714) e.g., "I have too many things to think about other than whether or not I recycle my food waste".

4.4.2.2. Identification of covariates

To avoid reducing the statistical power of the main analyses, the demographic covariates included in the regression analyses were determined by whether they had significant relationships with the outcome variables in the current sample.

Given that some levels of these demographic variables contained a small number of participants, some of the groups were combined or omitted to reduce unequal group sizes and to ensure that post hoc tests could be conducted if required. Specifically, for ethnicity, ‘Black or Black British’, ‘Asian or Asian British’, Arab or Arab British’ and ‘Mixed’ were combined into ‘other’. For gender, only ‘Man’ and ‘Woman’ categories were used. For annual household income, ‘Less than £10,000K’, ‘£10,000-£19,000’ and ‘£20,000-£29,000’ were combined; £30,000-£39,000’, ‘£40,000-£49,000’ and £50,000-£59,000’ were combined and anything higher than £60,000-£69,000’ was combined. For dwelling types ‘flats high rise’ and ‘flats non-high rise’ were grouped while ‘other’ and ‘tiny home’ categories were omitted. For housing type, all categories except for ‘owned home’ were grouped as ‘other’. For household relationships, ‘sharing with friends/flatmates’ was grouped with ‘other’. For employment status, ‘self-employed’ and ‘employed’ were combined while all other categories, except for ‘retired’ were combined into ‘other’. For education, all degrees lower than an undergraduate degree were combined into an ‘up to associate degree’ category. Table 4.2 summarises how the demographic variables were grouped and used in the regression analyses.

Table 4.2 Demographic variables used in the regression analyses.

Variable	N (missing)	Percentage %
Ethnicity	937 (7)	
White or White British	875	93.3
Other	62	6.6
Gender	931 (13)	
Woman	649	69.7
Man	282	30.3
Annual household income pre tax	742 (202)	
£10,000-£29,000	258	34.8
£30,000-£59,000	260	35
£69,000 +	224	30.2
Housing type	944 (0)	
Owned home	836	88.6
Other	108	11.4
Dwelling type	937 (7)	
Detached	386	41.2
Semi-detached	285	30.4
Terraced	193	20.6
Flat	73	7.8
Household relationships	944 (0)	
Couple	381	40.4
Family	384	40.7
Single	38	4
Other (e.g., flat-share)	141	14.9
Employment	944 (0)	
Retired	408	43.3
Employed/self-employed	443	46.9
Other (e.g., student)	93	9.9
Education	944 (0)	
Up to associate degree	226	23.9
Undergraduate degree	362	38.3
Postgraduate degree	356	37.7

Correlational analyses and independent t-tests indicated that the number of people in the household, age, housing type and ethnicity were not associated with participants' frequency of recycling food waste (*p*'s > .05). Similarly, one-way ANOVAs revealed that there were no significant differences in frequency of recycling according to employment status or the relationship between household members (*p*'s > .05).

There was a significant difference in the frequency of recycling according to gender $t(929) = 2.52$, $p = .012$, with women ($M = 4.02$; $SD = 1.51$) more likely to recycle than men ($M = 3.7$; $SD = 1.66$). There was a significant difference in the frequency of recycling according to education $F(2, 941) = 4.821$, $p = .008$, $\eta_p^2 = .01$. Pairwise comparisons (with Bonferroni adjustment) revealed participants with postgraduate degrees ($M = 3.75$; $SD = 1.63$) were less likely to recycle food waste than those with undergraduate degrees ($M = 4.11$; $SD = 1.45$). There was also a significant difference in the recycling frequency according to income $F(2, 739) = 4.62$, p = .01, $\eta_p^2 = .01$, and dwelling type $F(3, 933) = 3.30$, $p = 0.2$, $\eta_p^2 = .01$. Pairwise comparisons (with Bonferroni adjustment) revealed that participants with incomes in the £30,000-£59,000 range ($M = 4.14$; $SD = 1.41$) were more likely to recycle than those in the £10,000-£29,000 range ($M = 3.74$; $SD = 1.64$) and participants living in terraced housing ($M = 3.74$; $SD = 1.61$) were less likely to recycle than participants in semi-detached housing ($M = 4.15$; $SD = 1.43$). Hence, four demographic variables were controlled for in subsequent analyses: gender, education, income, and dwelling type.

4.4.2.3. Assumption check

The relevant assumptions of this statistical analysis were met. Specifically, an analysis of standard residuals was carried out, which showed that the data contained no outliers (Std. Residual Min = -2.43, Std. Residual Max = 2.63). Collinearity statistics (i.e., Tolerance and VIF) were all within accepted limits (236) (Psychological Capability, Tolerance = .37, VIF = 2.70; Social Opportunity, Tolerance = .67, VIF = 1.50; Physical Opportunity, Tolerance = .60, VIF = 1.66, Automatic Motivation, Tolerance = .40, VIF = 2.52, Reflective Motivation, Tolerance = .43, VIF =

2.31). The data met the assumption of independent errors (Durbin-Watson value = 1.98). Residual and scatter plots indicated the assumptions of normality, linearity and homoscedasticity were all satisfied. The data also met the assumption of non-zero variances.

4.4.2.4. Predicting food waste recycling behaviour

Using the enter method (i.e., all independent variables entered into the equation at the same time), a two-stage hierarchical regression was conducted with food waste recycling behaviour as the dependent variable. Gender, education, income and dwelling type were entered in the first stage to control for these factors. COM-B factors were entered at the second stage. Descriptive statistics for the study variables are reported in Table 4.3. Intercorrelations between the continuous multiple regression variables are reported in Table 4.4 and the regression statistics are in Table 4.5.

The hierarchical multiple regression revealed that at stage one gender, income, education and house structure accounted for 10.5% of the variation in food waste recycling behaviour but did not significantly contribute to the regression model $F(4, 737) = 2.025$, $p = .089$. Adding COM-B components in stage two significantly contributed to the regression model by explaining 39% of the variation in participants' food waste recycling $F(9,737) = 14.54$, $p < .001$. Inspection of the beta weights revealed that participants' automatic motivation and psychological capability were associated with a significant increase in frequency of food waste recycling while education was significantly associated with a decrease in frequency of food waste recycling.

Table 4.3 Descriptive statistics for study variables.

Variables	***n***	***Mean***	***SD***	**Min**	**Max**
Recycling behaviour	738	3.91	1.57	1.00	5.00
Gender	738	1.32	.48	1.00	2.00
Income	738	1.96	.8	1.00	3.00
Education	738	2.17	.76	1.00	3.00
House structure	738	1.98	.98	1.00	4.00
Psychological capability	738	4.75	.54	1.00	5.00
Social opportunity	738	4.18	.74	1.00	5.00
Physical opportunity	738	4.48	.57	1.00	5.00
Automatic motivation	738	4.43	.81	1.00	5.00
Reflective motivation	738	4.12	.39	1.00	5.00

Notes: n = sample size; *SD* = standard deviation

Table 4.4 Correlations between study variables.

Variables	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
1. Recycling behaviour	-	.339**	.189**	.204**	.351**	.256**
2. Psychological capability	-	-	.384**	.618**	.722**	.599**
3. Social opportunity	-	-	-	.308**	.373**	.566**
4. Physical opportunity	-	-	-	-	.486**	.431**
5. Automatic motivation	-	-	-	-	-	.655**
6. Reflective motivation	-	-	-	-	-	-

Notes: **All correlations were significant at $p < .001$

Table 4.5 Regression of COM-B factors on behaviour.

Covariates/predictors	***β***	***t***	**sr²**	***R***	***R²***	***ΔR²***
Step 1				.105	.001	.006
Gender	-.037	-1.062	.071			
Income	.067	1.912	.071			
Education	-.08*	-2.294	-.085			
Structure of housing	.048	1.363	.05			
Step 2				.390	.152	.142
Psychological Capability	.188***	3.345	.123			
Social Opportunity	.058	1.378	.051			
Physical Opportunity	-.019	-.433	-.016			
Automatic Motivation	.233***	4.298	.157			
Reflective Motivation	-.026	-.510	-.019			

Notes: $n = 738$; β = standardized beta coefficients; t = t-test value; sr^2 = semi-partial correlation coefficient; p = significance; ΔR^2 = adjusted R^2.

* $p < .05$, ** $p < .01$, *** $p < .00$

4.4.3. Reasons for not recycling food waste via council food waste collection

Those who said 'no' to recycling their food waste via local services provided reasons for their answer. The notation '*k*' is used to denote the number of themes. Eight themes emerged from the responses, relating to physical opportunity ($k = 6$), psychological capability ($k = 1$) and automatic motivation ($k = 1$). These are summarised in Table 4.6 with frequencies and example quotes.

The most popular methods for dealing with food waste mentioned were home composting followed by feeding any leftover food waste to pets (e.g., dogs, chickens) or nearby wildlife and strays. Others said that they put any food waste in with garden waste to be collected. Two participants said that they use their neighbours' bins when they need to. Another reason for not using food waste collection was not producing any or producing minimal food waste in the first place. Relating to this, following a predominantly plant-based diet (both vegan and vegetarian) was attributed to not needing to use council waste collection services as participants were able to manage plant-based food waste at home.

Hygiene (e.g., bacteria), odour (e.g., bad smell) and pest concerns relating to keeping food waste in the house were mentioned. Cost was also a barrier to recycling food waste via council waste collection both in terms of financial and time costs. For example, participants mentioned that it was too much effort and hassle to recycle food waste, particularly for those who produce little food waste anyway; for these participants recycling food waste was not seen as justifiable. Related to cost, participants mentioned the high cost of buying separate compostable caddy liners for a food waste bin. Participants also mentioned service-related barriers to using council food waste collection. These include unreliable (e.g., late) and inadequate

(e.g., the council only provides non-compostable bags) food waste collection services.

The lack of space for bins was a barrier to recycling food waste. For example, this included no space within the home due to living in a small flat or having a small kitchen. Participants also mentioned that there is not enough space outside their homes to fit an extra bin for food waste on top of the existing bins for recycling and landfill. Other participants mentioned not having control over household management (e.g., living at home with parents who manage household waste and decide to not recycle food) and not having a separate food waste bin at home in the first place.

Lack of knowledge and awareness was also a barrier identified. For example, some participants did not understand why recycling food waste is necessary or environmentally beneficial while others indicated that they did not know how to go about recycling their food waste.

Table 4.6 Frequency of themes and sub-themes with quotes depicting reasons for not recycling food waste via local services.

COM-B	Themes	Subthemes	Example quotes
Physical opportunity	Recycles food waste in other ways (*n* = 97)	- engages in home composting (*n* = 76) - feed food waste to pets/local wildlife (*n* = 10) - puts it in garden waste (*n* = 9) - uses neighbours bin (*n* = 2)	*"I compost it myself";* *"…anything we do not eat goes to birds, foxes/strays..."* *"It goes in the green garden waste bin, together with perennial weeds, woody garden waste, etc.";* *"Very very occasionally we put something (such as meat bones, which we seldom have) into our neighbours' food recycling bin."*
Physical opportunity	Produces no/minimal food waste (*n* = 20)		*"I don't produce any food waste"*
Automatic motivation	Pests/hygiene (*n* = 18)	Smell/hygiene (*n* = 9) Pests (*n* = 9)	*"The smell and hygiene associated.";* *"our previous experience is that it attracts a lot of flies and unsanitary bacteria to the house.";* *"I [don't] want it to make the house smell or attract mice/rats etc"*
Physical opportunity	Follows plant-based diet (*n* = 17)		*"Because we eat a vegetarian diet we put all our food waste in the bin"*
Physical opportunity	Cost (*n* = 15)	-too much effort/hassle to recycle food waste (*n* = 12) -compostable bags perceived as too expensive (*n* = 3)	*"It's too much hassle"; "[I] live alone and don't produce enough food waste to make it worthwhile";* *"Living in a small top floor flat, it's not convenient to store the food waste bin in a small kitchen and have to carry it down stairs. No one in the building (four flats) uses any of the food waste bins – I think for similar reasons."* *"The bags the council insist we use inside our food waste bins are so expensive!"*

Physical opportunity	Service-related factors (*n* = 12)	-unreliable food waste collection services (*n* = 9) -council doesn't provide free food waste bins (*n* = 2) -council only provides non- compostable bags (*n* = 1)	*"It's never collected and it stinks";* *"We are not given a bin for food waste where we live.";* *"Our council supply us with single use polythene bags as liners, rather than compostable material"*
Physical opportunity	Household related factors (*n* = 10)	-no space within home (*n* = 6) -no space for an extra food waste bin outside (*n* = 2) -don't have a bin at home (*n* = 1) -doesn't make household related decisions (*n* = 1)	*"We don't have space in our (rented) kitchen for an additional bin on top of the general and recycling bins.";* *"I have room for 3 wheelie bins outside my house, but I have 4 bins. I have chosen to leave the food/garden waste bin out of the way in my garage.* *It therefore doesn't get used.....";* *"We don't have a separate food waste bin"* *"My parents manage the food waste and they have chosen not to do so. I do not know their reasons for this."*
Psychological capability	Lack of knowledge/awareness (*n* = 4)	-doesn't understand why we need to recycle food waste (*n* = 3) -doesn't know how to recycle food waste (*n* = 1)	*"We just never have, no reason really, would be good to know what happens to food waste what are the benefits of putting it in a separate bin?";* "*not sure how to."*

Notes: n = number of participants.

4.4.4. Reasons for not using compostable caddy liners

Those who said ‘no’ to using compostable caddy liners provided reasons for their answer. Ten themes emerged from the responses, relating to physical opportunity ($k = 6$), reflective motivation ($k = 3$) and psychological capability ($k = 1$). These are summarised in Table 4.7 with frequencies and example quotes.

Repurposing other types of bags/materials was the main reason offered by those not using compostable bags. There was variation in the responses in terms of the different types of materials used in place of compostable caddy liners. Participants reported using other types of materials including newspaper or repurposing other types of packaging such as paper bags, paper towels, magazine wrappers and plastic shopping bags to line their food waste bins.

Factors relating to local councils’ food waste collection capabilities were also frequently mentioned such as: a) their council accepts non-compostable liners for food waste collection; b) the council does not provide compostable bags freely; c) their council has explicitly stated that they do not want compostable caddy liners to be used, d) council provides non-compostable caddy liners and e) that waste collectors do not collect their food waste if it is placed out for collection in a compostable bag as they think that it is plastic.

Accessibility was also an issue. For most participants, this manifested as barriers relating to cost – having to buy compostable caddy liners was reported as an additional expensive household cost. Another participant mentioned that disability prevents them from being able to access shops that stock compostable caddy liners. Availability was also an issue in that participants reported not being able to find compostable caddy liners in stores locally.

Competing priorities such as the perceived inconvenience of using an extra caddy liner was another issue. Relating to this, participants also reported feeling that there was no need for an additional caddy liner or that it was just as easy to clean the bin directly so chose not to use them. Beliefs about the environmental impacts of caddy liners were also an issue perceiving compostable caddy liners as wasteful in their own right.

Design-related issues such as size and durability were mentioned. Compostable caddy liners were reported to be too small and fragile. They reportedly tear too easily, producing more waste and making them more expensive. Not knowing that compostable caddy liners existed but also not knowing where to find them was also an issue.

Table 4.7 Frequency of themes and sub-themes alongside example quotes depicting reasons for not using compostable liners.

COM-B	Themes	Subthemes	Example quotes
Physical opportunity	Repurposing other types of bags/materials (*n* = 75)		*"I use paper bags"* *"We wrap our food waste in newspaper."* *"Stainless steel container and use paper towelling to line it."*
Physical opportunity	Council-related factors (*n* = 50)	-council accepts non-compostable liners (*n* = 38) -council does not provide them freely (*n* = 5) -council does not want them to be used (*n* = 6) - council provides non-compostable caddy liners (*n* = 14) -waste collectors will not collect food waste thinking it is wrapped in plastic (*n* = 1)	*"our local council recycling scheme says we can use any bag for recycling food waste"* *"They are not provided by the local council, we are a very low income family so its an extra expense we don't need."* *"Our local council do not accept any type of compostable plastic in with the food waste."* *"Council provides plastic bags for the purpose – they switched to plastic from starch 2 years ago"* *"Waste collectors think it is regular plastic and will not collect the bin until the bag is removed"*
Reflective motivation	Lack of necessity (*n* = 49)		*"Unnecessary additional waste"* *"No need for a bin liner"* *"I don't believe it's necessary to spend anything further to enable me to dispose of waste."*
Physical opportunity	Accessibility (*n* = 27)		*"…because I am disabled, I cannot always get to the correct supermarket that sells the right type & size of bin liner"* *"The price"* *"Quite expensive"*
Reflective motivation	Beliefs about environmental impacts (*n* = 21)		*"Even though they are compostable they still are bad for the environment. They require carbon to manufacture, transport etc and I'm not entirely sure whether they break down in "* *"…unsure if materials break down as easily as they should"*

		"I use paper bags instead. That way the paper bags are used twice. (and I do not need to use specially made bin liners at all) I believe this is less wasteful."
Physical opportunity	Cleans food waste bin directly (*n* = 21)	*"We simply wash the container"* *"In my kitchen bin I use no liner at all, just regularly brush the material into the council bin ready to go out to the kerb later."* *"I did not find the compostable food caddy liners you can buy particularly helpful – it is just as easy to empty the food bin into the one council collect."*
Physical opportunity	Availability (*n* = 15)	*"Not always available"* *"My local shop doesn't sell them"*
Physical opportunity	Design-related factors (*n* = 12)	*"The bin liners are very fragile and tear a lot, wasting bags. I have to pay for them (to not be suitable for what I need)"* *"They are not always available or big enough"*
Psychological capability	Lack of knowledge/awareness (*n* = 6)	*"I don't know where to get them from"* *"Wasn't aware of them or how to use them"*
Reflective motivation	Priorities (*n* = 6)	*"Inertia. I've not got around to sourcing any."* *"I use the depending on what I'm putting in it to make the bin easier to fully empty into my garden waste/food recycling bin."* *"Inconvenience and cost of maintaining supply of compostable bags.*

Notes: n = number of participants.

4.4.5. Reasons for not feeling ready for nationwide food waste collection

Although the majority (73.9%) of participants had not heard of the UK government's plan to implement separate food waste collection services nationwide by 2023, the majority (84.6%) of participants reported feeling ready for these changes (see Table 4.1). Those who did not feel ready or were unsure provided a reason for their answers. Seven themes emerged relating to psychological capability ($k = 2$), physical opportunity ($k = 1$), automatic motivation ($k = 1$) and reflective motivation ($k = 3$). These are summarised in Table 4.8 with frequencies and example quotes.

Many participants expressed that their lack of readiness was due to not knowing what such a scheme would mean for them and their households. For example, this included not knowing whether there would be penalties for not using the service (e.g., if they prefer to home-compost their waste), what types of food waste the scheme would accept and whether they would have to pay additional costs for this service (e.g., via the raising of their council tax, additional caddy liner costs).

Participants reported lacking the space to take on the additional responsibility of recycling their food waste including mental 'headspace' (i.e., the additional burden of having to take on a new recycling responsibility) and physical space in their homes or kerbside for an additional bin. Participants also mentioned no need for the scheme as a reason why they did not feel ready for it either because they produce little food waste or prefer to deal with their waste in other ways (e.g., via home-composting).

Participants expressed worries concerning the hygienic storage of food waste between collections. This concern manifested both within the home and outside within the local community. Within the home, there were worries concerning the smell of rotting food waste and its attracting pests such as rats and flies. There were also similar concerns of bad smells around the outside bins and food waste bins attracting cats, dogs, foxes and other animals that look through the bins and scatter their contents on the streets polluting the neighbourhood. Participants also mentioned that an extra food waste bin outside, in addition to all the other bins residents must have outside their homes, would cause clutter.

Participants, particularly those living in multi-occupancy buildings (e.g., estates and flats), expressed implementation concern about the logistics and practicalities of rolling out such a scheme citing a lack of faith in their local council to be able to offer such a service efficiently.

Pessimism over the success of such a scheme was reported as a reason for not feeling ready for food waste collection services as was a lack of knowledge of what food waste items can be recycled.

Table 4.8. Frequency of themes and sub-themes alongside example quotes depicting reasons for not feeling ready for nationwide food collection.

COM-B	Themes	Subthemes	Example quotes
Psychological capability	Scheme awareness/clarity (*n* = 93)		*"Ready in principle, but until details are made public it's hard to know how it will work for our household"* *"We have not yet been provided with any information about how this will work in my local area."*
Physical opportunity	Space for the additional responsibility (*n* = 36)	-headspace (*n* = 8)	*"Sounds like a lot of hassle"* *"I think my household are currently unprepared as this is something we do not do at the moment and would need to get into the routine of doing."* *"…If it means more bins cluttering streets and gardens I should not be pleased"* *"Limited space in my kitchen already used for normal waste, paper, home compost, glass. So how do [I] organise space for yet another bin?"*
Reflective motivation	Public need for the scheme (*n* = 35)		*"As an older person I have next to nothing to send to a food waste collection so for me it would be a waste of resources."* *"We produce such a small amount of food waste it would generally mean putting out a container with next to nothing in it."* *"I currently compost what little food waste that we have and I would very much object to being mandated to change that very satisfactory method."*
Automatic motivation	Pests and pollution (*n* = 33)		*"I see reservations re pollution and smells"* *"I think [it's] a great idea, but it is difficult to do. I live in an area with a lot of foxes and other animals that look through the bin and scatter the contents which makes me somewhat hesitant."* *"I would like more information. I would wish to [know] the containers were well sealed and very regular and definite collections before I agree"*
Reflective motivation	Implementation concerns (*n* = 20)	-lack of trust in council (*n* = 8)	*"Multi occupancy buildings have challenges with dealing with this and the necessary infrastructure may not be available to support its implementation."*

		"I personally am ready and willing to recycle food waste separately, however the block of flats that I currently live in do not currently provide recycling bins for other recycling such as plastic or card. *Due to this I feel that I would not be ready or able to recycle food waste."* *"Our local council does not supply any recycling facilities at all for our block of flats, and has not done so for over a year."*
Reflective motivation	Pessimism (*n* = 5)	*"I am not sure if this would actually make a difference"* *"People still won't bother"*
Psychological capability	Knowledge (*n* = 3)	*"Not sure what can go in food waste recycling."* *"…Bit more training on what goes in would be nice."*

Notes: n = number of participants.

4.5. Discussion

This study aimed to identify: capability-, opportunity- and motivation-related influences on food waste recycling amongst UK citizens; the reasons why citizens with access to food waste collection services do not recycle food waste; the reasons why citizens who do recycle do not use compostable caddy liners, and; the reasons why citizens feel unprepared for UK-wide food waste collection services.

Quantitative findings showed that psychological capability and automatic motivation were significant predictors of food waste recycling behaviour. Having a higher annual household income, identifying as female, being less educated and living in semi-detached (vs terraced) housing made citizens more likely to recycle food waste. Physical opportunity (i.e., dealing with food waste in other ways such as home-composting or feeding pets/strays, time and financial costs) was the main barrier to recycling food waste identified in qualitative analyses. Participants also reported automatic motivation-related barriers such as concerns over pests, odour and/or hygiene and local authorities' food waste collection capabilities.

Barriers to using compostable caddy liners included: engaging in conflicting behaviours such as cleaning the bin out after each use or repurposing other materials such as newspaper (physical opportunity), council-related barriers such as the council not accepting compostable liners (physical opportunity), low availability and accessibility of compostable liners (physical opportunity) and the perception that compostable liners are unnecessary and wasteful themselves (reflective motivation).

Participants reported feeling unprepared for nationwide food collection services due to a lack of scheme awareness (psychological capability), not having

the time or space to take on the extra responsibility (physical opportunity) and a lack of confidence that there is a public need for food waste collection services (reflective motivation). Concerns relating to pests, pollution and implementation (automatic motivation) were also reported.

These results support and extend prior findings. There is ample research showing that higher-income households (237, 238) and women are more likely to recycle (239); this study suggests that this also extends to food waste. The higher rates of recycling by citizens living in semi-detached (vs terraced housing) could be due to these homes being more spacious e.g., by allowing for more bin space both inside and outside the home – the qualitative findings support the lack of household space as a barrier to recycling.

Some results contradict prior findings. Higher levels of education are, in general, found to positively influence recycling behaviours (238, 240, 241) whereas we found higher levels of education to decrease recycling. Given the older age, majority retired and higher income nature of the sample, the results could be explained by the fact that those who were more educated were more likely to engage in home-composting and so less likely to recycle food waste using local services; older age, being retired, higher household income and higher education are all factors associated with engagement in home-composting (242, 243). However, since data was not collected on participant home-composting status, it is difficult to ascertain conclusively whether this factor influenced results.

The association of automatic motivation and psychological capability on behaviour is expected. Automatic motivation-related behavioural influences including

emotions, such as guilt, and habits have previously been identified as predictors of both recycling behaviours (152, 153) and household food waste management behaviours (150, 151). Disgust has been identified, across a variety of countries and contexts, not only as a key emotion specific to deterring the handling of food waste (244, 245) but also as an emotion important to understanding food waste behaviours, more generally (150, 246, 247). As reported in the previous chapter of this thesis (Study 2), psychological capability-related barriers, such as lack of knowledge (i.e., knowing which bin to what which waste items in), are associated with disposal of biodegradable and compostable plastic packaging (48, 50) and recycling of waste materials more generally (248).

The salience of physical opportunity as a key barrier across the qualitative findings is also in line with prior findings. Other studies report the lack of necessary infrastructure to participate in household waste recycling as one of the most important barriers for households not to participate in recycling activities (249). In addition, participants' reasons for feeling unprepared for nationwide food collection (i.e., concerns relating to space, hygiene, implementation and management) are echoed in other similar studies investigating barriers to engagement with food waste recycling schemes (245).

4.5.1. Implications and recommendations

There are strong implications and potential applications of the findings in this study. Getting citizens engaged in food waste recycling schemes is a major concern for local UK authorities (250). It is hoped that the results can help inform behaviour change interventions that will lead to successful food waste collection and recycling strategies. In terms of intervention design, the results suggest that strategies

increasing citizen's automatic motivation (e.g., making recycling food waste a regular household routine and reducing the perceived 'unpleasantness' associated with handling food waste) and psychological capability (e.g., increasing knowledge of what items can go into their food waste bins) are likely to be most effective at getting citizens to separate their food waste for recycling within the home. This could involve the development of clear, consistent communications aimed at increasing knowledge of what can and cannot be put in food waste bins. This, in turn, would benefit from consistency in the items that can be collected and processed across regions. It could also involve the improved functional design and free distribution of bins (e.g., well-ventilated) and compostable caddy liners (e.g., that do not disintegrate), developed according to user-centred needs for cleanliness, convenience and hygiene.

The study findings reveal a lack of faith in local authorities' ability to collect waste regularly and efficiently. There also appears to be inconsistent messaging from local authorities concerning compostable caddy liner use – some residents are asked to use them while others are told not to. At present, there also appears to be concern from UK citizens about whether implementing nationwide food waste collection and recycling services is a meaningful and useful use of public funds. So, although the majority of participants felt ready for nationwide food waste collection services, the results suggest that to increase the likelihood of successful implementation, a UK-wide food waste collection service would benefit from ensuring it is nationally uniform (to increase consistency), efficient (to increase engagement) and reliable (to increase trust). It is therefore imperative that alongside increasing local councils' physical capabilities to collect food waste, there are public campaigns aimed at not only increasing the public's confidence in local council's capabilities but

also highlighting the importance of food waste recycling for public and environmental health to shift public perception of the value of this service. Only when this system runs sufficiently is there the appropriate behavioural and material context for the disposal of compostable plastic packaging.

4.5.2. Limitations and future research

This study's sample has some limitations regarding generalizability. While the sample was representative in terms of ethnicity, income, dwelling type, and access to local food waste collection services, as well as cohabitation arrangement and the number of people in the household, it primarily consists of older, retired, female, and highly educated homeowners. These groups may differ in their capability, opportunity, and motivation to recycle food waste when compared with other demographics such as people with less education, renters or young professionals.

Informed by the limitations of the previous study in this thesis (outlined in Chapter 3), extensive socio-economic and behavioural demographic data was collected to better understand the participant sample and control for these variables in analyses. Nonetheless, given the recruitment strategy and self-selecting and voluntary nature of participation, this study may have attracted more ‘pro-environmental’ participants and those more likely to recycle food waste. This is exemplified by the fact that although many participants had not heard of the UK’s plan to implement nationwide food waste collection, the majority indicated feeling ready for it. Recycling behaviours are morally relevant (154) and often exaggerated behaviours (251). Though meta-analyses have shown the relationship between social desirability and pro-environmental intentions and behaviours to be small (252), it is not unlikely for this study to have suffered social desirability bias. This is exemplified by the fact that the

majority of participants indicated that they *always* put food waste in the food waste bin.

To address this limitation, it is recommended that future studies also collect data on 'psychological' demographics, e.g., environmental orientation, political leaning, etc. This is particularly important for environmental research where such variables may influence results. There are evidence-based toolkits designed to support this process. For instance, the segmentation of the British public was published by Climate Outreach in its Britain Talks Climate report (253). Based on research and stakeholder consultation, this report segments the British public into seven possible 'psychological' groups using a range of ideological and psychological factors which provides insight on how they might engage with issues relating to climate change. Collecting such data allows for more holistic participant sample descriptions, the ability to control for these variables in analyses and better contextualisation of results.

A further limitation of this study is the fact that data was not collected on whether participants engaged in home composting. Given that one of the sampling techniques was via a home-composting citizen science experiment mailing list, it is plausible that home-composting status may have impacted whether or not one recycled via local collection services; this was also the top reason provided for not recycling food waste via local collection services. Collecting this data would have allowed for this factor to be controlled for in regression analyses if found to be associated with food waste recycling behaviour. Data relating to home-composting status and psychological demographics are collected and factored into the analysis of the final study in this thesis (Study 6 reported in Chapter 7).

Reflecting on the process of 'diagnosing' behaviour this study versus the previous study, potential methodological challenges were identified. In the previous study, COM-B was used as a qualitative data analysis framework to analyse open-ended answers to a survey question; TDF was not used at all. In this study, COM-B was used both as a qualitative and quantitative data collection and data analysis framework; TDF was only used to help inform the development of the survey items. As in Study 2, no major issues were identified using COM-B as a deductive data analysis framework to organise inductive thematic findings aside from minor challenges in judging which COM-B category to map thematic findings to. However, using COM-B alone to design a survey was found potentially limiting due to the model's breadth. TDF's granularity made it easier to check no likely important influences on behaviour were being omitted from the survey e.g., by cross-referencing a preliminary set of survey items with each TDF domain. As highlighted in Study 1, using TDF as the regression framework may have allowed for quantitative conclusions about behavioural influences to be made at a more granular level, with clearer implications for intervention design. Although the COM-B model offers many advantages, such as its ability to communicate research findings accessibly, it has limitations when it comes to providing detailed information in some contexts. On the other hand, the TDF provides a higher level of detail, making it useful for designing surveys and conducting more targeted analyses. Therefore, it is recommended to use a combination of both models in research to capitalize on their strengths and address their limitations.

4.6. Conclusion

Implementation of a nationwide food waste collection strategy relies not only on developing the appropriate infrastructure but also on citizens adopting the necessary set of food waste recycling behaviours. Adoption of this new set of recycling behaviours is a prerequisite for the recycling of compostable plastic packaging. Although UK-focused, the results have valuable implications for food and compostable plastic policy and intervention design. To achieve food recycling behaviour change, strategies for increasing capability might include ensuring clear and consistent messaging about what can and cannot be put in food waste bins; strategies for increasing opportunity might include providing free bins, caddies and liners; strategies for increasing motivation might include ensuring bins, caddies and liners are designed to meet user needs for cleanliness, convenience and hygiene; and ensuring new services are properly resourced to run effectively in the first instance. Only when this system runs sufficiently is there the appropriate behavioural and material context for the disposal of compostable plastic packaging. Collecting 'psychological' demographic data and data on participants' home-composting status will help promote the richness and conclusiveness of results.

5. Chapter 5 – Improving compostable plastic disposal: an application of the Behaviour Change Wheel intervention development framework (Study 4)

5.1. Abstract

Background: Compostable plastics have great potential environmental benefits; however, the damage caused by incorrect waste management offsets them.

Aims: This study aims to develop a behaviour change intervention that enables the desired disposal of compostable plastics.

Materials: The Behaviour Change Wheel framework is applied to guide intervention development. The GUIDED (Guidance for the reporting of intervention development) framework is used to improve documentation of the development process. Scientific findings, including the results of previous studies in this thesis, are used as evidence alongside industry data and stakeholder feedback.

Method: The target behaviour was specified and potential behavioural influences were identified using the COM-B model. Behavioural influences were systematically linked to potential intervention strategies and refined by evaluating them against APEASE criteria in a UK implementation context. Intervention content and policy options were finalised by systematically selecting specific behaviour change techniques and refining them by evaluating them against APEASE criteria.

Results: The target behaviour was identified as UK citizens disposing of compostable plastic waste in the food waste bins used for collection by local authorities. Influences on compostable plastic disposal were identified as "psychological capability" (i.e., attention and knowledge), "reflective motivation" (i.e.,

beliefs around the environmental impact of compostable plastics) and “physical opportunity” (i.e., access to appropriate waste management). “Education” and “environmental restructuring” were the intervention types selected. “Communications/marketing”, “guidelines” and “restructuring the physical and social environment” were the policy options selected. Selected behaviour change techniques were: instruction on how to perform the behaviour, prompts/cues, adding objects to the environment and restructuring the physical environment. The resulting intervention is a disposal instruction label for compostable packaging, comprising instructions and a logo.

Conclusions: This study documents the application of a behaviour change framework to the development of an intervention to reduce compostable plastic waste. Systematically developing interventions and documenting the process advances behaviour change science by promoting a transparent approach to intervention design.

5.2. Background

The studies reported in Chapters 2-4 in this thesis aimed to identify and understand key behaviours concerning plastic waste. Chapters 3 and 4 specifically focus on behaviour concerning compostable plastic packaging. The present study aims to integrate the findings of the prior studies in this thesis to develop an intervention aimed at promoting compostable plastic disposal. Such an intervention is important given the rise in compostable plastic. Global bioplastics production capacities are expected to increase from around 2.23 million tonnes in 2022 to approximately 6.3 million tonnes in 2027 (254). The intervention is evaluated for effectiveness in the final study of this thesis (Study 5). A version of the work presented in this chapter has been published in the journal Frontiers in Sustainability (51).

As highlighted in Chapters 1, 3 and 4, many aspects of the compostable plastic 'system' are currently unregulated, lacking or underperforming. These include labelling, certification, infrastructure and citizens' behaviours (182, 255). As shown in Figure 5.1, this hinders the potential environmental benefits of compostable plastic production, use and waste management. An overview of the problem areas relating to compostable plastic production, use and waste management are provided below.

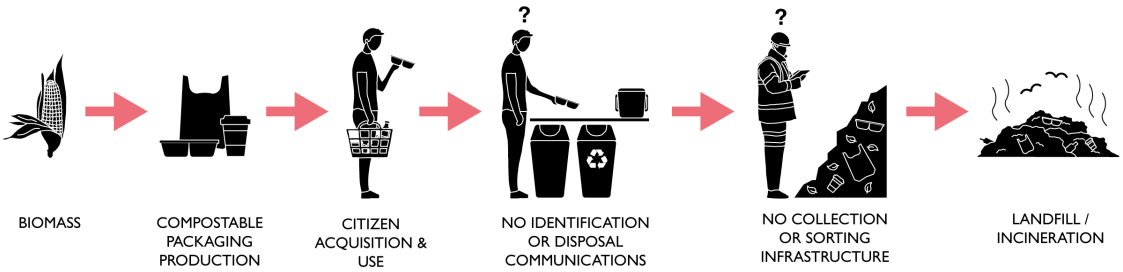

Figure 5.1 A linear economy of compostable plastics (reproduced with permission from (51)).

5.2.1. Labelling

Compostable packaging labelling is defined by mandatory and non-mandatory labelling requirements as well as manufacturing marketing strategies. General Product Safety Regulations 2005 (256) set out the mandatory labelling criteria for products being supplied within or into the UK and Northern Ireland by producers and importers. In the UK, enforcement of the 2005 Regulations is carried out by local trading standards authorities and the UK Secretary of State (257). The Regulations set out the minimum labelling requirements for all products and packaging including the display of the name and address of the producer and product reference or batch code (257).

Labelling plays a key role in providing packaging and product visibility. It also helps communicate information about material identity and disposal instructions. While special rules apply for precious metals, footwear, food and drink, and products for children e.g., prepacked food and drink must display information that includes best before or use-by date, quantitative ingredients list, and nutrition information (258), there are currently no special rules for compostable plastics. As mentioned in Chapter 1, this means that manufacturers and suppliers of these materials are at liberty to label and market them as they prefer, leading to inconsistencies. Study 2 (Chapter 3) revealed some of the key impacts of these inconsistencies; widespread citizen confusion surrounding compostable packaging terminology such as “home compostable,” “industrially compostable,” and “biodegradable,” leading to growing public mistrust in compostable packaging claims.

5.2.2. Certification

Given that citizens struggle to distinguish the biodegradability of compostable plastic, authorities need to provide definitions of biodegradability and biodegradation, and for international testing methodologies to be developed. ISO 14021:2016 standard specifies requirements for self-declared environmental claims, including statements, symbols and graphics, regarding products, not precluding legally required environmental information, claims or labelling (259). The standard does not serve as verification of environmental claims, instead requiring third-party verification through an accredited certification scheme (260). UK guidance about non-mandatory packaging communications for compostable packaging labels exists, including advice to avoid statements such as “100% compostable,” “compostable,” “biodegradable,” and “plastic-free” (192).

Although information about a product's packaging material type and recycled content or disposal instructions is not currently mandatory, the UK Government is consulting on the introduction of mandatory labelling of packaging under new Extended Producer Responsibility scheme reforms to be introduced in early 2024 (209). Current implementation target dates are mandatory labelling for all packaging types (except plastic films and flexibles) by 2026, with plastic film and flexibles included by 2027 (261). Other comparable non-mandatory labelling schemes exist such as the On-Pack Recycling Label (OPRL). While there is no comprehensive EU legislation specifically harmonizing standards for environmental and product marketing claims, several logos and standard labels exist that can serve as a basis for evaluating claims for compostable plastics (260).

In addition, manufacturers can obtain third-party certification of industrial and/or home compostable plastic performance from several certification bodies that use overarching standard test criteria to demonstrate compliance. In Europe, the most important certification schemes that demonstrate compliance with EN 13432 (suitable for industrial composting conditions), are DIN CERTCO (Germany), TÜV Austria (formerly Vinçotte), OK Compost label (Belgium), and Compostabile CIC (Italy) (262). In the UK, the Association for Organics Recycling operates a certification scheme in partnership with Germany's DIN CERTCO scheme that aligns with the requirements of EN 13432 (263).

While these certification schemes for industrially compostable plastics are a step in the right direction, there exists no legislation, at present, to enforce them. In addition, there lacks a reliable, nationally uniform system for collecting, sorting and processing compostable plastic waste in the UK. As a result, certified as compostable or not, compostable plastics represent a growing contaminant in plastics recycling and some food waste collection systems if the system cannot manage them.

5.2.3. Infrastructure

Life cycle assessment shows that the current system, with no dedicated UK-wide collection and processing facilities for compostable plastics, is not environmentally favourable (264, 265). Compostable plastics could be part of a sustainable UK packaging system with improved systems for collection, sorting and processing. More work is required to ensure reliable sorting of compostable plastics; there is currently no working technical solution to the automatic separation and sorting of compostable plastics, though progress is slowly being made in this space (266).

As mentioned in Study 3 (Chapter 4), the UK Government has consulted on changes to waste collection consistency and aims to introduce mandatory food waste collection for UK households by 2024 (261). This is largely driven by policy targets to improve recycling rates, reduce contamination to improve recyclate quality across different waste streams, and reduce the associated environmental impacts of sending compostable waste to landfills (261). The proposed scheme provides a promising opportunity to reliably collect and process a growing waste stream of compostable plastics. However, there are challenges to this. For instance, some local authorities in the UK do not want compostable plastic to go to food waste as they do not send food waste to Industrial Composting. Additionally, the development of new waste infrastructure raises critical questions about UK citizens' behavioural adaptation to changes in current residual waste disposal and recycling practices and their preparedness for new and unfamiliar separate compostable waste recycling infrastructure.

5.2.4. Public engagement

As highlighted in Chapter 1, engaging the public is critical for a sustainable compostable plastic packaging system. Citizens are the ones who purchase, use and initiate the end-of-life pathway of compostable plastic waste, ensuring whether or not composting takes place. Chapter 1 and Chapter 4 (Study 3) highlight how citizens' adoption of the required food waste recycling behaviours will be critical for a circular economy of compostable plastics, as food waste collection is the only viable route for their management, en masse. The findings of Chapter 4 suggest that more work is needed in this area. Not only are there still many UK citizens who lack access to food waste collection services, but many with access still do not engage

with these services. Study 2 (Chapter 3) highlights the public's lack of understanding about compostable plastics including confusion regarding their disposal. These findings are supported by studies assessing people's disposal of compostable plastics showing that they frequently dispose of them incorrectly e.g., in the recycling bin (49, 50). Taken together, this evidence shows that changes to current patterns of disposal behaviour are required to fully realize the benefits of compostable plastics. Introduced in Chapter 1, Figure 5.2 highlights what a circular economy of compostable plastics in the UK could look like.

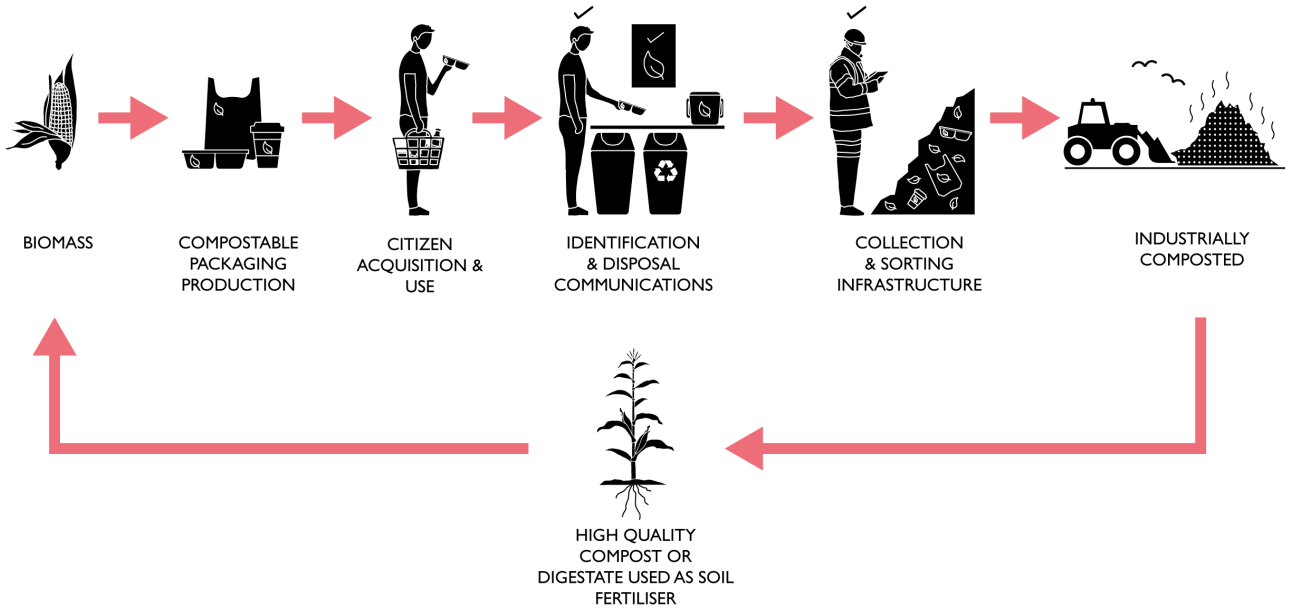

Figure 5.2 A circular economy of compostable plastics (reproduced with permission from (51)).

Disposal behaviour (i.e., which bin citizens put plastic into) is a key part of getting the compostable plastic "system" to work; if citizens get it wrong then the system does not work because the materials will not end up composting. As found in Study 2 (Chapter 3), there is widespread confusion about what compostable plastics are and

how to dispose of them. Behaviour change in this area is likely to achieve the desired outcome of reducing plastic waste by reducing the rates of incorrect disposal. To this end, this study aims to design a behaviour change intervention that improves the disposal of compostable packaging in the UK.

5.3. Materials

This section details the materials used to develop the intervention.

To guide the intervention development process, the Behaviour Change Wheel (34, 35) introduced in Chapter 1 was applied as an intervention development framework.

To improve intervention documentation, the GUIDED framework, which guides the reporting of intervention development studies in health research, was used (267).

As evidence, the findings from previous studies in this thesis (which have been peer-reviewed and published in journals) were used as source material. Other peer-reviewed scientific studies and industry findings were also used. These were sourced through the systematic review conducted in Study 1 and supplementary literature searches. Stakeholder feedback was also used as source material and was obtained via two stakeholder consultation workshops.

5.3.1. GUIDED framework

GUIDED is a 14-item checklist which contains a description and explanation of each item alongside examples of good reporting. Its objective is to improve the quality and consistency of intervention development reporting in health research. The GUIDED framework was prioritised over the TIDieR framework (162) as GUIDED was designed not only to improve the reporting of intervention descriptions (i.e., TIDierR's aim) but also to improve the reporting of *how* interventions are designed e.g., their rationale, involvement of stakeholders etc. GUIDED also encompasses TIDieR. Though developed for a health context, GUIDED's checklist items are also valuable to the present circular economy context as they offer

transferrable principles for good intervention documentation practice. The checklist was used to ensure that the following were reported:

1. The context for which the intervention was developed,
2. The purpose of the intervention,
3. The target population,
4. How published intervention development approaches contributed to the development process,
5. How evidence from different sources informed the intervention development process,
6. How published theory informed the intervention development process,
7. How guiding principles, people or factors were prioritized when making decisions during the intervention development process,
8. How stakeholders contributed to the intervention development process,
9. How the intervention changed in content and format from the start of the intervention development process,
10. The uncertainties that remained at the end of the intervention development process (e.g., requirement for piloting),
11. The intervention is described according to TIDieR guidance (162),
12. The study is published via an open-access format at the publication stage.

The items not reported on included “use of components from an existing intervention in the current intervention development process” and “any changes to interventions required or likely to be required for subgroups” as these were not deemed applicable to the present intervention.

5.3.2. Intervention development framework

Introduced in Chapter 1, Section 1.3.1, the Behaviour Change Wheel framework was used to understand the target behaviour in its context, to select intervention options and to identify content and implementation options. These broad phases were broken down into the sub-stages shown in Figure 5.3. The subsequent sections of the Method (5.4) and Results (5.5) are structured according to these three broad phases.

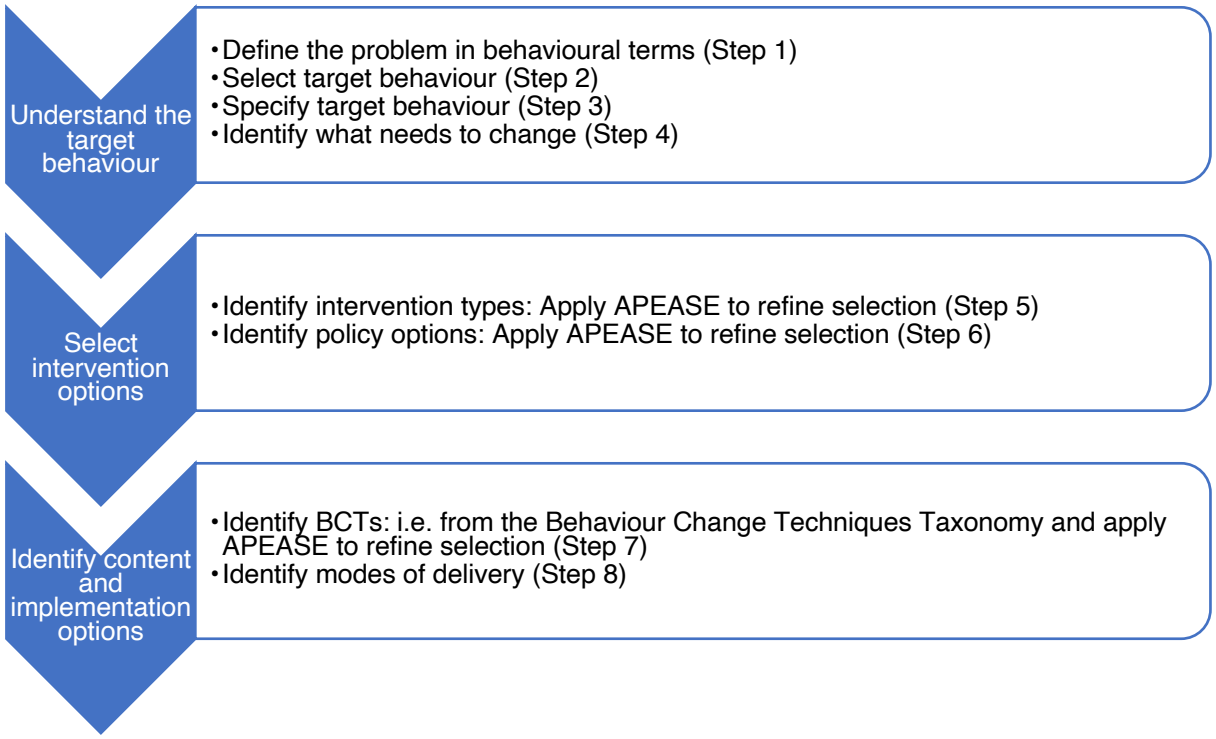

Figure 5.3 Overview of the Behaviour Change Wheel's systematic and theory driven intervention development approach (reproduced with permission from (51)).

5.3.3. Evidence

A multi-method, iterative approach was used to integrate seven sources of evidence as outlined in Figure 5.4 and listed below.

1. The findings of Study 1 reported in Chapter 2 (Reducing plastic waste: a systematic review and meta-analysis of behavioural influences and interventions),
2. The findings of Study 2 reported in Chapter 3 (Barriers and enablers to compostable plastic packaging purchase: a qualitative study amongst UK citizens),
3. The findings of Study 3 reported in Chapter 4 (Barriers and enablers to recycling food waste: a mixed methods study amongst UK citizens),
4. Two experiments testing citizens' disposal of compostable plastics (49, 50)
5. A survey investigating citizen's bioplastic knowledge, perceptions and end-of-life management (174)
6. A report summarizing research insights on citizen's behaviour toward packaging labelling design by OPRL (268)
7. A review of research studies into On-pack Labelling and Citizen Recycling Behaviour (269).

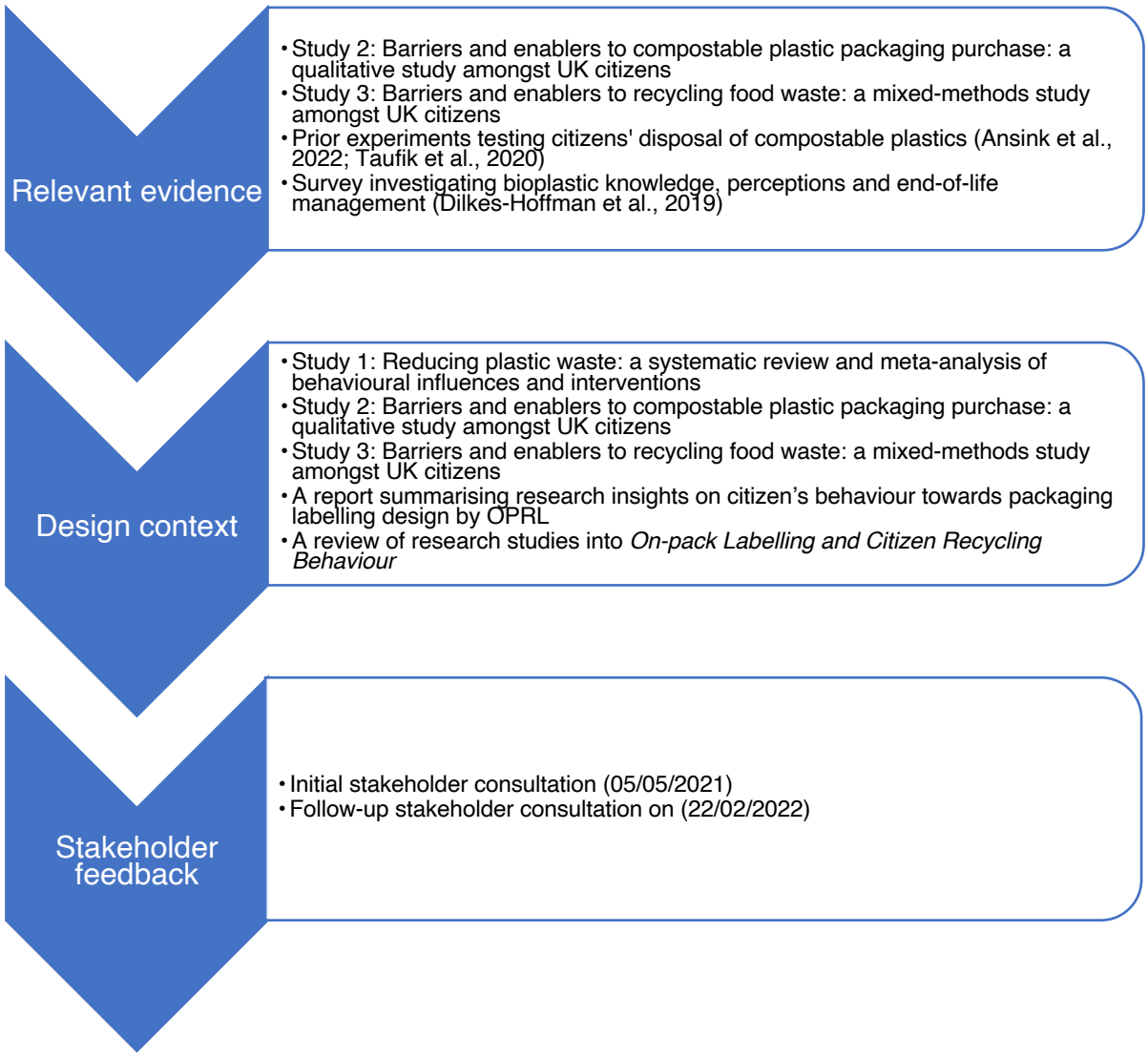

Figure 5.4 Overview of materials and resources used as evidence (reproduced with permission from (51)).

Two consultation workshops were conducted on 05/05/2021 and 22/02/2022. The consultations aimed to support the design process and ensure the practicability, relevance, utility and acceptability of the intervention. Stakeholders for the first consultation workshop were engaged via the UCL Plastic Waste Innovation Hub's professional network of industry stakeholder partners; an invitation email was sent out to all contacts. Stakeholders for the second consultation workshop were

purposefully selected as priority industry stakeholder contacts. As shown in Table 5.1, a range of UK stakeholders ended up participating including representatives from academia (n = 4), industry (n = 3), non-profit (n = 7) and government (n = 3). To protect anonymity, the names of individuals have been omitted.

Owing to COVID-19 lockdown measures, stakeholders were consulted via a 2-hour virtual workshop for the first stakeholder consultation. Potential intervention strategies and methods for evaluation were presented to stakeholders via slides. All workshop attendees were encouraged to contribute their views and opinions on the intervention and evaluation approaches via a live Q&A afterwards (verbal feedback) or the chat function (written feedback). The workshop slides were circulated to attendees via email after the meeting where they could provide additional written feedback via email. The second stakeholder consultation workshop took place in person. It involved showing the prototype label designs to the attendees and obtaining their verbal feedback on the label designs.

Table 5.1. Groups represented in the stakeholder consultation workshops.

Stakeholder group	**Workshop 1 (05/05/2021)**
Non-profit	On-Pack Recycling Label (OPRL), n = 2
	Bio-based and Biodegradable Industries Association (BBIA), n = 1
	The National Association of Waste Disposal Officers (NAWDO), n = 1
	Renewable Energy Association (REA), n = 1
	The Waste and Resources Action Programme (WRAP), n = 1
Industry	Vegware, n = 1
	Renewable Energy Assurance Limited (REAL), n = 1
Government	Department for Environment, Food & Rural Affairs (DEFRA), n = 3
Academic	UCL (Behaviour), n = 1

	UCL (Materials), *n* = 1
	UCL (Design), *n* = 1
	UCL (Policy), *n* = 1
Stakeholder group	**Workshop 2 (22/02/22)**
Non-profit	On-Pack Recycling Label (OPRL), *n* = 1
	A Plastic Planet, *n* = 1
Industry	Co-op, *n* = 1
Academic	UCL (Behaviour), *n* = 1
	UCL (Materials), *n* = 1
	UCL (Design), *n* = 1

Notes: n = number of people; For non-profit, total *n* = 7 because the one person attended both workshops and so is represented twice.

5.4. Method

5.4.1. Understand the target behaviour

As detailed in Figure 5.3, four steps were taken to understand the target behaviour. First, the problem of plastic waste was conceptualised in behavioural terms. Second, a target behaviour for the intervention was selected. Steps one and two were completed by reviewing the literature referenced in Chapters 1-2. The findings of Study 1 (Chapter 2) also informed these steps. Third, the target behaviour was clearly specified as per Behaviour Change Wheel guidance i.e., in terms of who does what, where, when, and with whom (34).

Finally, potential influences on the target behaviour were identified. As shown in Figure 5.4, this was done by synthesising the findings of five relevant studies that identified potential influences on the target behaviour. Two of these studies included Study 2 (Chapter 3) and Study 3 (Chapter 4). An additional three studies were included to supplement the behavioural diagnosis which were identified through the systematic review in Study 1 (50) and a supplementary online peer-reviewed literature search (49, 174). Illustrated in Table 5.2, the process of identifying influences on the behaviour was supported via a systematic mapping exercise. Potential influences were extracted from the written manuscripts of the five relevant studies, entered into a table and mapped onto the elements of COM-B that they were judged to best represent (i.e., physical capability, psychological capability, social opportunity, physical opportunity, automatic motivation and reflective motivation).

5.4.2. Select intervention options

The Behaviour Change Wheel guide offers guidance on the types of intervention types and policy options that are most likely to be effective at targeting physical capability, psychological capability, social opportunity, physical opportunity, automatic motivation and reflective motivation (34). This stage of intervention development involved selecting intervention types (Step 5) and policy options (Step 6) from the Behaviour Change Wheel guidance that were most likely to be effective for changing the behavioural targets identified in the COM-B analysis in the previous step. This process was supported by two separate mapping exercises, the results of which are illustrated in As shown in Table 5.3, the intervention types selected were education and environmental restructuring. As shown in Table 5.4, the policy options selected were guidelines, communications/marketing and environmental/social planning.

Four intervention types were considered inappropriate and so excluded: enablement, persuasion, modelling and training. Persuasion and modelling were not deemed likely to be very effective as the target behaviour is not one where people lack motivation or inspiration to enact the desired behaviour. The analysis of influences on behaviour showed that people have pro-environmental intentions and wish to “do the right thing” when it comes to compostable plastic packaging. The issue rests primarily in attention and misinformation, therefore inducing positive or negative feelings or providing something for people to aspire to in order to stimulate action is unlikely to inspire significant behaviour change. Training was excluded on grounds of practicality and affordability. A training programme would likely be costly to run and not practical in terms of where, when, how and by whom it could be

implemented. Enablement was excluded because, based on the behavioural diagnosis, any intervention strategy is unlikely to go beyond education and environmental restructuring.

Four policy options were excluded: service provision, legislation, regulation and fiscal measures. Service provision was excluded as the implementation of nationwide food waste collection services is already planned by the UK government; therefore, addressing the physical opportunity-related barriers concerning access to waste management services. Fiscal measures would likely require legislation changes, something that would rely upon elected politicians' willingness to propose such changes. There would also be questions of affordability dependent on the economic climate at the time of the intervention, and thus the use of this policy category could become less acceptable. At the time of writing this thesis in 2023, there is an ongoing cost of living crisis in the UK. Legislation was not practical to focus on within this project as the process involved would be out of scope for a PhD research study.

Table 5.3 (intervention types) and Table 5.4 (policy options).

5.4.2.1. Selecting intervention types

In the first exercise, the COM-B behavioural targets identified were mapped onto the potential intervention types that the Behaviour Change Wheel guide suggests could be used to change them. Introduced in Chapter 1, all of the potentially relevant intervention types identified were evaluated against APEASE criteria (Acceptability, Practicability, Effectiveness, Affordability, Side-effects) to decide whether or not they should be moved forward to the next stage of intervention design.

5.4.2.2. Selecting policy options

In the second exercise, the intervention types decided on in the previous step were mapped onto the potential policy options the Behaviour Change Wheel guide suggested. All of the potentially relevant policy options identified were evaluated against APEASE criteria to decide whether or not they should be moved forward to the next stage of intervention design.

5.4.3. Identify content and implementation options

The content (Step 7) and implementation (Step 8) options were considered and developed iteratively, in the phased approach shown in Figure 5.5.

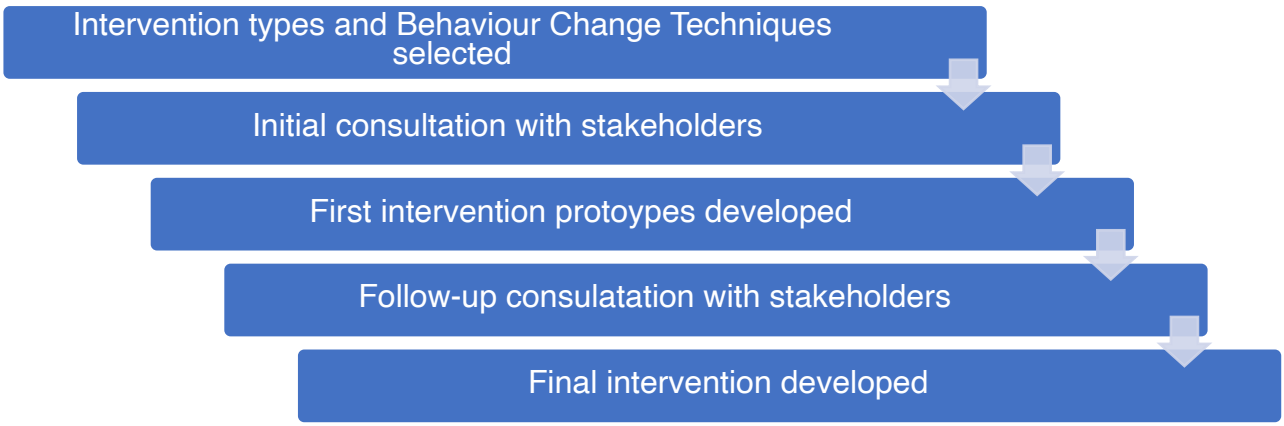

Figure 5.5 Steps taken to develop content and implementation options (reproduced with permission from (51)).

5.4.3.1. Intervention content

Content refers to the potentially 'active ingredients' of an intervention that can bring about change. They were chosen using the Behaviour Change Technique Taxonomy to select BCTs. The BCT Taxonomy has been introduced in Chapter 1. The Behaviour Change Wheel guide offers guidance on the BCTs most commonly used per intervention type and was used in two mapping exercises, illustrated in two separate tables, supporting the process of selecting BCTs.

In the first exercise, the selected intervention types were mapped onto the potential BCTs recommended by the Behaviour Change Wheel guide (see Table 5.5).

In the second exercise, all of the potentially relevant BCTs identified were evaluated against APEASE criteria to decide whether or not they should be moved forward to the next stage of intervention design (see Table 5.6).

5.4.3.2. Implementation options

Selected BCTs at this stage were taken to the initial stakeholder workshop for consultation. Potential implementation options were discussed. Based on the implementation option decided upon by the group, the selected BCTs were further narrowed down (see Table 5.7).

The prototype intervention was developed to deliver the final selected BCTs by the author of this PhD in collaboration with an architect and designer at the UCL Plastic Waste Innovation Hub (DP). They were then revised iteratively based on feedback from a second stakeholder workshop.

5.5. Results

5.5.1. The target behaviour

5.5.1.1. The problem defined in behavioural terms

The issue of plastic waste was conceptualised as a problem with waste management i.e., a lack of reducing, reusing, recycling and composting plastic. This is in line with the UK Plastics Pact (270) and "waste hierarchy" set out in Article 4 of the European Union's revised Waste Framework (Directive 2008/98/EC) (25). The systematic review in Study 1 supported this by showing that all behaviours identified in the literature related to either one of these four broad categories of behaviour.

5.5.1.2. The target behaviour selected

To reduce plastic waste, various behaviours relating to reducing, recycling, reusing and composting could have been selected. The disposal of compostable plastics was prioritized owing to a dearth of evidence on this topic, as identified by the systematic review in Chapter 2 (Study 1) - behaviour concerning compostable plastic was the most understudied of these four broad groups of waste management behaviours. Compostable plastics are becoming increasingly available on the market without a reliable system for collecting, sorting or processing them (182). This means there is an increasing risk of contaminating other plastics recycling and some food waste collection systems, which are not able to process compostable plastics. Improving the current system for the disposal of compostable plastics is likely to be an effective way of reducing plastic waste.

5.5.1.3. The target behaviour specified

The selected behaviour of compostable plastic disposal was further specified as UK citizens (who), discarding compostable plastic packaging (what), in the food

waste bin meant for collection by local authorities (how), at the point of disposal (when) within the home (where).

5.5.1.4. What needed to change

As shown in Table 5.2, influences on disposal behaviour were found to be predominantly rooted in psychological capability, reflective motivation and physical opportunity. Citizens were found to lack knowledge of and familiarity with compostable plastics which led to confusion regarding what to do with these items at end-of-life. This was also related to issues of attention i.e., not being able to identify compostable packaging over non-compostable plastic packaging and not noticing the wording and logos on packaging that are intended to communicate the appropriate end-of-life instructions. Lack of knowledge and familiarity is also likely related to holding erroneous beliefs about the nature and processing of compostable plastic waste (e.g., that they cannot be processed via mechanical recycling). In addition, without access to appropriate waste management infrastructure i.e., bins and waste collection services, people cannot dispose of these correctly.

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Table 5.2. Factors associated with compostable plastic waste disposal.

	Taufik et al 2019 (50)	**Ansink et al 2022 (49)**	**Dilkes-Hoffman et al 2019 (174)**	**Study 2 (Barriers and enablers to compostable plastic packaging purchase)**	**Study 3 (Barriers and enablers to recycling food waste)**
Phys Cap	n/a	n/a	n/a	n/a	n/a
Psych Cap	Compostable plastic familiarity Understanding terminology and labels used to communicate disposal instructions Not being able to distinguish between compostable and non-compostable plastic packaging	Compostable plastic familiarity Understanding terminology and labels used to communicate disposal instructions Attention to waste management labels and logos on packaging	Compostable plastic familiarity Understanding terminology and labels used to communicate disposal instructions	Compostable plastic familiarity Understanding terminology and labels used to communicate disposal instructions Attention to waste management labels and logos on packaging	Compostable plastic familiarity
Soc Opp	n/a	n/a	n/a	Tension with neighbours if compostable plastic is put in communal organic/food waste bins	Waste collectors think organic/food waste has been contaminated with plastic bag and so do not take the waste
Phys Opp	n/a	n/a	n/a	Access to local organic/food waste collection services	Access to local organic/food waste collection services
Aut Mot	n/a	Environmental concern	n/a	n/a	n/a
Ref Mot	Belief that plastic should always be recycled and not composted Belief that plastic can be compostable in the first instance	Personal moral norms	Perception that it is okay to litter compostable plastics	n/a	n/a

5.5.2. Intervention options selected

As shown in Table 5.3, the intervention types selected were education and environmental restructuring. As shown in Table 5.4, the policy options selected were guidelines, communications/marketing and environmental/social planning.

Four intervention types were considered inappropriate and so excluded: enablement, persuasion, modelling and training. Persuasion and modelling were not deemed likely to be very effective as the target behaviour is not one where people lack motivation or inspiration to enact the desired behaviour. The analysis of influences on behaviour showed that people have pro-environmental intentions and wish to “do the right thing” when it comes to compostable plastic packaging. The issue rests primarily in attention and misinformation, therefore inducing positive or negative feelings or providing something for people to aspire to in order to stimulate action is unlikely to inspire significant behaviour change. Training was excluded on grounds of practicality and affordability. A training programme would likely be costly to run and not practical in terms of where, when, how and by whom it could be implemented. Enablement was excluded because, based on the behavioural diagnosis, any intervention strategy is unlikely to go beyond education and environmental restructuring.

Four policy options were excluded: service provision, legislation, regulation and fiscal measures. Service provision was excluded as the implementation of nationwide food waste collection services is already planned by the UK government; therefore, addressing the physical opportunity-related barriers concerning access to waste management services. Fiscal measures would likely require legislation changes, something that would rely upon elected politicians' willingness to propose

such changes. There would also be questions of affordability dependent on the economic climate at the time of the intervention, and thus the use of this policy category could become less acceptable. At the time of writing this thesis in 2023, there is an ongoing cost of living crisis in the UK. Legislation was not practical to focus on within this project as the process involved would be out of scope for a PhD research study.

Table 5.3 Intervention types appropriate for targeting underlying behavioural influences.

COM-B	Intervention type	Definition	APEASE	Included/exclude from next stage
Psychological Capability (i.e., attention and knowledge)	Education	Increasing knowledge or understanding	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Included
	Training	Imparting skills	Considered potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity** but not considered **affordable** or **practical**	Excluded
	Environmental restructuring	Changing the physical or social context	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Included
Physical Opportunity (i.e., access to appropriate waste collection services)	Environmental restructuring	Changing the physical or social context	Access to the appropriate waste collection services is going to become available with the introduction of nation-wide food waste collection in 2023	Excluded
Reflective motivation (i.e., beliefs)	Education	Increasing knowledge or understanding	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Included
	Persuasion	Using communication to induce positive or negative feelings to stimulate action	Considered **practical**, potentially **acceptable**, should have limited **side effects,** shouldn't create significant issues of **equity** but not considered **affordable** or likely to be very **effective**	Excluded
	Modelling	Providing an example for people to aspire to or imitate	Considered potentially **acceptable**, should have limited **side effects,** shouldn't create significant issues of **equity** but not	Excluded

			considered **practical**, **affordable** or likely to be very **effective**	

Table 5.4 Policy options appropriate for leveraging proposed intervention options.

Intervention type	Policy option	Definition	APEASE	Included/exclude from next stage
Education	Communications/ marketing	Using print, electronic, telephonic or broadcast media	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Include
	Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Include
	Regulation	Establishing rules or principles of behaviour or practice	Not considered **practical** for this project as the timeline would not allow for the process of changes to current labelling regulations	Exclude
	Legislation	Making or changing laws	Not considered **practical** for this project as the timeline would not allow for the process of changes to law	Exclude
	Service Provision	Delivering a service	Implementation of nation-wide food waste collection services are already planned by UK government	Exclude
Environmental restructuring	Guidelines	Creating documents that recommend or mandate practice. This includes all changes to service provision	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Include
	Fiscal measures	Using the tax system to reduce or increase the financial cost	Not considered **equitable** (further marginalise lower income segments of society), unlikely to be **acceptable** to citizens who will have to pay or policy makers who would probably need to instigate legislation changes, considered not **affordable** contingent on the economic climate at the time of the change	Exclude
	Regulation	Establishing rules or principles of behaviour or practice	Not considered **practical** for this project as the timeline would not allow for the process of changes to current labelling regulations	Exclude
	Legislation	Making or changing laws	Not considered **practical** for this project as the timeline would not allow for the process of changes to law	Exclude
	Environmental/ social planning	Designing and/or controlling the physical or social environment	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable**, should have limited **side effects** and shouldn't create significant issues of **equity**	Include

5.5.3. Content and implementation options selected

5.5.3.1. Intervention content

The nine potential BCTs that could be employed are shown in Table 5.5. Table 5.6 shows the BCTs separated into those that were included or excluded from the next stage of intervention design, based on an assessment against APEASE criteria. Selected BCTs at this stage included: instruction on how to perform the behaviour, information about social and environmental consequences, prompts/cues, self-monitoring of behaviour, adding objects to the environment and restructuring the physical environment.

Table 5.5 Identification of BCTs that could be used in the intervention.

COM-B	**Intervention type selected**	**BCTs identified**
Psychological Capability (i.e., attention and knowledge)	Education	• Instruction on how to perform the behaviour • Information about social and environmental consequences • Information about health consequences • Feedback on behaviour • Feedback on outcome of the behaviour • Prompts/cues • Self-monitoring of behaviour • Adding objects to the environment • Restructuring the physical environment
	Environmental restructuring	
Reflective motivation (i.e., beliefs)	Education	• Instruction on how to perform the behaviour • Information about social and environmental consequences • Information about health consequences • Feedback on behaviour • Feedback on outcome of the behaviour • Prompts/cues • Self-monitoring of behaviour

Table 5.6 List of included/excluded BCTs with reasons for inclusion/exclusion.

BCTs	APEASE	Included/excluded
Instruction on how to perform the behaviour	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable** (for citizens, policy makers and companies), should have limited **side effects** and shouldn't create significant issues of **equity**	Included
Information about social and environmental consequences	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable** (for citizens, policy makers and companies), should have limited **side effects** and shouldn't create significant issues of **equity**	Included
Information about health consequences	Not considered applicable for the present context	Excluded
Feedback on behaviour	Not considered **practical** for this context as disposal behaviour is happening in the privacy of homes	Excluded
Feedback on outcome of the behaviour	Not considered **practical** for this context as disposal behaviour is happening in the privacy of homes	Excluded
Prompts/cues	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable** (for citizens, policy makers and companies), should have limited **side effects**	Included
Self-monitoring of behaviour	Considered **affordable**, **practical,** potentially **effective**, potentially **acceptable** (for citizens, policy makers and companies), should have limited **side effects** and shouldn't create significant issues of **equity**	Included
Adding objects to the environment	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable** (for citizens, policy makers and companies), should have limited **side effects** and shouldn't create significant issues of **equity**	Included
Restructuring the physical environment	Considered **affordable**, **practical**, potentially **effective**, potentially **acceptable** (for citizens, policy makers and companies), should have limited **side effects** and shouldn't create significant issues of **equity**	Included

Table 5.7 shows the final selection of BCTs based on the outcomes of the first stakeholder workshop which are mentioned in the next section. The final BCTs selected for the intervention were: Instruction on how to perform the behaviour, prompts/cues, adding objects to the environment and restructuring the physical environment. Information about social and environmental consequences and self-monitoring of behaviour were excluded based on the practicality of implementing these via a disposal instruction label, the chosen implementation option, which would have to be simple, with minimal wording/design.

Table 5.7 Narrowing down selection of BCTs.

BCT	Included/Excluded	Rationale
Instruction on how to perform the behaviour	Included	Prioritized as lack of disposal instructions identified as key barrier to correct disposal
Information about social and environmental consequences	Excluded	Limitation of space to provide information on a label
Prompts/cues	Included	A new label on packaging delivers this
Self-monitoring of behaviour	Excluded	Not practical to deliver via a label on packaging
Adding objects to the environment	Included	A new label on packaging delivers this
Restructuring the physical environment	Included	A new label on packaging delivers this

5.5.3.2. Implementation options

5.5.3.2.1. Additional relevant context

This section details the structural, industry and policy context around the intervention to help the reader better understand the context in which the selected BCTs were further refined and implementation options were considered.

To set the scene, at the time of writing this study in 2023, the UK Government is consulting on new mandatory labelling for packaging in the UK as part of the Extended Producer Responsibility scheme reforms. The key aim of mandatory labelling is to give citizens clear information about what they can and cannot recycle using simple binary messaging i.e., “recycle” or “do not recycle” (209). The strategy for a binary label messaging system is adopted from recommendations in OPRL's Evidence Base report (OPRL) and is widely supported by industry members (271).

Compostable packaging, except for compostable packaging used in “closed loop” scenarios (i.e., where products are sold, used and disposed of within a single venue e.g., festivals), is not currently deemed recyclable and so will likely incur higher Extended Producer Responsibility fee rates, payable by obligated producers, and a mandatory “do not recycle” label from 2024. Nonetheless, the UK Government recognizes that it may support an alternative approach to compostable packaging in the future should greater certainty over a lack of any negative effects and evidence of the benefits in end applications be demonstrated (209). Packaging types under Extended Producer Responsibility include single and multi-material primary packaging and shipment packing. Where packaging consists of multiple components clear advice on whether each component is recyclable or not is required (209).

The UK Government considered two options for Extended Producer Responsibility mandatory labelling. Option 1 is the use of approved labels where the Government would set in regulations the criteria that labels must meet such as format, size and appearance. In this scenario obligated producers could establish their own label or subscribe to and use labels from an existing labelling scheme (for example OPRL). A variation of this approach could be to set the requirements for “do not recycle”' in Extended Producer Responsibility regulations thereby restricting how producers label packaging that is not recyclable (209). Option 2 is a government-appointed single labelling scheme whereby producers would need to adhere to a single labelling scheme and use the same labels. In this scenario all obligated producers would be required to register with a single labelling scheme; the scheme operator would establish the process of registration, labelling design and auditing (209).

5.5.3.2.2. Disposal instruction labels

The outputs of As shown in Table 5.3, the intervention types selected were education and environmental restructuring. As shown in Table 5.4, the policy options selected were guidelines, communications/marketing and environmental/social planning.

Four intervention types were considered inappropriate and so excluded: enablement, persuasion, modelling and training. Persuasion and modelling were not deemed likely to be very effective as the target behaviour is not one where people lack motivation or inspiration to enact the desired behaviour. The analysis of influences on behaviour showed that people have pro-environmental intentions and wish to “do the right thing” when it comes to compostable plastic packaging. The

issue rests primarily in attention and misinformation, therefore inducing positive or negative feelings or providing something for people to aspire to in order to stimulate action is unlikely to inspire significant behaviour change. Training was excluded on grounds of practicality and affordability. A training programme would likely be costly to run and not practical in terms of where, when, how and by whom it could be implemented. Enablement was excluded because, based on the behavioural diagnosis, any intervention strategy is unlikely to go beyond education and environmental restructuring.

Four policy options were excluded: service provision, legislation, regulation and fiscal measures. Service provision was excluded as the implementation of nationwide food waste collection services is already planned by the UK government; therefore, addressing the physical opportunity-related barriers concerning access to waste management services. Fiscal measures would likely require legislation changes, something that would rely upon elected politicians' willingness to propose such changes. There would also be questions of affordability dependent on the economic climate at the time of the intervention, and thus the use of this policy category could become less acceptable. At the time of writing this thesis in 2023, there is an ongoing cost of living crisis in the UK. Legislation was not practical to focus on within this project as the process involved would be out of scope for a PhD research study.

Table 5.3, Table 5.4, Table 5.5 and Table 5.6 were discussed in the initial stakeholder workshop. The key outcome of this initial workshop was a consensus that a disposal instruction label for compostable plastic packaging, consisting of a written disposal instruction and a logo, was the most suitable implementation option for the selected BCTs. Additional outcomes were a consensus that:

- The labels should be tested on packaging formats as outlined in WRAP's Considerations for Compostable Packaging report, as they represent likely applications for compostable packaging in the future (192). WRAP stands for The Waste and Resources Action Programme; a climate action non-governmental organisation and British charity dedicated to working with businesses, individuals and communities to achieve a circular economy.
- The labels should be tested on additional packaging formats such as sauce sachets and takeaway food and drinks containers as they also represent likely applications for compostable packaging.
- The packaging formats used for testing should be representative of the types of packaging people can find in UK stores e.g., a PG tips tea box rather than a fictional box of tea.
- There is a need to test how the wording ‘compost with food waste’ and ‘recycle with food waste’ are understood by citizens.
- A range of new disposal instruction logos, specifically for compostable packaging should be designed and evaluated.
- An evaluation of any disposal instruction labels should be in the form of an online task-based experiment in the first instance.

- The OPRL binary labelling system should be chosen to form the basis of any logo in the disposal instruction labels.

Figure 5.6 depicts the final disposal instruction labels and logos. These were developed with input from a final stakeholder workshop. The feedback from this second workshop was minor and focused mostly on finalising the exact wording that should be tested in the different disposal instructions. The top section consists of variations of disposal instructions and ORPL's “Recycle Now” logo. The bottom section consists of potential alternative logo imagery for uniquely communicating the compostability of material at end-of-life. These were developed using associative graphic imagery commonly used in UK waste disposal infrastructure and communications, such as an image of a ‘leaf’, ‘seedling’, ‘apple core’, ‘chasing arrows recycling symbol’, and WRAP’s ‘chasing heart’ logo.

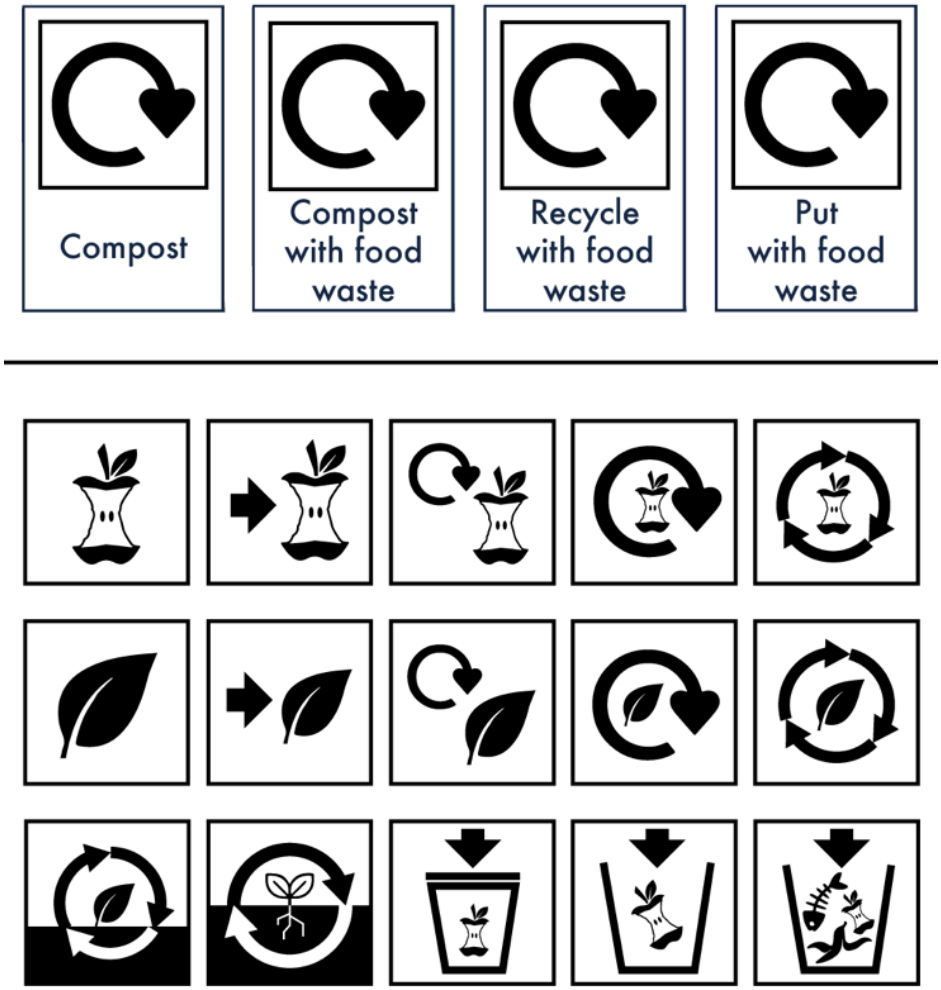

Figure 5.6 Examples of the disposal instruction labels developed (reproduced with permission from (51)).

5.6. Discussion

This study aimed to design a behaviour change intervention to enable the disposal of compostable plastics. The development of this intervention involved a rigorous and structured design process built on a foundation of primary research and evidence synthesis. This was supported by input from academic, industry and policy experts.

The behavioural analysis revealed that citizens are generally motivated to dispose of compostable plastics correctly. The barriers relating to reflective motivation (i.e., beliefs about a plastic waste item's composability) were more related to a lack of knowledge about how compostable plastics biodegrade rather than a lack of intention to dispose of the items correctly. In addition, people's physical opportunity (e.g., availability of resources for waste management) and psychological capability (i.e., knowing which bin to put them into) were identified as key barriers to disposing of compostable plastics correctly. Using the Behaviour Change Wheel led to identifying intervention types of education and environmental restructuring which could be delivered through policy options such as environmental and social planning, communications and marketing or guidelines. Thus, rather than focusing on motivating individuals, intervention in this context requires the provision of the appropriate opportunities to dispose of compostable plastic packaging (i.e., access to appropriate bins and waste collection services) as well as education to ensure that individuals possess the procedural knowledge necessary to put the materials in the right bin. To address psychological capability, the resulting intervention is a disposal instruction label for compostable plastics, consisting of instructions and a logo.

Physical opportunity will be addressed by the impending implementation of nationwide food waste collection services by the UK national government.

This study supports and extends prior research. The utility of the Behaviour Change Wheel has been demonstrated previously, in the context of interventions aimed at changing recycling behaviour (272). The present study supports the Behaviour Change Wheel's utility for designing interventions changing waste-related behaviours and extends it to the specific context of compostable plastic disposal, the first application of the Behaviour Change Wheel in this context.

The strengths of this study include the intentional and systematic application of a behaviour change framework to guide the intervention development process as opposed to relying on a cursory analysis or "common sense" – a common error in preventing the successful implementation of behaviour change (147). As mentioned in Chapter 1, the UK Medical Research Council framework for designing and evaluating "complex" interventions has advocated systematic intervention development, using evidence and theory (30).

No issues were identified with the application of the frameworks to this novel context. The simplicity yet comprehensiveness of COM-B was highly practical to conduct an overarching narrative synthesis and organisation of the research evidence relating to behavioural influences for then mapping onto potential intervention strategies. The Behaviour Change Wheel was found to be a versatile and accessible framework for working with stakeholders. The systematic approach enabled a limited and defensible set of appropriate interventions that could be proposed for discussion with stakeholders. This was not only practical in terms of stakeholder time but it also helped assure stakeholders of a rigorous intervention

development method based on previous research and theory. Though no context-specific issues were identified, general issues with how best to narrow down the selected BCTs from the "long list" of potential BCTs were identified. This issue has also been reported by others using the BCW within the implementation research (273). Potentially relevant BCTs were selected based on the list provided in the Behaviour Change Wheel guide (34). The list shows which BCTs are appropriate for each intervention type. This "long list" was narrowed down using logical self-imposed rules, followed by the application of APEASE criteria. So, despite the highly systematic and structured approach of the Behaviour Change Wheel, some subjective and pragmatic decisions had to be taken which could be viewed as being at odds with a scientific framework.

The value of this study lies in demonstrating a method. However, as it is very specific to a UK waste context, the findings may not be generalizable to other waste-management settings. Nonetheless, the method is general and could be applied to a local authority, region or country that wants to use labelling to influence behaviour to direct compostable plastics to a different destination other than food waste collection. A further strength of this work lies in its step-by-step documentation of the intervention development process which demonstrates a transferrable methodology and series of research outputs (i.e., tables) which can be used as templates by others. A further limitation to the strength and generalisability of this study is the lack of end-users (representing the general public) and local councillors (representing local authorities) consulted. As key groups of people within the system of compostable plastic waste management, their views could have potentially improved the logo designs or generated other types of wording to be selected for testing.

There are practical applications of this work. Unless citizens can dispose of compostable plastic waste materials in the correct bin, these materials will continue to contaminate other waste streams or be sent to landfills and incineration. When evaluated for effectiveness, the labels may provide answers relating to how best to get citizens to dispose of compostable plastic waste appropriately. This, in turn, has policy implications for product and package labelling.

This study also has implications for advancing behaviour change science as it openly documents intervention development methods. There is a paucity of intervention development studies in academic journals (274). When intervention development studies are published, they are usually included as part of a feasibility or pilot study (267). The author has published a version of the work presented in this chapter in an open, peer-reviewed scientific journal (51). Publishing intervention development studies as standalone papers, and in line with established guidance, may allow for a more systematic and transparent approach to intervention development reporting. This, in turn, enhances the quality of interventions and improves learning about intervention development research and practice.

Implications for future research involve user testing. In line with the UK Medical Research Council's guidance for developing complex interventions, the next stage of this thesis is to pilot the prototype labels developed (30). The evaluation of the intervention developed in this study is reported in the final study of this thesis in Chapter 6.

5.7. Conclusion

This study aimed to design an intervention promoting the correct disposal of compostable plastic packaging. The Behaviour Change Wheel intervention development framework was applied to guide intervention design. The benefits of systematically developing interventions and documenting the process include promoting a transparent approach to intervention design. Documenting intervention development methodology also helps advance behaviour change science by providing adaptable templates to other researchers and practitioners. The next step is to evaluate the disposal instruction labels for their effectiveness in enabling the desired disposal behaviours.

6. Chapter 6 – Enabling desired disposal of compostable plastic packaging: an evaluation of disposal instruction labels (Study 5)

6.1. Abstract

Background: An intervention consisting of a series of disposal instruction labels was developed.

Aims: This study aimed to evaluate the disposal instruction labels for their effectiveness in promoting the desired disposal of compostable plastic packaging.

Method: This study used mixed methods, consisting of an online experiment and a survey. The experiment employed a mixed 6x11 factorial design. Independent variables were disposal instruction (between, 6 levels) and packaging format (within, 11 levels). The dependent variable was disposal behaviour (correct vs incorrect) operationalised as whether or not participants correctly disposed of the packaging in a given trial. Participants (n =1,008) completed a task where they sorted a series of packaging stimuli, with various disposal instructions, into one of three bins (general waste, food waste, recycling) and a survey where they chose a preferred logo from an array of disposal instruction logos, providing a reason for their choice.

Results: With no disposal instruction, items with a common practice of being compostable went into food waste, items with a common practice of being recycled went into recycling and the remaining items went into general waste. 'Compost with food waste' had the highest rate of correct disposal in the food waste bin when compared to the control group with no disposal instruction and the disposal instruction 'compost', but it was not statistically different from 'put with food waste' or

‘recycle with food waste’; all three disposal instructions led to statistically similar rates of disposal in the food waste bin. ‘Do not recycle’ was, overall, more effective than no disposal instruction (control) to promote disposal into general waste. Nonetheless, disposal rates for tea and compostable shopping bag remained low in this condition (both ≤50%). Qualitative results showed that participants had a clear preference for clarity and directness in a disposal instruction logo for compostable waste. They valued the depiction of simple yet comprehensive, instructive and explicit symbols, i.e., an arrow pointing into a bin, avoidance of associative symbols such as variations of the recycling chasing arrows symbol and depiction of a variety of different organic waste items that one can put in a council food bin.

Conclusions: Findings suggest that citizens struggle to identify compostable plastic packaging from appearance alone. Clear direct disposal instruction wording can help enable the appropriate disposal behaviours. While ‘do not recycle’ may currently work for some types of compostable plastic packaging to denote disposal with general waste, it may not work for all, especially items with a common practice of being compostable. Qualitative findings corroborate these results showing that participants preferred clarity and directness in disposal instructions logo denoting compostability. This speaks to citizen’s need for a clear and direct command in a disposal instruction label suggesting that simple yet unambiguous and instructive symbols are likely to be the better instigators of behaviour change compared with associative symbols.

6.2. Background

Study 4, reported in Chapter 5, documented the design of an intervention aimed at promoting compostable plastic disposal. The intervention was created using a multi-disciplinary co-production approach and integrated the findings of all previous studies in this thesis. The developed intervention consisted of a series of disposal instruction labels. As mentioned in Chapter 5, compostable plastics could be part of a sustainable UK packaging system; however, this would require UK citizens to adopt the appropriate waste management behaviours that lead to the materials being composted i.e., putting them in the correct bin for processing (see Figure 5.2). Incorrect disposal offsets any of the potential environmental benefits of compostable plastic packaging. As compostable plastics are relatively new in terms of an integrated UK waste management strategy, there is little research to inform the design of behaviour change interventions to increase appropriate waste management of these materials. This final study aims to address this gap by evaluating these disposal instruction labels in Study 4 (Chapter 5) for their impact on influencing disposal behaviour.

The problem areas relating to compostable plastic production, use and waste management were reviewed in Study 4 (Chapter 5). This included the structural, industry and policy contexts around the present intervention. To remind the reader, there is currently no cohesive, unified Government waste management strategy for the management of compostable plastics. Industry is at liberty to market these materials as they please. To make progress in this area, at the time of this study in 2023, the UK Government was consulting on new mandatory labelling for packaging as part of the Extended Producer Responsibility scheme reforms (209, 261). The key

aim of mandatory labelling is to give citizens clear information about what they can and cannot recycle using simple binary messaging i.e., 'recycle' or 'do not recycle' (209). Since compostable plastics are not deemed 'recyclable' (as they are not designed to be mechanically recycled), the current plan is to label these, from 2024 onwards with 'do not recycle' so that they are disposed of with general waste (261). This is significant because, from 2024 onwards, the UK government also aims to roll out nationwide food waste collection services. There are concerns that food waste collection services may become overwhelmed with large volumes of compostable plastic packaging waste that are not currently able to be processed by the majority of UK waste processing facilities. While there is an understanding amongst Government and industry that collecting and processing these materials via food waste is likely to be the desired end-point (192), this is an anticipated future scenario once other aspects of the compostable plastics system outlined in Chapter 5 improve (see Figure 5.2).

Mandating the use of 'do not recycle' to direct compostable plastics to general waste raises questions about behaviour change. To enable correct practices, it is necessary to gather information about what UK citizens are currently doing with compostable plastics without government-mandated disposal instruction labels. This would form a baseline for evaluating the impact of the disposal instruction 'do not recycle'. Since 'recycle' / 'do not recycle' is a binary messaging system that was designed for a two-bin scenario (recycling and general waste), it is empirically unknown how effective 'do not recycle' will be once there are three mainstream options for the disposal of waste (recycling, general waste and food waste). It is

unclear how obvious the general waste bin will be as the disposal option for compostable plastics in this 'three-bin' scenario.

To prepare for an ideal future scenario where compostable plastics are disposed of with food waste (so they can be composted), UK industry and the Government are discussing the potential implementation of a new disposal instruction logo indicating 'compostability'. However, the UK Government have been clear that this would only be used to label compostable plastics in the instance that there is a strong, evidence-based case for this scenario. For example, this will require sound evidence that there is adequate infrastructure in place to appropriately manage compostable plastics and evidence that compostable plastics provide ecological or agricultural benefits to soils or digestate when properly broken down (261). Therefore, there is also a need to understand which types of logos and disposal instructions might be most effective to denote the disposal of compostable waste with food waste to support policy decision-making in this area.

To this end, the current study has four research questions:

1) In a three-bin scenario (food waste, general waste, recycling), which bin do citizens put various types of compostable plastic packaging in when there is no disposal instruction?
2) In a three-bin scenario (food waste, general waste, recycling), is 'do not recycle' an effective disposal instruction for getting citizens to dispose of compostable plastic waste with general waste?
3) In a three-bin scenario (food waste, general waste, recycling), which disposal instruction ('compost', 'compost with food waste', 'put with food waste',

‘recycle with food waste’) is most effective at getting citizens to put compostable plastic packaging with food waste?

4) Which potential alternative disposal instruction logos do citizens prefer for compostable packaging and why?

6.3. Method

All materials for this study including raw data and analysis code are available openly via OSF https://osf.io/vj9hy/.

6.3.1. Participants

Study participants were members of the UK public (n = 1,008). They had to be over 18, normally resident in the UK for the last 12 months and have sufficient English to complete the study. Participants were recruited via Prolific (222) and advertising the study through email to the Big Compost Experiment citizen science project's mailing list (178). Participants recruited via Prolific were compensated for their time at a rate £10.23/hr. Prolific ensures a representative sample in terms of gender, age and ethnicity for UK participants. Participants recruited via the Big Compost Experiment took part voluntarily.

6.3.2. Design

This study had a mixed methods design. It consisted of an experiment and questionnaire.

The experiment had a mixed 6x11 factorial experimental design. There were two independent variables. One was between-participants: disposal instruction, on six levels (control, do not recycle, compost, recycle with food waste, compost with food waste and put with food waste). Disposal instruction was operationalised as the wording on the disposal instruction label presented to participants. Participants were randomly allocated to either one of the six disposal instruction conditions, one of which included a control condition consisting of no disposal instruction.

The other independent variable was within-participants: packaging format, on 11 levels (sachet, bag, clamshell, container, plastic cup, food sticker, hot drink cup,

coffee packaging, sandwich packaging, tea packaging and ready meal tray). Packaging format was operationalised as the type of compostable plastic packaging the disposal instruction labels were tested on.

The study had one binary dependent variable: disposal behaviour (correct vs incorrect) which was operationalised as whether or not participants disposed of the packaging in the desired bin during a given trial. To complete a trial correctly, all items had to be disposed of in the right bin. In the case of multi-material packaging, all parts had to be disposed of correctly e.g., in the case of the tea package consisting of a box and compostable teabag, the participant had to sort the box correctly (i.e., in the recycling bin) and the teabag correctly (i.e., in the food waste bin or general waste bin depending on the analysis scenario) to get a correct score for that trial.

The questionnaire consisted of an online cross-sectional survey of close-ended and open-ended questions.

6.3.3. Materials

6.3.3.1. Experimental stimuli

6.3.3.1.1. Disposal instruction labels

The rationale for the disposal instructions labels has been justified in Chapter 5. The final wording and logo used in the disposal instruction labels is depicted in Figure 6.1.

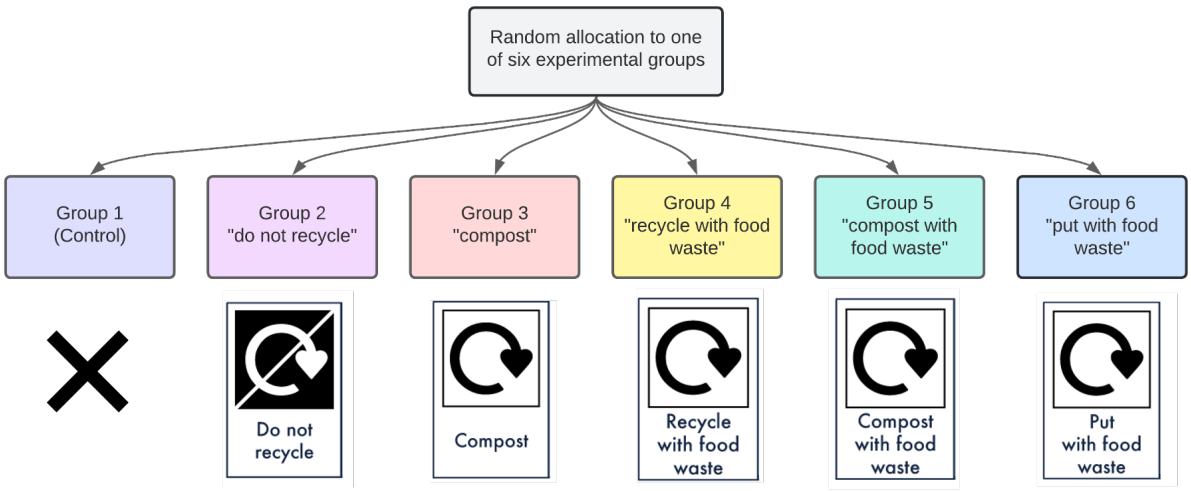

Figure 6.1 The disposal instruction labels used for the compostable plastic packaging in each condition.

6.3.3.1.2. Compostable packaging formats

The disposal instruction labels were superimposed onto images taken of 11 compostable plastic packaging formats (see Table 6.1). The rationale for the selection of these formats has been justified in the previous study (Study 4 reported in Chapter 5). It is recognised that many different aspects of packaging labelling and communication design (words, logos, pictures, colour, material choice) have varying influences on citizen behaviour and that disposal instruction labels are one aspect of a larger complex system of communication (269). These particular items were selected as they are items available in high street shops in the UK, marketed as compostable, and made from compostable materials (e.g., PLA, PBAT and corn starch).

6.3.3.1.3. Distractor packaging formats

Distractor stimuli were also used and consisted of images taken of common general waste and dry recycling items e.g., a juice carton and a chocolate wrapper

(see Table 6.1). The disposal instruction labels that were superimposed onto the distractor items consisted of the disposal instruction ‘recycle’ for recyclable items and ‘do not recycle’ for general waste items, with the same OPRL Recycle Now logo, as this is the current UK system for labelling this type of waste, at the time of this study. In the control condition, the distractor waste items had no disposal instruction label.

Table 6.1 Table showing the images of the packaging formats used trials.

Compostable items	Sachet	Bag	Clamshell	Container	Cup	Food sticker	Hot drink container (cup and lid)	Coffee (box and pod)	Sandwich (box and film)	Ready meal (sleeve, tray and film)	Tea (box and teabag)
											
	Chocolate wrapper (General waste)			Plastic milk bottle (Recycling)		Juice carton (Recycling)		Glass jar (Recycling)		Aluminium can (Recycling)	
Distractor items											

6.3.3.2. Questionnaire

6.3.3.2.1. Hypothetical disposal instruction logo for compostable waste

Introduced in Chapter 5, Figure 6.2 reminds the reader of the 15 hypothetical disposal instruction logos that were developed in collaboration with a designer at the UCL Plastic Waste Innovation Hub (DP) and industry, policy and academic stakeholders. They were developed using associative graphic imagery commonly used in UK waste disposal infrastructure and communications, such as an image of a 'leaf', 'seedling', 'apple core', 'chasing arrows recycling symbol' and WRAP's 'chasing heart' logo.

Participants were asked to select their preferred logo, provide a reason for their preference ("Please provide a reason for your answer") and to provide their thoughts for a potentially better disposal instruction logo for compostable packaging waste ("If you think there could be a better disposal instruction label for compostable packaging than the ones we have shown you, could you please share your thoughts with us?").

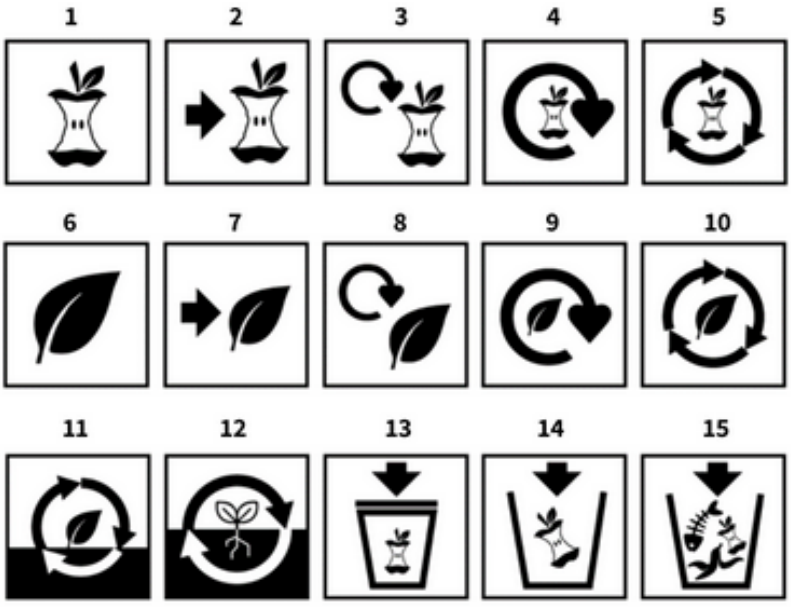

Figure 6.2 The disposal instruction logos (reproduced with permission from (51)).

6.3.3.2.2. Britain Talks Climate toolkit

Mentioned in Study 3 (Study 4), the Britain Talks Climate citizen engagement toolkit's 'Golden Questions' were used to collect psychological demographics. This toolkit was developed using prior research and stakeholder consultation and has been tested and validated for use in UK-specific research (253). Based on how participants respond to the toolkit's 16 questions, the tool 'segments' respondents into one of seven possible 'psychological' groups using a range of ideological factors which provides insight on how they might engage with issues relating to climate change (see Table 6.2).

The challenges posed by only having socio-demographics to contextualise results was highlighted in Study 3 (reported in Chapter 0). Collecting a wider range of demographic variables that go beyond the standard sociodemographic variables (e.g., age, ethnicity, gender, education level etc) has the potential to help better understand participant samples, control for these factors in analyses and contextualise findings.

Table 6.2 Summary of the seven segments of the UK public.

Segment	Britain Talks Climate toolkit definition
Progressive Activists *(13% of UK Public)*	Vocal and passionate, politically active but pessimistic about the direction society has taken, climate change is central to Progressive Activists' identity and politics. They are despairing about governments' moral failings on the issue, which they believe will make all other challenges and inequalities worse
Civic Pragmatists *(13% of UK Public)*	Moderate and tolerant, Civic Pragmatists are anxious about the future, with climate change contributing to that fear. They try to follow a low-carbon lifestyle, but feel demotivated by a lack of political ambition on climate change and other social issues. Reflecting their pragmatic nature, they are likely to look past their opinion of the government of the day and support progressive climate policies when they see them.
Disengaged Battlers *(12% of UK Public)*	Feeling unheard and unrepresented, Disengaged Battlers are nevertheless broadly convinced of the need to take action on climate change. However, they do not yet believe the transition will benefit them, and are too busy surviving from day to day to give it more of their attention.
Established Liberals *(12% of UK Public)*	Confident and comfortable, Established Liberals have a global outlook driven more by their professional networks than a sense of solidarity with communities around the world. They don't necessarily view climate change as something that will affect them personally, but they do want to hear how low-carbon solutions will drive economic resilience and growth.
Loyal Nationalists *(17% of UK Public)*	Traditional and proud to be British, Loyal Nationals feel threatened and are galvanised by issues such as crime, immigration and terrorism. They believe the UK is already living with the reality of climate change, but they understand it as an issue linked to localised (rather than global) inequality and environmental degradation. Their relatively high political participation is driven by moral outrage about a system that supports corporate greed over every day working people.
Disengaged Traditionalists *(18% of UK Public)*	Disillusioned and sceptical, Disengaged Traditionalists recognise tangible environmental risks like air pollution, but are far from 'sold' on the need for action on climate. They are more likely to see it as a problem for foreign governments to deal with.
Backbone Conservatives *(15% of UK Public)*	Conservative, patriotic and optimistic, Backbone Conservatives take pride in tangible success stories about British environmental achievements and care deeply about food, farming and the rural economy. But they are more sceptical about grand claims of global leadership, or the 'virtue signalling' of (what they sometimes see as) symbolic lifestyle changes.

Notes: Adapted from (253).

6.3.4. Procedure

Ethical approval was received from UCL (project ID: CEHP/2020/579, data protection: Z6364106/2022/03/63). The study was built on Gorilla and piloted with a sample of university staff and students prior to data collection for usability and accessibility. Participants accessed the study via an online web link which took approximately 10 minutes to complete. Informed consent was obtained before any data collection. Data collection occurred between the 14th and 28th of November 2022.

Participants completed 16 experimental trials in total. Each trial consisted of sorting images of waste items into one of three bins: either the food waste bin, recycling bin or general waste bin (if the packaging had multiple parts, each part had to be sorted separately). In each experimental group, participants sorted packaging that had disposal instruction labels superimposed onto them. In the control group, participants sorted the different types of packaging with no disposal instruction label superimposed onto them.

Examples of the trials are shown in Figure 6.3. Eleven trials consisted of experimental stimuli i.e., compostable plastic packaging (e.g., a compostable coffee cup). Five trials consisted of distractor stimuli i.e., dry recyclable waste (e.g., a juice carton) or general waste (e.g., a chocolate wrapper). The order of trials was counterbalanced to minimise order effects (275).

Figure 6.3 Example trials from the 'compost' disposal instruction condition. The image on the left depicts an example of what participants saw when sorting an item of mono-material packaging while the image on the right depicts an example of what participants saw when sorting an item of multi-material packaging.

Participants subsequently completed a survey answering questions about: a) their preferences for the new hypothetical disposal instruction logo specifically for compostable waste; b) reasons for their chosen logo preference; c) current waste management behaviours e.g., those relating to separating food waste for recycling, home-composting, dry recycling and bin use, and; d) demographic information.

6.3.5. Data analysis

Data points from 1008 participants were prepared for analysis in Microsoft Excel and subsequently entered into analysis in RStudio (276). Descriptive statistics and thematic analyses (183) were conducted to present findings summarising participant characteristics.

To answer Research Question 1 (in a three-bin scenario, which bin do citizens put various types of compostable plastic packaging in when there is no disposal instruction?), all compostable plastic packaging components were analysed in

isolation and not as part of a wider packaging format e.g., just the teabag, not the box. Frequencies were used to summarise findings. To answer Research Question 4 (which potential alternative disposal instruction logos do citizens prefer for compostable packaging and why?), percentages were used to summarise logo preferences and thematic analyses (183) were conducted on open-ended survey responses exploring reasons for preference.

Inferential statistics were run to answer Research Question 2 (in a three-bin scenario, is 'do not recycle' an effective disposal instruction for getting citizens to dispose of compostable plastic waste with general waste?*)* and Research Question 3 (in a three-bin scenario, which disposal instruction is most effective at getting citizens to put compostable plastic packaging with food waste?). The data analytic approaches for these two research questions are detailed in the subsequent sections.

6.3.5.1. Building the models for Research Question 2 and Research Question 3

R Packages 'lme4' (277) and 'lmertest' (278) were used for the main tests and 'emmeans' (279) for follow-up tests. Two separate Generalised Linear Mixed-effects models were run to see if disposal instruction predicted correct disposal. To account for the repeated-measures methodology (all participants disposed of each packaging format), a by-participant random intercept was added. The same control group was used for the analyses pertaining to Research Question 2 and Research Question 3. In the former, the control group results were based on the data coded as the *general waste bin* being the correct bin. In the latter, the control group results were based on the data coded as the *food waste bin* being the correct bin.

6.3.5.1.1. Control variables

To assess for any control variables, the relationship between the socioeconomic (i.e., age, gender, income, education), psychological (i.e., ideological orientation) and behavioural (i.e., home-composting and food waste recycling status) demographic variables and the dependent variable (i.e., correct disposal) were explored via two different approaches: a) separate Generalised Linear Mixed-Effects Models per variable and b) one Generalised Linear Mixed-Effects Model with all control variables included. The control variables were introduced as predictors of correct disposal, with a by-participant random intercept, following the structure of the main models. Variables found to be significant at $p < .05$ across both approaches were entered into the main models. If the main models failed to converge, the control variables were removed on the basis that it is not necessarily the 'maximal', but more parsimonious model, with a random effects structure, that may be most suitable for describing the data in factorial experiments with repeated-measures aspects (280, 281). Details of the control variable analyses can be found openly available via OSF (https://osf.io/vjmne).

6.3.5.2. Analytic approach for Research Question 2

The first independent variable in the model was the disposal instruction, operationalised as either the control or the 'do not recycle' disposal instruction. The second independent variable was packaging format. An interaction term was included to assess whether effectiveness of 'do not recycle' as a disposal instruction varied according to packaging format. The dependent variable was binary (correct vs incorrect disposal). Correct disposal was operationalised as disposal of compostable plastic packaging items with *general waste*. Incorrect disposal was operationalised

as disposal with food waste or recycling. Shown in Equation 6.1, the final model (Conditional R^2 = 57.5%) had the following structure[9]:

Equation 6.1. The model for Research Question 2

```
disposal ~ experimental_group * packaging_format + (1 | participant_id)
```

6.3.5.3. Analytic approach for Research Question 3

The first independent variable in the model run was the disposal instruction operationalised as either the control, 'recycle with food waste', 'compost', 'compost with food waste' or 'put with food waste' disposal instructions. The second independent variable was packaging format. Correct disposal was operationalised as disposal of compostable plastic packaging items with *food waste*. Incorrect disposal was operationalised as disposal with general waste or recycling. Disposal rates across the different conditions were compared against each other. The control variables *home composting status* and *food waste recycling status* were significantly associated with disposal rates and so were included in the final analysis[10].

An interaction term was initially included to assess whether effectiveness of the disposal instructions varied according to packaging format. However, the model did not converge, likely because the interaction term lead to the estimation of more than 5x11 parameters. To simplify the model, the random intercept was prioritised over the interaction between the fixed effects in line with guidance (282) and given how

[9] The control variable *income* was initially included in the main model; this was the only control variable significantly associated with disposal rates. However, the main model did not converge when *income* was included and so was removed.
[10] *Age* was also significant so initially included in the model but the model did not converge. As this was the variable with the lowest estimate, it was omitted from the analysis to reduce complexity as per guidance (293, 294).

much variance the random effect structure explained (Marginal R^2 = 38%, Conditional R^2 = 62%). Shown in Equation 6.2, The final model had the following structure:

Equation 6.2. The model for Research Question 3.

```
disposal ~ experimental_group + packaging_format + home_composting_status +
food_recycling_status (1 | participant_id)
```

6.4. Results

6.4.1. Participant characteristics

Participant characteristics are summarised in Table 6.3. The majority identified as women (55%) followed by men (43.8%) and with a small percentage as non-binary (0.6%) or preferring not to disclose their gender (0.6%). The mean age of participants was 53.57 (*SD* = 16.59) with most either educated to undergraduate (37.1%) or master's level (22%). This indicates an older (230), and more educated (231) sample than UK averages. The majority of participants had a household income between £20,000-£29,000 (17.6%), aligning with national figures (228).

The majority of participants were classified as 'Progressive activists' (39.5%) and 'Established liberals' (21.6%) which is considerably higher than the UK averages of 13% and 12% respectively (253). The third most populous segment were 'Civic pragmatists' (16.1%) which is closer to the UK average of 13% (253).

About half of participants (53.67%) indicated that they were being provided with a local food waste collection service. This mirrors UK statistics for household food waste collection services with about half of households offered such services (213). Almost all participants recycled dry recyclables (97.62%). About half engaged in home-composting (53.57%) which is likely to be much higher than national averages and other studies suggest that only about a third of households in England with a garden home-compost (283). The question asking likelihood of engaging with local food waste collection services if provided with free compostable liners was explored in more depth by asking participants to provide a reason for their answer. This supplementary analysis, including direction to the raw data and codebook, can be found openly available via OSF (https://osf.io/jvfyk).

Table 6.3 Table summarising participant demographics.

Characteristics	N (missing)	%	Mean (SD)
Gender	1008 (0)		
Man	442	43.8	
Woman	554	55	
Non-binary	6	0.6	
Prefer not to say	6	0.6	
Age (years)	988 (20)		53.57 (16.59)
Highest level of education	1008 (0)		
Primary education	2	0.2	
Lower secondary education	36	3.6	
Higher secondary education	146	14.5	
Vocational certificate	105	10.4	
Associate degree	48	4.8	
Undergraduate degree	374	37.1	
Postgraduate masters	222	22.0	
Postgraduate doctorate	75	7.4	
Ideological demographic	1008 (0)		
Progressive Activist	401	39.5	
Civic Pragmatists	163	16.1	
Disengaged Battlers	54	5.3	
Established Liberals	219	21.6	
Loyal Nationalists	63	6.2	
Disengaged Traditionalists	35	3.5	
Backbone Conservatives	79	7.8	
Annual household income pre tax	1008 (0)		
Less than £10,000	62	6.2	
£10,000 to £19,999	109	10.8	
£20,000 to £29,999	177	17.6	
£30,000 to £39,999	136	13.5	
£40,000 to £49,999	115	11.4	
£50,000 to £59,999	96	9.5	
£60,000 to £69,999	48	4.8	
£70,000 to £79,999	52	5.2	
£80,000 to £89,999	36	3.6	
£90,000 to £99,999	24	2.4	
£100,000 to £149,999	52	5.2	
£150,000 or more	12	1.2	
Prefer not to say	89	8.8	
Recruitment Method	1008(0)		
Prolific	600	59.5	
Big Compost Experiment mailing list	408	40.5	
Access to local food waste collection services at primary residence	1008 (0)		
Yes	541	53.67	
No	413	40.97	

Unsure	54	5.35
If YES, currently separates food waste from other waste for local waste collection	541 (0)	
Yes	470	86.88
No	71	13.12
If YES, frequency of food waste recycling	470 (0)	
Never	0	0
Almost never	1	0.21
About half of the time	18	3.83
Most of the time	119	25.32
Always	331	70.43
Access to an outdoor space at primary residence e.g., garden, terrace	1008 (0)	
Yes	952	94.44
No	56	5.56
Currently engages in home-composting	1008 (0)	
Yes	540	53.57
No	468	46.43
Currently recycles dry recyclables (e.g., plastic, glass, metal, cardboard, paper)	1008 (0)	
Yes	984	97.62
No	24	2.38
If YES, frequency of dry recycling	984 (0)	
Never	0	0
Almost never	0	0
About half of the time	15	1.52
Most of the time	172	17.48
Always	797	81.00
Likelihood of engaging with local food waste collection services if provided with free compostable liners by local authority	1008(0)	
Yes	599	59.42
No	277	27.48
Unsure	132	13.10

6.4.2. General descriptive statistics

The percentage correct disposal of the recyclable and general waste used as distractor stimuli can be found openly available via OSF (https://osf.io/5mquj). The overall count data across all conditions, i.e., the frequency of disposal, into each bin, per disposal instruction for each item of mono-material and multi-material packaging, can be found openly available via OSF (https://osf.io/jm35y).

6.4.3. Which bin do citizens put various types of compostable plastic packaging in when there is no disposal instruction label? (Research Question 1)

Table 6.4 summarises the frequencies with which each item of compostable plastic packaging was disposed of in each bin when there was no disposal instruction (i.e., the control condition). The packaging parts that were most likely to go in general waste were: sachet, food sticker, coffee pod, sandwich film and ready meal film. Packaging parts that were most likely to go in food waste were: bag and teabag. Packaging parts that were most likely to go in recycling were: clamshell, container, plastic cup, hot drink cup, hot drink lid and ready meal tray.

Table 6.4. Frequency of disposal in each bin for each item of compostable plastic packaging in the control group.

Compostable packaging format		General waste bin	Food waste bin	Recycling bin
	Sachet	156	8	11
	Bag	41	93	41
	Clamshell	58	13	104
	Container	32	5	138
	Cup	57	11	107
	Food sticker	147	8	20
	Hot drink container (cup)	52	29	94
	Hot drink container (lid)	61	3	111
	Coffee (pod)	129	15	31
	Sandwich (film)	147	2	26
	Tea (teabag)	49	124	12
	Ready meal (tray)	49	4	122
	Ready meal (film)	147	7	21

6.4.4. Is ‘do not recycle’ an effective disposal instruction for getting citizens to dispose of compostable plastic waste with general waste? (Research Question 2)

Table 6.5 summarises the rates of correct disposal rate for each packaging format (i.e., percentage of participants putting that item in *general waste* vs food waste or recycling). Results showed that when the label reads ‘do not recycle’, participants were, overall, 11.15% more likely to correctly dispose of the packaging in the general waste bin (OR = 0.09, 95% CI [0.08, 0.10], $p < .0001$). Post-hoc analyses revealed that this effect was evident for 7 packaging formats – all but the sachet, the food sticker, the sandwich, and the tea (see Table 6.6).

In a three-bin scenario, ‘do not recycle’, overall, significantly increased participants’ disposal of compostable plastic packaging with general waste when compared with controls with no disposal instruction. However, this effect was coming from certain packaging formats: bag, clamshell, container, cup, hot drink container, coffee, and ready meal. It was not coming from the tea, sachet, sandwich or food sticker packaging formats for which the difference in disposal rate was not statistically significant.

Table 6.5 Correct disposal rate for compostable plastic packaging per disposal instruction instructing disposal with general waste.

	Sachet	Bag	Clamshell	Container	Cup	Food sticker	Hot drink container (cup and lid)	Coffee (box and pod)	Sandwich (box and film)	Ready meal (sleeve, tray and film)	Tea (box and teabag)
Packaging format											
Control (*n* = 175)	89.14%	23.43%	33.14%	18.29%	32.57%	84%	13.71%	72.57%	79.43%	25.14%	28.00%
Do not recycle (*n* = 167)	94.01%	50.30%	87.43%	89.82%	93.41%	91.02%	87.43%	91.62%	91.02%	91.62%	41.92%

Table 6.6 Post-hoc comparisons for correct disposal of each packaging format in the general waste bin between the control and do not recycle conditions.

Packaging format	**OR**	**SE**	***p***
Sachet	0.47	0.21	.986
Bag	**0.24****	0.07	**<.001**
Clamshell	**0.04****	0.001	**<.001**
Container	**0.01****	0.004	**<.001**
Cup	**0.02****	0.007	**<.001**
Food sticker	0.46	0.21	.92
Hot drink container (cup and lid)	**0.19****	0.07	**.001**
Coffee (box and pod)	**0.19****	0.07	**<.001**
Sandwich (box and film)	0.33	0.12	.244
Ready meal (tray, sleeve and film)	**0.02****	0.006	**<.001**
Tea (box and bag)	0.49	0.14	.56

Notes: ** = *p*-value is statistically significant at <.001. OR = odds ratio. OR < 1 means that the control group was less likely to dispose of packaging in the general waste bin.

6.4.5. Which disposal instruction is most effective at getting citizens to put compostable plastic packaging with food waste? (Research Question 3)

Table 6.7 summarises the rates of correct disposal for each packaging format (i.e., percentage of participants putting that item in *food waste* vs general waste or recycling). Across all conditions, the two packaging formats with the highest rate of correct disposal in the food waste bin were the tea and bag packaging formats. *Food waste recycling status* was not significantly associated with disposal rates in the food waste bin (OR = 0.16, 95% CI [0.12, 1.28], $p = 0.20$) however, *home-composting status* was (OR = -0.30, 95% CI [-0.42, -0.18], $p = 0.01$). The odds of correctly disposing with food waste were *higher* amongst those who did not engage home-composting.

Results showed that, in a three-bin scenario, 'compost with food waste' had the highest rate of correct disposal in the food waste bin when compared to the control group with no disposal instruction. However, it was not statistically different from 'put with food waste' or 'recycle with food waste'. All three disposal instructions led to statistically similar rates of disposal in the food waste bin. 'Compost with food waste', 'put with food waste' and 'recycle with food waste' were all significantly better at promoting disposal of compostable plastic packaging in the food waste bin when compared with 'compost'. These results can be seen in Table 6.8. An odds ratio (OR) of less than 1 means that the first group was less likely to dispose of packaging in the food waste bin. An OR greater than 1 indicates that first group was more likely to dispose of packaging in the food waste bin.

Table 6.7 Correct disposal rate for compostable plastic packaging per disposal instruction instructing disposal with food waste.

Packaging format	Sachet	Bag	Clamshell	Container	Cup	Food sticker	Hot drink container (cup and lid)	Coffee (box and pod)	Sandwich (box and film)	Ready meal (sleeve, tray and film)	Tea (box and teabag)
											
Control (*n* = 175)	4.57%	53.14%	7.43%	2.86%	6.29%	4.57%	1.71%	8.57%	1.14%	1.71%	69.71%
Recycle with food waste (*n* = 167)	69.46%	85.01%	79.01%	73.05%	76.65%	63.47%	61.68%	72.46%	68.86%	74.85%	94.01%
Compost with food waste (*n* = 166)	76.51%	84.34%	81.33%	76.51%	82.53%	65.66%	81.33%	75.30%	76.51%	80.72%	93.38%
Compost (*n* = 164)	59.15%	74.39%	65.85%	56.10%	57.32%	57.93%	59.76%	60.98%	53.05%	58.54%	86.59%
Put with food waste (*n* = 169)	76.33%	84.02%	83.43%	74.56%	78.11%	63.32%	81.66%	71.01%	72.78%	78.70%	94.67%

Table 6.8 Comparisons of correct disposal between disposal instruction labels designed to denote disposal of compostable plastic packaging with food waste.

Disposal instruction	**OR**	**SE**	***p***
Compost / Control	12.82	2.4	**<.001****
Compost with food waste / Control	34.01	6.46	**<.001****
Control / Put with food waste	0.33	0.006	**<.001****
Control / Recycle with food waste	0.04	0.008	**<.001****
Compost / Compost with food waste	0.38	0.07	**<.001****
Compost / Put with food waste	0.42	0.08	**<.001****
Compost / Recycle with food waste	0.53	0.1	**0.005***
Compost with food waste / Put with food waste	1.12	0.21	0.971
Compost with food waste / Recycle with food waste	1.4	0.26	0.361
Put with food waste / Recycle with food waste	1.25	0.23	0.742

Notes: ** = *p*-value is statistically significant at <.001, * = *p*-value is statistically significant at <.05.

6.4.6. Which potential alternative disposal instruction logos do citizens prefer for compostable packaging and why? (Research Question 4)

Results for logo preferences can be found openly via OSF (https://osf.io/px4d3). Thematic findings for the top two logos are summarised in this chapter i.e., Logo 15 (49.8%) and Logo 5 (24.58%). The full detailed thematic analyses for the top five logos (>5% preference) are openly available via OSF (https://osf.io/7xnv6).

Participants selected their preferred logo on the basis that it was the clearest to understand. However, there was variation between logos in terms of why it was perceived this way (see Table 6.9). Logo 15 was valued for its inclusion of a range of organic waste materials, instructive imagery and avoidance of associative symbols. Logo 5 was valued for its use of associative symbols which were deemed intuitive and logical. Nonetheless, across both logos, participants felt that a logo alone would be insufficient as a disposal instruction strategy and emphasised the importance of written disposal instructions to reduce any potential confusion. Findings on participants' ideas for a better logo can be found openly available via OSF (https://osf.io/xczdt).

Table 6.9. Thematic findings on reasons for logo preferences.

Logo 15		
	Inclusive	• Logo depicts a variety of organic waste items, indicating that the food waste bin is designed for multiple types of organic waste • The depicted items include unusual items (e.g., fish bones) • Symbols clearly indicate what can be put in food waste
	Instructive	• Variety of food waste depicted shows that item bearing the logo should be disposed of with other food waste items • Thanks to the arrow, the food waste bin is marked as the clear destination for items with this logo
	Direct & recognisable	• Avoids symbolism (like variations of the chasing arrows recycling logo) and just uses recognisable food waste and a recognisable bin
	Room for improvement	• The imagery could be confused with general waste if that's where people discard of their food waste currently • Unlikely to be sufficient as a strategy without the inclusion of written disposal instructions
Logo 5		
	Associative linking of familiar symbols	• Apple core is a good symbol to relate the logo to the food waste concept • Chasing arrows are a well-known recycling symbol and so linking an established waste management process (recycling) to a newer process (composting)
	Appropriate presentation & adaptation	• Placing these two symbols together logically links the recycling concept to the food waste concept • Adapting dry recycling logic to biodegradation
	Room for improvement	• The imagery could be confused with traditional dry recycling as entirely associative • Unlikely to be sufficient as a strategy without the inclusion of written disposal instructions

6.5. Discussion

The results are discussed according to each research question followed by the implications of the study findings for policy and practice. Study strengths, limitations and avenues for future research are then considered.

6.5.1. Which bin do citizens put various types of compostable plastic packaging in when there is no disposal instruction? (Research Question 1)

Results show that with no disposal instruction label, the correct disposal of these items is not obvious from their appearance. Items that 'look' like dry recyclable waste were put in the recycling bin (i.e., similar appearance to traditional dry recyclable plastics like PET), those that 'look' like general waste were put in general waste (i.e., similar appearance to non-recyclable plastic like and semi-flexible or plastic-coated materials) and those that have a familiar status as being compostable went in food waste (i.e., the bag and teabag).

These findings align with Ansink et al. (49) and Taufik et al. (50) where citizens incorrectly disposed of compostable plastic cups and water bottles into the recycling bin, even those labelled with messaging designed to communicate disposal instructions. The authors speculated that these patterns are likely to be due to a habitual association between these packaging formats and the recycling bin – it is difficult to 'snap' citizens out of their default waste management patterns. In the present study, the teabag and compostable shopping bags may have been less likely to trigger an automatic response with the recycling bin as they do not 'look' like traditionally recyclable waste, unlike the plastic water bottles and cups in the Ansink et al. (49) and Taufik et al. (50) studies. It is also likely that the UK public's familiarity

with the compostability of teabags and the particular brand of shopping bag used in this study led to them being more likely to put them in food waste.

6.5.2. Is ‘do not recycle’ an effective disposal instruction for getting citizens to dispose of compostable plastic waste with general waste? (Research Question 2)

The label ‘do not recycle’, overall, significantly increased the rate of correct disposal with general waste. However, post hoc analyses revealed that this effect was coming from the bag, clamshell, container, cup, hot drink container (cup and lid), coffee (box and pod) and ready meal (sleeve, tray and film), not the tea (teabag and box), sandwich (box and film), sachet or food sticker. The significant effect of ‘do not recycle’ appears to be mostly due to packaging that ‘looks’ like dry recyclable waste being re-directed to general waste. Since the packaging that ‘looks’ like general waste already had high rates of disposal with general waste in the control, ‘do not recycle’ only increased that figure from what was already quite high to even higher. In the case of the sachet, sandwich, and food sticker, the increase was not high enough to reach statistical significance as disposal rates into general waste were already very high in the comparison group. It is possible that ‘ceiling effects’ were occurring (284). This is when the scores of research participants are clustered near the best possible score (i.e., the ‘ceiling’; in this case, 100% correct disposal) and so the measure (the disposal instruction) loses value.

The post hoc analyses showed that ‘do not recycle’ did not significantly increase the rate of correct disposal for the tea (teabag and box). While the correct disposal of compostable shopping bags did increase significantly, the rate was still low in comparison to the other packaging formats; correct disposal was only increased to

50%. An explanation for this could be that for items that 'look' recyclable or like general waste, the food waste bin was not a plausible option. It is likely less intuitive to dispose of something that does not 'look' compostable with food waste than to dispose of something that 'looks' recyclable or organic with general waste. For items that have entered the mainstream UK public consciousness as being compostable (e.g., teabags and compostable shopping bags), 'do not recycle' may not indicate a clear enough disposal instruction in a three-bin system and so disposal decisions are being split between the food waste bin (because that is the intuitive option) and general waste bin (because that is what this instruction has been used to denote in the past).

These findings suggest that 'do not recycle' may be effective for diverting some types of waste when there are three bins to choose from but not for waste items that have an association with compostability. For items associated with compostability, 'do not recycle' may not provide the clear and direct instruction that seems to be a running theme in terms of what citizens desire in a disposal instruction label (48, 285). An avenue for future research could be to investigate whether a direct positive command e.g., 'dispose of with general waste' would perform better at increasing rates of compostable plastic packaging with general waste.

6.5.3. Which disposal instruction is most effective at getting citizens to put compostable plastic packaging with food waste? (Research Question 3)

To promote disposal with food waste, 'compost with food waste' had the highest rate of correct disposal in the food waste bin when compared to no disposal instruction. However, there was no difference between the three types of disposal instruction. This suggests that explicitly mentioning 'food waste' is important as

‘compost’ alone was not as effective as ‘compost with food waste’, ‘put with food waste’ or ‘recycle with food waste’.

These findings support and extend prior research. There is a growing body of evidence showing citizen’s desire for clear, specific and directive disposal instructions to enable the correct waste management behaviours (48, 285). This study provides supporting experimental evidence; clear, directive disposal instructions are not only desired by citizens but also promote the disposal of compostable plastics in the instructed manner.

Engagement in home composting was, overall, associated with reduced rates of correct disposal of packaging with food waste. A possible explanation for this is that many of the home composters may have been participants of the Big Compost Experiment citizen science project since this project’s mailing list was used to recruit participants. A key finding from this citizen science project was that much of the compostable plastic packaging on the UK market does not break down efficiently in most home composts (48, 182). This has, in turn, resulted in mistrust of this type of packaging amongst those research participants (48, 182). It is therefore plausible that home-composting participants disposed of these types of packaging in the general waste bin instead of the food waste bin as they did not trust the disposal instructions. As home composting is a niche practice in the UK (283), the impact of this on the wider population in terms of a broader waste management strategy is likely to be minimal.

6.5.4. Which potential alternative disposal instruction logos do citizens prefer for compostable packaging and why? (Research Question 4)

The logo that participants had the strongest preference for a simple, direct, comprehensive and explicit in denoting disposal in the food waste bin. The second preference was for a logo based on adaptations of the more established 'chasing arrows' recycling logo. Some thought that an instructive logo was easier to understand while others thought that a logo they associated with recycling was easier to understand.

Most logos denoting compostability make use of associative symbols e.g., the European Bioplastics 'seedling' logo. Nonetheless, symbols only have meaning within a context since they are something that represents or stands for something else. In the case of the European Bioplastics seedling logo, the logo represents adherence to compostability standards set by independent certifiers e.g., TÜV Austria and DINCERTCO (286). In addition, there are highly efficient organic waste collection systems across Europe including Austria, Slovenia, Belgium and Germany where the bio-waste capture rate is over 60% (this figure represents the percentage of food waste collected as a percentage of food waste generated) (205). Their success can be attributed to infrastructure, including simple-to-use, nationally uniform and reliable waste collection and processing services, but also to high citizen engagement which has been achieved through behaviour change interventions, including effective educational and motivational communications (214). The European Bioplastics seedling logo is therefore emblematic of a collectively understood and agreed upon *something else*. The more instructive logos were likely preferred in a UK context given the widescale citizen confusion about these

materials and the wider system failures outlined earlier. In a UK context, there is yet to be a functional and collectively established *something else* for which an associative symbol could meaningfully be emblematic.

Another reason for the differences in preferences could be that those who are generally more acquainted with and involved in waste management (e.g., those who home compost, already recycle food waste or who are generally pro-environmentally oriented) are more knowledgeable and so prefer associative recycling logic while less knowledgeable citizens are more likely to prefer a direct and instructive logo. This is difficult to ascertain as the thematic findings were not linked to survey respondents' home composting status, recycling status or ideological orientation. Overall, the findings suggest that a more direct and instructive logo is likely the preferable choice if the goal is to maximise general public engagement. This is corroborated by the quantitative results; clear, instructive messaging was most effective for all.

6.5.5. Implications

The findings have implications for Government policies and industry practices around labelling of compostable plastics. To direct items into food waste, explicitly mentioning food waste in a disposal instruction is likely to be effective. To direct items to general waste, 'do not recycle' might work for some packaging formats but it is likely that a clearer, directive disposal instruction e.g., 'dispose of with general waste' may be more effective. Evidence from WRAP corroborates this; citizens have a clear preference for labels which are directive, telling them exactly what to do with waste (285). If a separate compostability logo comes into practice, it will be important for this to be as direct, explicit and comprehensive as possible. While symbolic and

associative logos may be liked, for example, those based on adaptations of the more established ‘chasing arrows’ recycling logo, these types of logos may be more aesthetically pleasing than they are instigators of behaviour change.

The study findings also have wider implications for product and packaging design. The findings from the control group with no disposal instructions show that citizens struggle to identify compostable plastic packaging based on appearance alone. Other studies support that distinguishing these materials from their appearance is challenging (50, 287). A recent study by the US-based Composting Consortium and Biodegradable Products Institute shows that there was an increase in US citizens’ identification of a range of compostable plastic packaging formats based on varying uses of colour (288). It may therefore be useful to ensure compostable plastic packaging is as distinct as possible to enable their identification and promote their correct sorting for disposal. This could look like using material textures and colours that are not associated with the look and feel of recyclable waste.

6.5.6. Strength, limitations and future research

A strength of this study is the testing of a range of different compostable plastic packaging formats. Prior experiments have relied on testing a single packaging format (e.g. plastic water bottles or plastic cups) (49, 50). Testing a wider range of packaging formats minimises the potential confounding effects of participants’ existing behavioural associations with a type of packaging.

The study method presents some issues with ecological validity since it does not accurately simulate the real-world disposal environment, meaning that the effectiveness of the disposal instructions may be overestimated. The stimuli were

maximised on screen and participants concentrated on a science experiment. In reality, people often do not look at or notice labels on packaging, as disposal behaviour is highly habitual and automatic (48-50, 285). Even if the ideal wording and logo for compostable packaging were identified, people need to engage with them in the first instance.

Natural experiments or other types of in-person user experience studies where people physically interact with packaging can overcome some of these limitations and improve confidence in the generalisability of findings. Testing potential interaction effects between other packaging attributes on disposal behaviour can also extend findings as they have been found to influence disposal decisions e.g., the physical texture of the material, the condition of the material or the degree to which the material is food contaminated (289-292)

Future research is required to confirm whether other, clearer disposal instructions might be better to divert compostable plastic packaging to general waste. Based on the study findings, we speculate that a positive direct command e.g., 'dispose with general waste' may be a better disposal instruction when compared to the negative command 'do not recycle' especially for more ambiguous packaging formats or those that look organic. The present experimental paradigm could be adapted to investigate this.

Another potential limitation of this study is the sample used. Although about 60% of the participants were recruited via Prolific, which ensures diversity in terms of ethnicity, age, and gender, the overall sample was not entirely representative. It consisted of older, more politically left-leaning, and more educated individuals who were more involved in home-composting than national averages. While the overall

sample was representative in terms of gender, income, and access to local food waste collection services, the findings may not be generalizable to less educated, and more politically right-leaning groups in the UK. These groups may differ in their capability, opportunity, and motivation to dispose of compostable plastic packaging as desired.

6.6. Conclusion

This study aimed to evaluate disposal instruction labels for their effectiveness in promoting the desired disposal of compostable plastic packaging. With no disposal instructions, citizens disposed of compostable plastic packaging using intuitive logic. For instance, items that had a common practice of being compostable were put in food waste, items that had a common practice of being recycled were put in recycling and items that had a common practice of being disposed of with general waste were put in general waste. These automatic pathways may nonetheless be disrupted with the appropriate disposal instructions. While 'do not recycle' may currently work to divert some types of compostable plastic packaging to general waste, it may not work for all, especially items with a common practice of being compostable e.g., tea bags. Disposal instructions that explicitly mentioned food waste (e.g., 'compost with food waste' vs 'compost') led to a statistically higher rate of disposal of compostable plastics in the food waste bin. Citizens valued the depiction of simple yet comprehensive, instructive and explicit symbols in a logo for compostable waste, i.e., an arrow pointing into a bin, avoidance of associative symbols such as variations of the recycling chasing arrows symbol and depiction of a variety of different organic waste items that one can put in a council food bin. Taken together, findings are in line with a substantial body of research showing that citizens

have strong preferences for disposal instructions and logos that are clear, directional and explicit. Further, in-person studies and natural experiments in this area can improve the conclusiveness of findings.

7. Chapter 7 – General Discussion

The research presented in this thesis aimed to advance scientific understanding of the public's behaviour in relation to plastic waste. It drew on frameworks, methods, and principles from the behavioural sciences and circular economy literature. The focus was on behaviours concerning the waste management of compostable plastic packaging. The studies comprised a meta-analytic systematic review, one methodology and three empirical studies. These studies addressed the following research aims, as outlined in Chapter 1:

1. Identify key behaviours related to plastic waste;
2. Identify influences on key behaviours related to the purchase and disposal of compostable plastic packaging;
3. Design and evaluate an intervention aimed at enabling the desired disposal of compostable plastic packaging.

This chapter discusses the key findings and their interpretations in relation to each of these broad research aims. A reflection on the general strengths and limitations of the research process is outlined. The chapter finishes with discussing the broader implications this thesis has for research, policy and practice, and identifies unanswered questions and avenues for future research.

7.1. Summary and interpretation of key findings

7.1.1. Objective 1: Identify key behaviours related to plastic waste

An objective of Study 1 (the systematic review and meta-analysis) was to identify and categorise behaviours that have been studied in relation to plastic waste. The behaviours identified in the review predominantly related to the dry recycling of plastic waste followed by plastic bag use. In relation to recycling, most studies were generic in their specification of the action studied while others were more specific e.g., cleaning, compressing, separating and sorting of plastic. Behaviours identified in relation to the use of plastic bags included: generic use of plastic bags, use of reusable shopping bags when shopping, purchasing or taking of free single-use plastic shopping bags at checkouts and using no plastic shopping bags when shopping. Less commonly identified behaviours included: the generic resale, reuse, upcycling and donation of plastic items. Littering of plastic waste, disposal of compostable plastic water bottles and refilling of water bottles were also investigated by one study each. All behaviours related to reducing, reusing or recycling materials to reduce plastic waste.

Study 1 corroborated a well-known concept within the plastic circular economy research evidence: plastic waste results from a lack of reducing, reusing and recycling (including composting) materials. Most of the research in this area focuses on the technical and economic aspects of reducing, reusing or recycling. Study 1 identifies the role of human behaviour within these strategies. The identification of behaviours in Study 1 highlighted a mismatch between the quantity of empirical research on recycling and its priority within the EU's waste management hierarchy (25). The EU waste hierarchy prioritises waste management options in terms of

resource efficiency, prioritising waste prevention strategies over waste processing strategies. There are many plastic items where recycling materials may be the most desirable option. In the case of compostable plastics, these materials can be beneficial in medical packaging applications or for food-contaminated packaging that would otherwise be difficult to mechanically recycle. Nonetheless, it is recognised that circular economy transitions will require other strategies beyond the recycling of materials (i.e., reduction and reuse) (293). To make progress in this area, a greater scientific understanding of higher priority waste management behaviours (such as reducing material use altogether, repair and reuse) is needed.

7.1.2. Objective 2: Identify influences on key behaviours related to the purchase and disposal of compostable plastic packaging

The aims of Studies 1-3 were to identify influences on behaviours. An objective of Study 1 was to identify, categorise and evaluate factors that might be associated with the behaviours identified as relevant to plastic waste. The objective of Study 2 was to identify influences on buying compostable plastic packaging. The objective of Study 3 was to identify influences on food waste recycling via local council collection services.

Study 1 revealed that psychological capability was associated with behaviour but was neither sufficient nor the strongest driver of behaviours concerning plastic waste. This was echoed by Studies 2-3. In Study 2, the most frequently reported influences on compostable plastic packaging purchase were related to reflective motivation (e.g., beliefs about the environmental impacts of the behaviour and scepticism over decomposition claims). The majority of participants indicated that they were more likely to buy this type of packaging, demonstrating a motivation to

behave pro-environmentally, even if confused by these products. Study 3, which investigated influences on household food waste recycling found that increased automatic motivation (i.e., habit and 'feeling good for doing good') was the strongest predictor of food waste recycling amongst those who engaged in the behaviour, followed by psychological capability (i.e., knowing what to put in food waste and remembering to do so). Furthermore, when survey participants who had access to food waste collections but did *not* engage with them were asked to provide a reason as to why, factors relating to physical opportunity (e.g., convenience, access, local waste collection capabilities etc.) were the most frequently identified barriers.

These findings disrupt lay ideas held about human behaviour which often assume awareness of a problem and behavioural intention as the main drivers of behaviour. For example, one of the key errors that policymakers make when designing interventions is assuming that interventions need only raise awareness of a problem and motivate people to want to 'do the right thing' (147). The findings of Studies 1, 2 and 3 demonstrate that a combination of capability, opportunity and motivation are required to enact behaviour. Therefore, multi-faceted intervention approaches are often needed. When it comes to reducing plastic or food waste, people appear to have a desire to behave pro-environmentally. However, there is a need to do more to enable behaviour change - make the optimal behaviour the more obvious, easier, cheaper and more convenient thing to do. The implications of this for public policy are discussed in the subsequent sections of this chapter.

7.1.3. Objective 3: Design and evaluate an intervention aimed at enabling the desired disposal of compostable plastic packaging

The aim of Study 4 was to integrate the findings of previous studies in this thesis, alongside other relevant research, industry and policy evidence, to develop an intervention aimed at promoting the desired disposal of compostable plastic packaging. The study's findings were that UK citizens are generally aware of plastic waste as an issue and are motivated to dispose of compostable plastics correctly but their physical opportunity (e.g., availability of resources for waste management) and psychological capability (i.e., procedural knowledge relating to which bin to put them into) were key barriers. This meant that focusing on 'motivating' individuals or raising awareness of the environmental issues associated with incorrect disposal of compostable plastics was not enough. An effective intervention would likely need to increase opportunities to dispose correctly (i.e., access to appropriate bins and waste collection services) as well as instructions to ensure that individuals possess the necessary procedural knowledge to put the materials in the right bin. Since infrastructure change is beyond the scope of a PhD project, the resulting intervention targeted psychological capability i.e., an informative disposal instruction label for compostable plastics, consisting of instructions and a logo.

Study 5 aimed to evaluate the disposal instructions developed in Study 4. An objective of this study was to understand what people do with compostable plastic packaging when there are no disposal instructions. Findings showed that with no disposal instruction label, the correct disposal of these items was not obvious from their appearance. Items that 'look' like dry recyclable waste were put in the recycling bin (i.e., similar appearance to traditional dry recyclable plastics like PET), those that 'look' like general waste were put in general waste (i.e., similar appearance to non-recyclable plastic like and semi-flexible or plastic-coated materials) and those that

have a familiar status as being compostable went in food waste (i.e., compostable shopping bag and teabag).

A further objective was to investigate the effectiveness of the disposal instruction 'do not recycle' for diverting compostable plastics into general waste as this will be the UK strategy until a better long-term strategy for managing these materials is developed (261). 'Do not recycle', overall, increased rates of disposal into general waste but remained low for packaging formats associated with composability (i.e., teabags and compostable shopping bags) suggesting that such items might still be at risk of contaminating another waste stream when this disposal instruction is implemented.

Another objective of Study 5 was to evaluate the effectiveness of various disposal instructions at increasing rates of compostable plastic packaging disposal into household food waste. This is because local household food waste collections represent the best long-term UK strategy for collecting and processing compostable plastics. Findings showed that to promote disposing with food waste, 'compost with food waste' had the highest rate of correct disposal in the food waste bin when compared to no disposal instruction. However, there was no difference between the three types of disposal instruction. This suggests that explicitly mentioning 'food waste' is important as 'compost' alone was not as effective as 'compost with food waste', 'put with food waste' or 'recycle with food waste'.

The final objective of Study 5 was to evaluate the types of disposal instruction logos UK citizens preferred for packaging designed to be disposed of with food waste. The logo that participants had the strongest preference for a simple, direct, comprehensive and explicit in denoting disposal in the food waste bin.

Taken together, the findings of Study 5 show that citizens require direct and clear disposal instructions messaging (in terms of wording and logo imagery) to appropriately dispose of compostable plastic waste. This is likely to reflect the fact that identification and correct disposal of these items is not obvious from their appearance. The findings of Study 6 support prior research showing that people find it difficult to distinguish compostable plastic packaging from other types of plastic packaging based on appearance alone and frequently dispose of these items incorrectly (49, 50). They also support a growing body of evidence showing that people desire clear, specific and directive disposal instructions (48, 285). Most of the evidence in this area has, however, been qualitative. This study provides additional, experimental evidence that, in practice, clearer disposal instructions (e.g., 'compost with food waste' over 'compost') are not only desired but also promote the disposal of compostable plastics in the desired manner.

7.2. Strengths

The use of mixed methods within and across studies is a strength of this thesis. There were similarities between the findings of the qualitative and quantitative studies, strengthening the conclusiveness of those findings. For example, the qualitative results of Study 2 (i.e., that UK citizens are confused by compostable plastic packaging and their disposal) were in line with the quantitative results of Study 5 (i.e., without disposal instructions, the identification and disposal of compostable plastic packaging is not obvious from appearance). The qualitative results regarding logo preferences in Study 5 (i.e., the strongest logo preference was for one that was direct, comprehensive and explicit in denoting disposal in the food waste bin) were in line with the quantitative results of Study 5 (i.e., that 'compost'

was not as effective as ‘compost with food waste’, ‘put with food waste’ or ‘recycle with food waste’). Putting these pieces of evidence together strengthened the conclusion that desired disposal of compostable plastic packaging amongst UK citizens is likely to be enabled via direct, informative, unambiguous and explicit disposal instruction messaging on packaging.

The co-creation involved in designing the intervention is another strength of this thesis. Participatory workshops with relevant industry and policy stakeholders improved the relevance and likely application of the disposal instruction labels (Study 4) by ensuring that they would be feasible and acceptable within a UK context. Stakeholder input also helped improve the design of the intervention evaluation (Study 5) by ensuring that a wide range of relevant packaging formats were selected to test the disposal instructions on. Testing a wide range of compostable packaging formats minimises the potential confounding effects of existing behavioural associations with type of packaging and so increases confidence in the research findings.

A further strength is that Open Science principles of FAIR (Findable, Accessible, Interoperable, Reusable) data guided the research in this thesis (294). To make the research *Findable*, all the work in this thesis has been published (or submitted for publication) in peer-reviewed Open Science journals (e.g., Frontiers in Sustainability) or via peer-reviewed Open Access routes (e.g., Journal of Cleaner Production). All relevant study materials have been made openly available to the wider academic community and the public via an open science repository, Open Science Framework (OSF), the links of which are provided in the relevant chapters. To make the research *Accessible*, web links to the journal publications and relevant study

materials have been included in all chapters. There could have been a better use of metadata to increase the *Interoperability* of data. While efforts were taken to upload 'tidy' files to OSF, detailed meta-data would have improved the ability for others to understand and 'recycle' the data – this is a lesson learnt for future research. To make the data *Reusable*, raw data (e.g., survey exports) and analysis code (e.g., R code and thematic codebooks) are openly available via OSF. Taken together, this strengthened the overall integrity of the thesis findings by enabling a more transparent and accurate verification of the results.

7.3. Limitations

A potential limitation of Study 1 is the synthesis of study findings across a range of different behaviours in order to evaluate interventions that have been effective at changing behaviour. The effect sizes of interventions related to recycling, reusing and reducing plastic waste were combined to provide an aggregate effect size for the impact of a specific type of intervention strategy or behaviour change technique on behaviour change. The utility of these findings for designing specific, tailored interventions is therefore limited to some degree. Nonetheless, the findings of Study 1 may be useful as a starting point and could be combined with local, primary data collection approaches to gain a more comprehensive understanding of how to change a behaviour in a given context.

Another potential limitation is that research participants were either entirely (Study 2) or partially (Study 3 and Study 5) recruited via a UK-wide home-composting citizen science project. These studies may have suffered from self-selection bias as participation was voluntary (295). These citizens may have been systematically different from the general UK population in terms of their

demographics (e.g., higher SES, higher education, retired, engaging in home-composting) and capability (e.g., higher than average waste management knowledge), opportunity (e.g., more leisure time) and motivation (e.g., pro-environmental orientations, sense of civic duty) to participate in the research. Efforts to overcome some of these limitations were taken in Study 3 and Study 5 by additionally recruiting research participants from Prolific (222), which ensures representativeness in age, gender and ethnicity for UK research participants, and local authority mailing networks. While no demographic information was collected in Study 2, a range of demographic information was collected and controlled for, where relevant and appropriate, in the main analyses for Studies 3 and 5.

The effectiveness of the disposal instructions may have been overestimated in Study 5 since an online experiment does not accurately simulate disposal behaviour in the real world. Participants would have had high levels of attention given that they were participating in a research study and the disposal instructions were maximised on the screen. It is unlikely that this situation reflects the largely habitual and unconscious process that waste disposal often is in practice. A natural experiment or in-person study might get closer to simulating the real-world disposal context and therefore help to clarify this.

7.4. Implications for research, policy and practice

7.4.1. Research

Study 1 identified the dry recycling of plastic waste followed by plastic bag use as the most empirically studied behaviours. This illustrates a mismatch between the quantity of empirical research on recycling and its priority within the EU's waste management hierarchy (25). Circular plastics economy transitions require the

prioritisation of plastic reduction and reuse (293). Since citizens are a key part of a circular system, progress in this area will benefit from a greater scientific understanding of the role of behaviour change within these strategies. To reduce plastic waste, applications of behavioural science to changing behaviours relating to different *product categories* are also needed. An example of the next steps in a research agenda could include focussing on understanding how to develop or strengthen systems to reduce or reuse other types of plastic products, aside from packaging, that are often wasted. For example, disposable absorbent hygiene products (AHPs) including nappies, incontinence pads and period products lead to millions of tonnes of plastic waste that are sent to landfill or incineration every year yet none of the studies identified in Study 1's review investigated them (296, 297). Future research could focus on identifying the barriers and enablers to reducing disposable nappies and period products (e.g., pads and tampons) and enabling the adoption of reusable nappies and period products (e.g., period underwear and menstrual cups) across the variety of contexts in which they are used (e.g., work, home, care homes, travelling).

The findings of the first four studies informed Study 4, the development of an intervention aimed at enabling the desired disposal of compostable plastic packaging. In this study, the issue of plastic waste was conceptualised behaviourally and a target behaviour was selected (informed by Study 1). This was followed by investigations of the behavioural influences (Studies 2-3). The intervention developed in Study 4 was evaluated in Study 5. These studies were underpinned by an intervention development framework, the Behaviour Change Wheel. This allowed for the consideration of a range of potential behaviours and intervention strategies to

achieve the target goal of reducing plastic waste. This framework was selected because it was comprehensive, unlike the dominant models and theories of behaviour used within waste management research which do not consider the range of potential individual, socio-cultural and environmental influences on a behaviour. An example is the Theory of Planned Behaviour (TPB) (43), an extension of the Theory of Reasoned Action (298). The TPB proposes that behaviour depends on intention to enact the behaviour and perceived behavioural control i.e., a person's perception of the ease or difficulty of performing the target behaviour. Intention is hypothesised to depend on attitudes towards the behaviour, subjective norms about the behaviour, and perceived behavioural control.

The TPB has been applied to environmentally-significant waste management research, for example, to investigate food waste separation (299, 300), plastic bag use (301, 302), reusable bag use (303-305), reduction of single-use plastic products (306) and recycling (307, 308). Key critiques of the TPB include its narrow assumptions about what drives behaviour i.e., conscious, reflective psychological processes that do not account for the more automatic processes of emotion, past experiences and habit, or situational variables that can influence behaviour (309, 310). Applications of TPB in waste management research are therefore sometimes adapted or extended to account for these other variables e.g., (154, 311-313).

Assumptions about what drives behaviour are important because they will often influence the types of interventions that are used to change behaviour. This is exemplified by a review of behaviour change interventions based on TPB which showed that the behaviour change interventions mostly used persuasion and awareness raising (314), which may have been due to TPB's focus on reflective

cognitive processes as the driver of behaviour. The broader scope of other behavioural models, such as the BCW's associated TDF and COM-B, means that the scope of potential interventions is broader. Further, TPB offers little guidance in terms of how to move from understanding behavioural influences to intervention design, whereas the BCW does.

Using limited models to understand behaviour can mean key pieces of information remain missing. In practice, this can reduce the effectiveness of interventions based on these findings. Future research agendas could invest in behavioural research underpinned by more comprehensive frameworks of behaviour and behaviour change, such as COM-B, TDF, and the BCW. These frameworks have been recognised as useful for guiding applied research and are widely used and advocated by Public Health England (36, 47), Public Health Wales (315), ActionAid Ireland (316) and the World Health Organization (317, 318).

7.4.2. Policy and practice

The findings of the study investigating influences on compostable plastic purchase (Study 2) can be considered when developing industry rules, standards, and regulations for the labelling of compostable plastic packaging. Findings showed that UK citizens demonstrated the intention to purchase compostable plastics in preference to 'regular' plastics (e.g., PET). However, they found it difficult to identify them from other types of packaging, trust environmental claims, or put them in the right bin after use. This was due to inconsistencies in waste collection and processing for compostable plastics, the packaging not living up to its biodegradation claims, and the confusing messaging on products and packaging. Banning confusing terms such as 'biodegradable' and mandating the consistent use of direct, clear, and

instructive disposal instruction language and imagery can reduce greenwashing and increase knowledge of how to dispose of these products. Progress in this area requires concurrent improvements in policies and practices relating to compostable plastic certification and waste management infrastructure.

The findings of the study evaluating the impact of disposal instructions on the disposal of compostable plastic packaging (Study 5) can also be considered when developing industry rules, standards, and regulations for the labelling of compostable plastic packaging. The findings showed that: a) the written disposal instructions that explicitly mentioned 'food waste' were the most effective at diverting items to food waste and, b) that the more direct, instructive disposal instruction logo aimed at denoting disposal with food waste had the strongest preference. If disposal instruction labels are to be mandated, it is recommended that they consist of wording and imagery that is direct, informative and unambiguous given the strong evidence that this is what is both preferred and most effective at changing behaviour. There are potential issues then with mandating 'do not recycle' as a disposal instruction to denote disposal with general waste as it does not explicitly tell citizens where to put waste (just where not to put it). While 'do not recycle' worked to divert some types of packaging formats (e.g., a takeaway food container) to general waste, it was less effective for compostable plastic packaging formats that are commonly perceived as compostable (e.g., tea bags). It is plausible that a more direct, specific and explicit instruction such as 'put in general waste' would be more effective. However, this was not tested and so cannot be determined without further investigation.

The findings of the study investigating influences on household food waste recycling (Study 3) can be considered when developing strategies for the

implementation of nationwide household food waste collection services. The findings showed that household food waste recycling is complex and driven by a combination of capability, opportunity, and motivation. While citizens felt prepared for the introduction of separate food waste collections, to increase the likely engagement with these services, multi-faceted intervention approaches will be needed to encourage the majority of households who do not currently recycle their food waste to do so. Prioritising the following strategies is recommended: increasing knowledge around what can be put in food waste (capability); provision of affordable and 'fit-for-purpose' products to reduce the unpleasantness of dealing with food waste (motivation) and; ensuring well-resourced collection services that are regular, reliable, and efficient from the start (opportunity).

Evidence shows that policymakers make consistent mistakes when they try to change public behaviour. Kelly and Barker highlight key errors policymakers make when trying to change public behaviour (147). They focus specifically on errors made concerning promoting health-related behaviour change (e.g., smoking) but the principles transfer to waste management. Examples of the decision-making errors identified include assuming that behaviour change is just 'common sense', about getting the message across or that knowledge and information are the key drivers of behaviour. As argued throughout this thesis, Kelly and Barker maintain that behaviour change requires thoughtful science and a consideration of the broader social, environmental, and economic pressures that citizens are subject to. There are guides to support the application of behavioural science to improve UK government policy, services, and communications (36, 47, 315). It is recommended that policy decision-making in relation to improving household food waste recycling is

underpinned by behavioural science to maximise effectiveness and minimise potential unintended side effects.

7.5. Unanswered questions and avenues for future research

Study 5, which evaluated the impact of disposal instructions on the disposal of compostable plastic packaging, was unable to determine whether another disposal instruction could be more effective at diverting compostable plastics to general waste. Since directing compostable plastics to general waste is an impending scenario in the UK, determining a more effective disposal instruction could help reduce plastic waste further. The effectiveness of clear, direct, and explicit disposal instructions is a running theme throughout the findings of this thesis. It is hypothesised that a more explicit disposal instruction, such as 'put with general waste', may be more effective. An experimental paradigm, akin to the one in Study 5, could be adapted to test this hypothesis.

The online nature of the experiment investigating the impact of disposal instructions on the disposal of compostable plastic packaging (Study 5) may have meant that the effectiveness of the disposal instructions was overestimated. The stimuli were maximised on screen and participants concentrated on a science experiment. Prior studies indicate people often do not look at or notice labels on packaging as disposal behaviour is highly habitual and automatic (48-50, 285). Even if the ideal wording and logo for compostable packaging were identified, it remains unclear whether people would engage with them as intended in practice. Natural experiments or other types of in-person user experience studies where people physically interact with packaging can overcome some of these limitations and improve confidence in the findings.

In-person studies could include ‘think aloud’ components to better understand people’s judgement and decision-making processes. This is a research method that can help capture participant thought processes when engaging with interventions (319). The method could be applied to understand experiences of engaging with disposal instruction labels. Research participants could verbalise, in running commentary, what they are looking at, thinking about, doing, and feeling as they interact with the packaging in response to a disposal instruction label. This would help to advance knowledge of how people experience various aspects of packaging and make the disposal decisions that they do.

7.6. Concluding remarks

Human behaviour is central to the transition from a linear to a circular economy of plastics. This thesis aimed to gain a better understanding of the key behaviours concerning plastic waste, the influences on behaviours on behaviours related to the purchase and disposal of compostable plastic packaging, and design an intervention aimed at enabling the desired disposal of compostable plastic packaging. This was achieved through using a variety of qualitative and quantitative research methods and applying behavioural and behaviour change frameworks. The take-home findings are that a combination of reducing, reusing, and recycling is required to reduce plastic waste; the strategy prioritised should balance practicality and resource efficiency for that given context. UK citizens have a strong desire to behave pro-environmentally when it comes to reducing plastic and food waste, however, their environments are often not set up such that the optimal behaviour is the most obvious, easiest, cheapest and convenient thing to do. Designing disposal instruction labels with clear, instructive, and explicit disposal language and imagery can help to

divert the disposal of compostable plastics into the desired bin. This, however, cannot happen without improvements to the wider systems around the production, application and waste management of compostable plastics. The findings of this thesis can be used to inform the amendment of existing, and design of novel, interventions and policies relevant to these behaviours, including improvements to the implementation of public services relevant to these behaviours.

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