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Improving compostable plastic disposal: An application of the Behaviour Change Wheel intervention development method

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Compostable plastics have great potential environmental benefits, however, the damage caused by incorrect waste management offsets them. This study aims to develop a behavior change intervention aimed at improving compostable plastic disposal. We illustrate application of the Behaviour Change Wheel framework to design an intervention in this context. First, the target behavior was understood by specifying it and identifying potential behavioral influences. Second, behavioral influences were systematically linked to potential intervention strategies and refined by evaluating the likely affordability, practicability, effectiveness, acceptability, equity and potential for side-effects (APEASE criteria) in a UK implementation context. Finally, intervention content and implementation options were selected by systematically selecting specific Behavior Change Techniques and refining them by evaluating them against APEASE criteria. The target behavior was identified as UK citizens disposing of compostable plastic waste in the food waste bin meant 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 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 behavior change techniques were: instruction on how to perform the behavior, prompts/cues, adding objects to the environment and restructuring the physical environment. The resulting intervention is a disposal instruction label for compostable packaging, comprising of instructions and a logo. The next step is user testing the developed disposal instruction labels in terms of their effect on promoting the desired disposal behavior. The novelty of this study includes the development of an intervention to reduce compostable plastic waste and the explicit, step-by-step documentation of the intervention development process. The scientific significance is therefore both applied and theoretical. When evaluated, our intervention has the potential to yield insights relating to what improves compostable plastic disposal amongst citizens.

This, in turn, has key policy implications for product and package labeling. By openly documenting our method, we demonstrate a systematic and transparent approach to intervention design, providing an adaptable template and model for others.

KEYWORDS

compostable, biodegradable, plastic packaging, consumer behavior, disposal, recycling, intervention, behavior change

Introduction

In response to the plastic waste crisis, the UK Plastics Pact was launched in April 2018 where members pledged to make all plastic packaging 100% “recyclable, reusable or compostable” by 2025 in order to transition to a circular economy of plastics (WRAP, 2018). This declaration has resulted in a substantial growth of the compostable plastics packaging sector. European Bioplastics estimate the global market for compostable plastics, which was 2.11 million tons in 2018 to increase to ~2.62 million tons in 2023 (Bioplastics, 2018). Citizen science research shows a strong demand in the UK too: 84% of UK households taking part in a home-composting experiment reported that they are more likely to choose products that are marked as “biodegradable” or “compostable” (Allison et al., 2021a). However, several aspects of compostable plastic production, use and waste management are currently unregulated, lacking or underperforming (i.e., labeling, certification, infrastructure and citizens’ behavior) hindering their potential environmental benefits (Aparsi et al., 2020). This current dysfunctional system is highlighted in Figure 1.

Labeling

Compostable packaging labeling is defined by mandatory and non-mandatory labeling requirements as well as manufacture marketing strategies. General Product Safety Regulations 2005 (Government, 2005) sets out the mandatory labeling criteria for products being supplied within or into the UK and Northern Ireland by obligated producers and importers. In Great Britain, enforcement of the 2005 Regulations is carried out by local trading standards authorities and the UK Secretary of State (Standards, 2022). The Regulations set out the minimum labeling requirements for all products and packaging including display of name and address of producer and product reference or batch code (Standards, 2022).

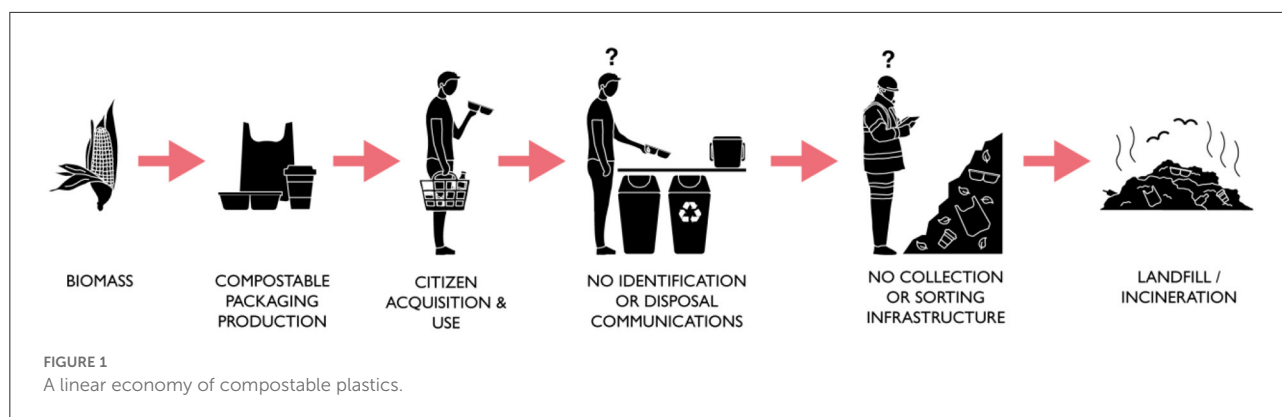
Abbreviations: APEASE, Affordability-Practicability-Effectiveness-Acceptability-Side-effects-Equity Framework; BCT, Behavior change technique; COM-B, Capability-Opportunity-Motivation-Behavior Model.

Labeling plays a key role in providing packaging and products 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 (Companion, 2021), there are currently no special rules for compostable plastics. This means that manufacturers and suppliers of these materials are at liberty to label/market them as they prefer. The inconsistency in labeling has resulted in widespread citizen confusion surrounding compostable packaging terminology such as “home compostable,” “industrially compostable,” and “biodegradable,” leading to growing public mistrust in compostable packaging claims (WRAP, 2007; Allison et al., 2021a; Companion, 2021).

Certification

Given that citizens struggle to distinguish the biodegradability of a waste material, it is especially important for authorities 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 labeling (International Organization for Standardization, 2016). The standard does not serve as verification of environmental claims, instead requiring third party verification through an accredited certification scheme (EuropeanBioplastics, 2019). UK guidance about non-mandatory packaging communications for compostable packaging label exists, including advice to avoid statements such as “100% compostable,” “compostable,” “biodegradable,” and “plastic free” (WRAP, 2020a).

Although information about a product’s packaging material type and recycled content or disposal instructions is not currently mandatory, UK Government is consulting on the introduction of mandatory labeling of packaging under new Extended Producer Responsibility scheme reforms to



be introduced from late 2022 (DEFRA, 2020). Current implementation target dates are mandatory labeling for all packaging types (except plastic films and flexibles) by 2026, with plastic film and flexibles included by 2027 (DEFRA, 2020). Other comparable non-mandatory labeling 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 (EuropeanBioplastics, 2019).

In addition, manufacturers can obtain third party certification of industrial and/or home compostable plastic performance from a number of 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) (Recycling AfO, 2011). 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 (Foundation BP, 2019). 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 the plastics recycling and some food waste collection systems if the system does not have the capacity to manage them.

Infrastructure

Life cycle assessment shows that the current system, with no dedicated UK-wide collection and processing facilities for

compostable plastics, is not environmentally favorable (Yates and Barlow, 2013; Spierling et al., 2018). 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 (Taneepanichskul et al., 2022). Nonetheless, the UK Government has consulted on changes to waste collection consistency and aims to introduce mandatory food waste collection for UK households by 2023 (DEFRA, 2020). This is largely driven by policy targets to improve recycling rates, reduce contamination and improve recycle quality across different waste streams, and to reduce the associated environmental impacts of sending organic waste to landfill (DEFRA, 2020). The proposed scheme provides a promising opportunity to reliably collect and process a growing waste stream of compostable plastics. However, there exists 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, development of new waste infrastructure raises critical questions about UK citizens' behavioral adaptation to changes in current residual waste disposal and recycling practices and their preparedness for new and unfamiliar separate organic waste recycling infrastructure.

Citizen engagement

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. Citizens' adoption of the required food waste recycling behaviors will therefore be critical for a circular economy of compostable plastics, as food waste collection is the only viable route for their management en masse. Evidence suggests, however, that more

work is needed in this area. Not only are there still many UK citizens who lack access to food waste collection services, many with access still do not engage with these services (Allison et al., 2022). In addition, there is widespread confusion relating to the terms, often used interchangeably, used to label compostable plastics which also leads to confusion regarding their end-of-life management (WRAP, 2007; Allison et al., 2021a). Experiments testing people's disposal of compostable plastics support this by showing that they frequently dispose of them incorrectly e.g., in the recycling bin (Taufik et al., 2020; Ansink et al., 2022). Changes to current patterns of behavior are therefore required to fully realize the benefits of compostable plastics. Guidance for developing and evaluating the kinds of "complex" interventions needed to achieve such behavior change argue for theoretically-grounded and evidence-informed approaches (Craig et al., 2008; French et al., 2012).

Behavior change

There are various behavioral models and theories that can underpin behavior change intervention development. One example is the Behaviour Change Wheel (Michie et al., 2011, 2014) which is itself an integrative framework synthesized from 19 other existing behavior change frameworks. The Behaviour Change Wheel's purpose is to provide a comprehensive and systematic analysis of all the available intervention options using behavior change theory and the available evidence. In stages, the Behaviour Change Wheel advocates a process of systematically mapping underlying influences on a behavior to specific techniques that have been deemed to best target and influence these determinants in order to bring about the desired behavior change. More detail on the Behaviour Change Wheel and its advocated method can be found in Section Materials and equipment. While the Behaviour Change Wheel has been widely applied in health behavior change research, it has had comparably limited application in sustainability research, despite many sustainability problems being behavior change issues. There is therefore great value in illustrating the Behaviour Change Wheel's application in the present context. Of the few studies in this area, the Behaviour Change Wheel has been shown to be a valuable tool for designing interventions targeting recycling (Allison et al., 2022) and reuse (Allison et al., 2021b). It has also been used in behavior change intervention development guides for local (England, 2020) and national (England PH, 2020) government and partners therefore making it an appropriate and useful framework for the design of the present intervention. Designing our intervention using an established theoretical behavior change framework is more likely to increase its effectiveness.

Aims

The primary aim of this paper is to design an implementable behavior change intervention that promotes the desired disposal of compostable packaging. A secondary aim is to document the systematic intervention development process using the Behaviour Change Wheel method.

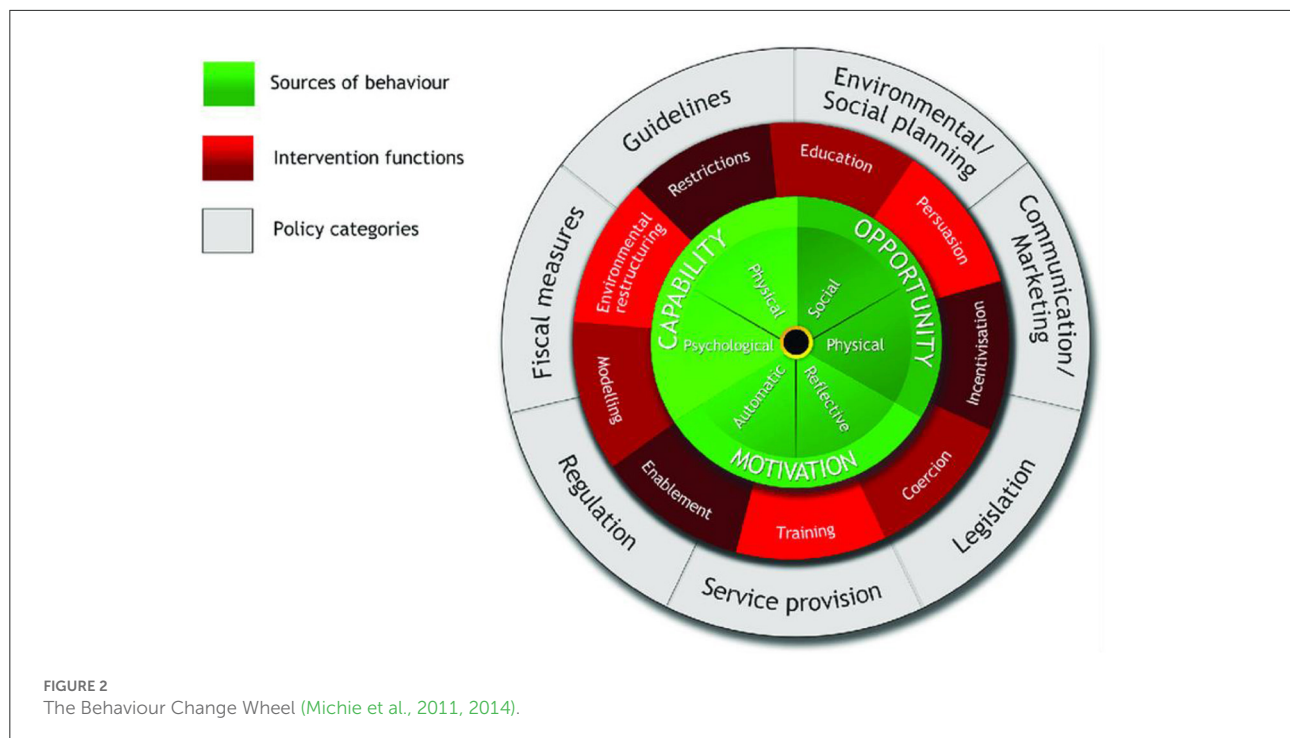
Materials and equipment

To improve intervention documentation, we used the GUIDED framework which provides guidance for reporting intervention development studies in health research (Duncan et al., 2020). To guide the intervention development process, we use the Behaviour Change Wheel as a theoretical intervention development framework (Michie et al., 2011, 2014). To ensure that our intervention was informed by evidence, we use peer-reviewed empirical findings, industry data and stakeholder feedback as source material.

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. Nonetheless, we believe the checklist items are valuable to the present circular economy context as they offer transferrable principles for good intervention documentation practice. For instance, we used the checklist to ensure that we 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. Uncertainties at the end of the intervention development process (e.g., requirement for piloting),
11. According to TIDieR guidance (Hoffmann et al., 2014) when describing the developed intervention and,



12. Via an open access format at the publication stage.

The items we did not report on were “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.

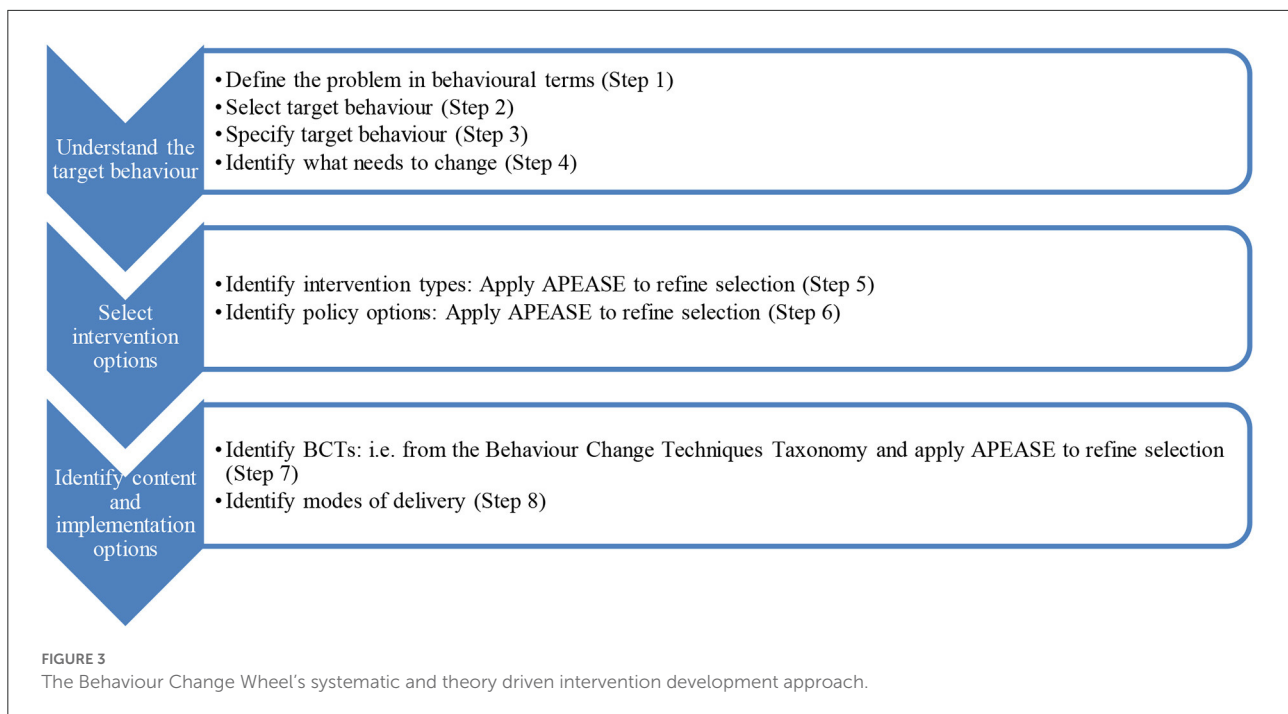
Behaviour Change Wheel intervention development framework

Shown in Figure 2, The Behaviour Change Wheel is a framework for designing interventions that change behavior. The wheel itself consists of three parts: (1) An inner hub which represents influences on behavior in terms of people’s capability, opportunity and/or motivation; (2) A middle layer of “intervention types” which are broad ways to target underlying influences to bring about behavior change, and; (3) An outer layer which are policy options for supporting delivery of the intervention types. The components of the wheel echo the method advocated by the Behaviour Change Wheel. It involves a process of systematically mapping underlying influences on behavior to broad types of interventions and potential policy options. Not depicted in the wheel itself is an additional step after intervention types and policy options have been

selected. This step involves systematically mapping intervention types to specific Behavior Change Techniques (BCTs) from the Behavior Change Technique Taxonomy (Michie et al., 2013) – a taxonomy of 93 hierarchically clustered techniques identified as being able to change behavior (e.g., action planning, goal setting etc.).

The definitions of each intervention type, policy option and BCT can be found in Appendix A. The Behaviour Change Wheel approach also advocates the use of APEASE criteria (Affordability, Practicality, Effectiveness, Acceptability, Side effects, Equity) throughout which is an evaluative framework to enhance the relevance, utility and practicability of a proposed intervention. APEASE criteria ask intervention designers to consider the following throughout their decision-making process:

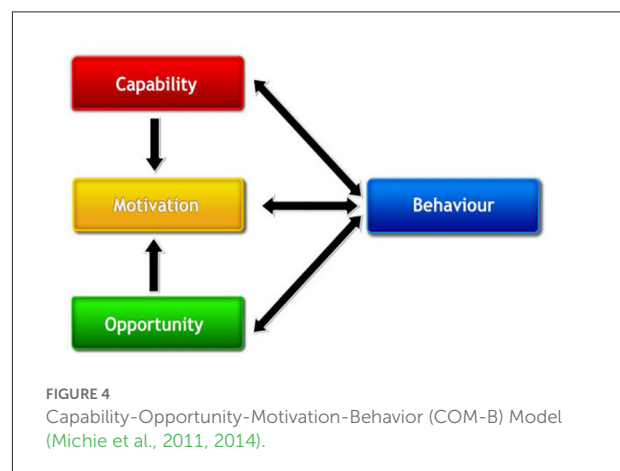
- (Affordability) How costly is the proposed intervention going to be?
- (Practicability) Can the intervention feasibly be delivered as designed in the intended setting?
- (Effectiveness) How effective is the intervention at changing the target behavior?
- (Acceptability) Is the intervention deemed appropriate by key stakeholders and those receiving the intervention?
- (Side effects) Are there any potential unwanted side effects from delivering this intervention that need to be considered?



- (Equity) Does the intervention instigate disparities between different sectors of society?

In terms of methodology, the Behaviour Change Wheel advocates three broad phases: first, to understand the target behavior; second, to identify intervention options and; finally, identify content and implementation options. These broad stages, which in turn can be broken in a series of further steps, are outlined in Figure 3. The Method and Results section are structured according to these three broad stages.

According to the Behaviour Change Wheel approach, an additional behavior change model may be used to help guide the process of understanding the target behavior. Shown in Figure 4, this is the COM-B model (Capability-Opportunity-Motivation-Behavior) (Michie et al., 2011, 2014). The COM-B model can help to identify underlying determinants of behavior i.e., identifying what needs to change (Step 4 in Figure 3). COM-B posits that for a behavior to occur there must be the capability, opportunity and motivation to perform the behavior. Capability can be psychological (e.g., knowledge) or physical (e.g., skills); opportunity can be social (e.g., social norms) or physical (e.g., environmental resources); motivation can be automatic (e.g., habits) or reflective (e.g., beliefs, intentions). These influences can be barriers, hindering a target behavior, or enablers that promote or maintain a target behavior. Identifying these barriers and enablers to a target behavior can help identify what the intervention needs to target to achieve the desired behavior change.



Evidence

A multi-method, iterative approach was used to integrate seven sources of evidence and systematically progress through the phases outlined in Figure 3. The evidence integrated included:

- A qualitative study of barriers and enablers to buying compostable plastic packaging (Allison et al., 2021a).
- A mixed-methods study on barriers and enablers to household food waste recycling (Allison et al., 2022).

- Two experiments testing citizens' disposal of compostable plastics (Taufik et al., 2020; Ansink et al., 2022).
- A survey investigating citizen's bioplastic knowledge, perceptions and end-of-life management (Dilkes-Hoffman et al., 2019).
- A report summarizing research insights on citizen's behavior toward packaging labeling design by OPRL (OPRL, 2020).
- A review of research studies into On-pack Labeling and Citizen Recycling Behavior (WRAP, 2020b).

Stakeholder involvement was assured *via* two consultation meetings conducted on 05/05/2021 and 22/02/2022 to support the design process and ensure the practicability, relevance, utility and acceptability of the intervention. A wide range of UK stakeholders were consulted including representatives from academia, industry, not-for-profit and government. To protect anonymity, their details have been omitted. Figure 5 provides a summary of the materials and resources used as evidence.

The subsequent section details what we did in each broad stage of the Behaviour Change Wheel approach (as outlined in Figure 3) in order to select intervention types, policy options and BCTs.

Method

Understand the target behavior

Detailed in Figure 3, four steps were taken to understand our target behavior. This was approached by reviewing literature to conceptualize the problem of plastic waste in behavioral terms (Step 1). This step was followed by selecting and specifying the target behavior and broad type of plastic waste item of focus (Step 2 and 3). A synthesis of existing relevant evidence supported understanding the influences upon the target behavior (Step 4). Mapping the identified behavioral influences onto COM-B enabled a better understanding of what needed to change.

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. This stage of intervention development therefore 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 behavioral targets identified in our COM-B analysis in the previous step. These steps also

involved a critical evaluation of possible intervention types and policy options against APEASE criteria.

Identify content and implementation options

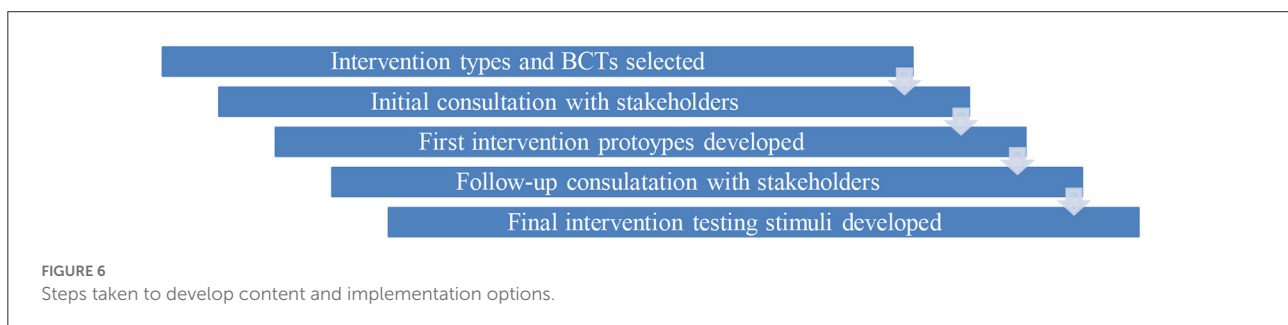
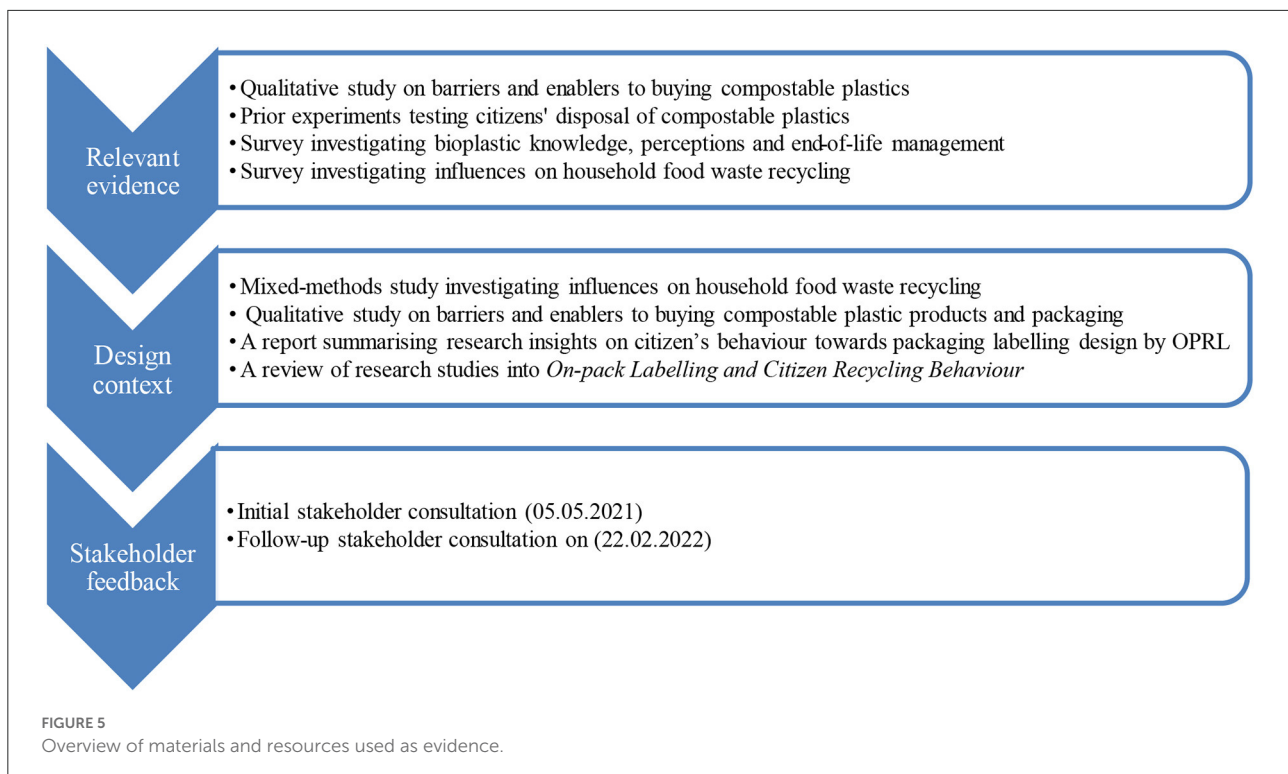
The content (Step 7) and implementation (Step 8) options were considered and developed iteratively, in the phased approach shown in Figure 6.

Content was chosen using the Behavior Change Techniques Taxonomy to select BCTs. The Behaviour Change Wheel guide offers guidance on the BCTs most commonly used per intervention type and so this was used to support consideration. APEASE criteria were applied throughout this selection process too. BCTs found not to meet APEASE criteria were not carried forward to the next stage of intervention design. Practicality and acceptability were deemed to be of particular importance in this evaluative process by the research team given the context for implementation.

To set the scene, at the time of this study in 2022, UK Government is consulting on new mandatory labeling for packaging in the UK as part of Extended Producer Responsibility scheme reforms. The key aim of mandatory labeling is to give citizens clear information about what they can and cannot recycle using simple binary messaging i.e., "recycle" or "do not recycle" (DEFRA, 2020). 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 (Ecosuricity, 2020).

Compostable packaging, with the exception of 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 mandatory "do not recycle" labeling from 2023. 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 (DEFRA, 2020). 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 (DEFRA, 2020).

UK Government is currently considering two options for Extended Producer Responsibility mandatory labeling. Option 1 is the use of approved labels where 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 labeling 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 (DEFRA, 2020). Option 2 is a government appointed single labeling scheme whereby producers would need to adhere to a single labeling scheme and use the same labels. In this scenario all obligated producers would be required to register with a single labeling scheme; the scheme operator would establish the process of registration, labeling design and auditing (DEFRA, 2020).

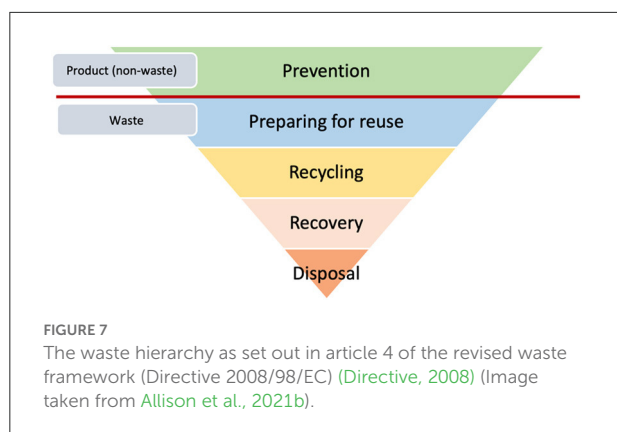
The implementation options for delivery of the BCTs (i.e., prototype interventions) were first developed by two members of the research team, a behavioral scientist (ALA) and architect designer (DP), with input from other members of the research team. They were then iteratively revised based on stakeholder feedback.

Results

Understand the target behavior

Define the problem in behavioral terms

In light of the UK Plastics Pact (WRAP, 2018) and the “waste hierarchy” set out in Article 4 of the European Union’s revised Waste Framework (Directive 2008/98/EC) (Directive, 2008), which ranks waste management options according to what is best for the environment (Figure 7), the problem of plastic waste was conceptualized behaviorally as poor waste management i.e., a lack of reducing, reusing, recycling and composting plastic to ensure that waste is kept to a minimum and materials are kept within a circular system.



Select the target behavior

To reduce plastic waste, various behaviors relating to reducing, recycling, reusing and composting could have been selected. As highlighted in Section Introduction, disposal of compostable plastics was prioritized because compostable plastics are proliferating on the market, yet there is no system for collection, sorting or processing of compostable plastic in the UK. They are also currently unregulated and there is widespread confusion about what they are and how to dispose of them. Therefore, they are increasingly contaminating other plastics recycling and some food waste collection systems, which are not able to process compostable plastics. Improving the current system for compostable plastics is therefore likely to be an effective way of reducing plastic waste.

Figure 8 highlights what a circular economy of compostable plastics in the UK could look like. Disposal behavior (i.e., which bin the citizens put the plastics into) is key part of getting the compostable plastic “system” to work; if citizens get it wrong then the system does not work. As highlighted in Section Introduction, there is widespread citizen confusion about what compostable plastics are and how to dispose of them which leads to incorrect disposal; therefore, behavior change in this area is likely to achieve the desired outcome of reducing plastic waste.

Specify the target behavior

The selected behavior 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 at an items end-of-life (when) within the home (where). While home/community-composting was another possible option, this was deemed unlikely to be feasible for the majority of urban-dwelling UK citizens who live in densely populated housing often without access to a garden (DEFRA, 2021). In addition, evidence suggests that most plastics labeled as compostable do not biodegrade in home-composts (Aparsi et al., 2020).

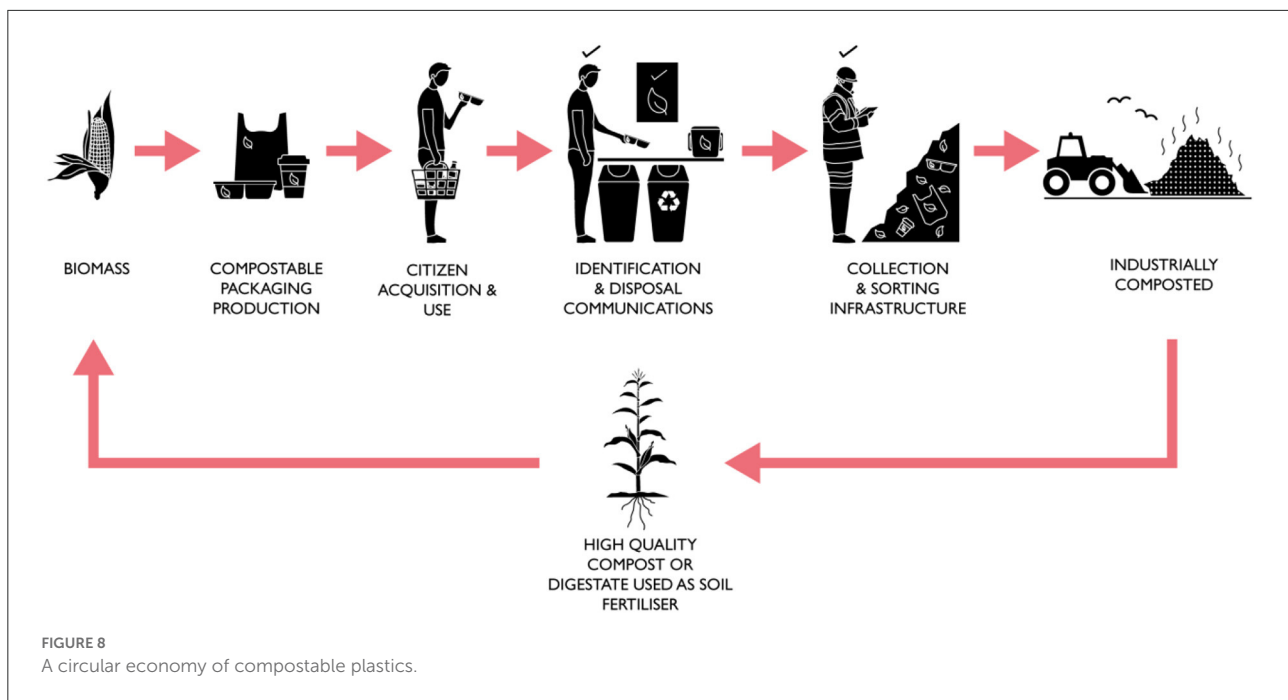
Identify what needs to change

As shown in Figure 5, five sources of evidence provided information on behavioral influences. One is a behavioral experiment testing disposal of compostable plastic water bottles in Germany (Taufik et al., 2020). The second is a similar study testing disposal of compostable plastic packaging in the Netherlands (Ansink et al., 2022). The third is a survey investigating perceptions, knowledge and end-of-life management of bioplastics in Australia (Dilkes-Hoffman et al., 2019). As these studies were not conducted within the present context, these findings were supplemented with a qualitative study of barriers and enablers to purchasing biodegradable and compostable plastic packaging amongst UK citizens (Allison et al., 2021a) and a survey of influences on household food waste recycling amongst UK citizens (Allison et al., 2022). Shown in Table 1, determinants of disposal behavior identified in these studies were mapped to COM-B, as this was selected as the theoretical framework to underpin intervention development.

In summary, the issue was found to be predominantly rooted in psychological capability, reflective motivation and physical opportunity. People lack knowledge of and familiarity with compostable plastics which leads to confusion in terms of 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 were put there to communicate the appropriate end-of-life instructions. Lack of knowledge and familiarity is also likely related to holding of erroneous beliefs around nature and processing of compostable plastic waste (i.e., that they can actually biodegrade and 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.

Select intervention options

A mapping process, recommended by Behaviour Change Wheel guidance was followed. We considered and selected from a range of potential intervention types (Table 2) and policy options (Table 3), based on the types on intervention strategies considered likely to be effective at addressing the psychological capability, physical opportunity and reflective motivation related barriers identified in Section Understand the target behavior. The use of APEASE criteria, along with consideration of intervention context, assisted in narrowing down potentially appropriate intervention types and policy options. The intervention types selected were education and environmental restructuring. The policy options



selected were guidelines, communications/marketing and environmental/social planning.

Four intervention types were considered inappropriate and so excluded: enablement, persuasion, modeling and training. Persuasion and modeling were not deemed likely to be very effective as the target behavior is not one where people lack motivation or inspiration to enact the desired behavior. In fact, people overwhelmingly have pro-environmental intentions and wish to “do the right thing” when it comes to compostable plastic packaging (Dilkes-Hoffman et al., 2019; Taufik et al., 2020; Allison et al., 2021a; Ansink et al., 2022). 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 make much of a difference. Training was excluded on ground 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 on the grounds that, based on the behavioral diagnosis, any intervention strategy is unlikely to go beyond education and environmental restructuring.

Four policy categories were excluded: service provision, legislation, regulation and fiscal measures. Service provision was excluded as implementation of nation-wide food waste collection services are already planned by UK government; therefore, addressing the physical opportunity related barriers of 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. Legislation was not practical to focus on within this project as the process involved would be out of scope for a research study.

Select content and implementation options

Content

A mapping process, recommended by Behaviour Change Wheel guidance was followed. We considered and selected from a range of potential BCTs, based on the intervention types selected. Selection of potential BCTs was informed by the types of BCTs recommended in the Behaviour Change Wheel guide as most commonly used to deliver each intervention type. The use of APEASE criteria, along with consideration of intervention context, assisted in narrowing down potentially appropriate BCTs (Table 5). Table 4 presents all nine potential BCTs. Table 5 presents BCTs, separated into those that will be included or excluded from the next stage of this intervention development. Reasons for inclusion or exclusion of each BCT are assessed against APEASE criteria (Table 5). Selected BCTs at this stage included: instruction on how to perform the behavior, information about social and environmental consequences, prompts/cues, self-monitoring of behavior, adding objects to the environment and restructuring the physical environment.

TABLE 1 Table showing factors associated with compostable plastic waste disposal.

	Taufik et al., 2020	Ansink et al., 2022	Dilkes-Hoffman et al., 2019	Allison et al., 2021a	Allison et al., 2022
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 neighbors 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

Implementation options

The outputs of Section Select intervention options and Section Content (illustrated in Tables 2–5) were taken to an initial stakeholder feedback session to narrow down the selection of BCTs. The outcomes of this meeting were the following:

- Consensus that a label designed to communicate end-of-life disposal instructions for compostable plastic packaging was the most suitable implementation option for this intervention.
- Consensus that the prototype labels 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 (WRAP, 2020a).
- Additional packaging formats requested to be tested were sauce sachets and takeaway food and drinks containers.
- There is a need to test how the wording “compost with food waste” and “recycle with food waste” are understood by citizens.
- Importance of testing different combinations of logos (WRAP “Recycle Now” logo), disposal instructions and packaging formats to see if this impacts citizen understanding of label messaging.
- The importance of testing potential alternative compostable logos to understand if this impacts citizen understanding and subsequent disposal behavior of compostable waste materials.
- Importance of testing labels alongside representative examples of packaging formats to understand if the presence of other mandatory and non-mandatory labeling impacts citizen understanding and behavior.
- Consensus regarding the utility of an online task-based experiment to test the impact of different labels on disposal behavior.
- Owing to industry support and UK Government's proposed Extended Producer Responsibility binary labeling system the OPRL label system was chosen to form the basis for prototype intervention labeling formats.

TABLE 2 Intervention types appropriate for targeting underlying behavioral 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
	Enablement	Increasing means/reducing barriers to increase capability (beyond education/ training) or opportunity (beyond environmental restructuring)	Not applicable because a strategy going beyond both education and environmental restructuring unlikely	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
	Enablement	Increasing means/reducing barriers to increase capability (beyond education/ training) or opportunity (beyond environmental restructuring)	Not applicable because a strategy going beyond both education and environmental restructuring unlikely	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
	Modeling	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 considered practical , affordable or likely to be very effective	Excluded

Once a label had been agreed on as the implementation option, our selection of BCTs were further refined (see Table 6). This was based on evidence showing how labeling design impacts citizen disposal behavior in relation to recyclable materials and recycling systems (OPRL, 2020; WRAP, 2020b). Although these studies do not relate specifically to compostable packaging labeling, they highlight several general packaging labeling design parameters that should be considered and controlled for in the design of intervention prototype labels. Practical considerations include size, color and format of label, and position on-pack (OPRL, 2020; WRAP,

2020b). Additionally non-statutory packaging graphics and branding plays an important role for product manufacturers in advertising, marketing and brand identity. These considerations practically limit the size and location of the intervention labeling designs.

Other considerations were the limitation of space to display an intervention prototype label due to mandatory product labeling requirements under Regulations 2005 (Government, 2005). For example, pre-packed food packaging labeling must include product name and name and address of manufacturer, ingredients list (by weight from largest to smallest) and

TABLE 3 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 behavior or practice	Not considered practical for this project as the timeline would not allow for the process of changes to current labeling 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
Enablement	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 marginalize 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 behavior or practice	Not considered practical for this project as the timeline would not allow for the process of changes to current labeling 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
Environmental restructuring	Service provision	Delivering a service	Implementation of nation-wide food waste collection services are already planned by UK government	Exclude
	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 marginalize 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

(Continued)

TABLE 3 Continued

Intervention type	Policy option	Definition	APEASE	Included/ exclude from next stage
	Regulation	Establishing rules or principles of behavior or practice	Not considered practical for this project as the timeline would not allow for the process of changes to current labeling 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

TABLE 4 Identification of the possible BCTs that could be used in the intervention.

COM-B	Intervention type selected	BCTs identified
Psychological Capability (i.e., attention and knowledge)	Education Environmental restructuring	<ul style="list-style-type: none"> • Instruction on how to perform the behavior • Information about social and environmental consequences • Information about health consequences • Feedback on behavior • Feedback on outcome of the behavior • Prompts/cues • Self-monitoring of behavior • Adding objects to the environment • Restructuring the physical environment
Reflective motivation (i.e., beliefs)	Education	<ul style="list-style-type: none"> • Instruction on how to perform the behavior • Information about social and environmental consequences • Information about health consequences • Feedback on behavior • Feedback on outcome of the behavior • Prompts/cues • Self-monitoring of behavior

emphasize any of the required 14 allergens, use by date, nutritional information, and storage or cooking instructions. For non-food packaging labeling other product labeling regulations apply (Companion, 2021). Therefore, “Information about social and environmental consequences” and “Self-monitoring of behavior” were excluded based on the practicality of implementing these *via* a label which would have to be very simple, with minimal wording/design. The BCTS selected were: “Instruction on how to perform the behavior,” “prompts/cues,” “adding objects to the environment” and “restructuring the physical environment.”

Figure 9 depicts examples of disposal instruction labels and logos which could be superimposed onto a variety of different types of packaging formats and evaluated to see whether they: (a) effectively communicate the food waste bin as the disposal end-point and (b) are effective at getting people to

actually *dispose* these waste materials in their food waste bins. The first row consists of variations of disposal instructions and ORPLs “Recycle Now” logo. The second row consists of potential alternative logo imagery for uniquely communicating compostability of material at end-of-life.

Discussion

This study aimed to report the multi-method process involved in designing an intervention to promote disposal of compostable plastics. A secondary aim was to do this using a theoretical behavior change framework – the Behaviour Change Wheel. Our proposed intervention involved a rigorous and structured design process built on a foundation of primary research and evidence synthesis by a team of multi-disciplinary

TABLE 5 List of included/excluded BCTs with reasons for inclusion/exclusion.

BCTs	APEASE	Included/excluded
Instruction on how to perform the behavior	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 behavior	Not considered practical for this context as disposal behavior is happening in the privacy of homes	Excluded
Feedback on outcome of the behavior	Not considered practical for this context as disposal behavior 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 behavior	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 6 Narrowing down selection of BCTs.

BCT	Included/excluded	Rationale
Instruction on how to perform the behavior	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 behavior	Excluded	Not practical to deliver <i>via</i> 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

researchers with expertise in behavioral science, implementation science, health psychology, design, architecture and material science. This was supported by input at each stage from industry and policy experts.

The resulting intervention is a disposal instruction label for compostable plastics, comprising of instructions and a logo. In this paper, we report on influencing disposal to local food waste collections in the UK. However, the method is general and could easily be applied to a local authority, region or country that wants to use labeling to influence behavior to

direct compostable plastics to a different destination other than food waste collection. Our step-by-step documentation of the intervention development process, including our systematic mapping exercises, has demonstrated a transferrable methodology and created a series of useful research outputs (i.e., tables) which can be used as guiding templates by others.

Our work has important practical applications. Unless citizens are able to dispose of compostable plastic waste materials in the correct bin, these materials will continue to contaminate other waste streams or sent to landfill and incineration. We have

designed an intervention that, when evaluated, has the potential to provide important answers relating to how best to get citizens to dispose of compostable plastic waste appropriately. This, in turn, has key policy implications for product and package labeling. In addition, applying behavioral science can aid in the designing of theory and evidence-based strategies that are more likely to be effective at achieving sustainable behavior change. The UK Medical Research Council framework for designing and evaluating “complex” interventions has advocated systematic intervention development, using evidence base and theory (Craig et al., 2008). Seemingly simple behaviors, such as disposing of compostable plastic waste, are located within complex systems of several interacting groups of actors (e.g., customers, manufacturers, suppliers, policy makers), operating across different groups (e.g., individual, community, population) and at various organizational levels (e.g., local, governmental). Therefore, a key strength of this work is the intentional and systematic application of a theoretical behavior 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 behavior change (Kelly and Barker, 2016).

Our work also has important theoretical implications. There are few published examples of the Behaviour Change Wheel applied to developing interventions sustaining environmental health e.g., (Gainforth et al., 2016; Allison et al., 2021b). Our study is therefore useful and novel in terms of its application within a circular economy context. We outline a clear process that can serve as a template for understanding and changing a wide variety of environmentally significant behaviors. The open documentation of our methods is also important for advancing behavior change science. When intervention development studies are published, they are usually included as part of a feasibility or pilot study. Publishing them as standalone studies and in line with established guidance for reporting interventions (Duncan et al., 2020) allows for a more systematic, comprehensive and transparent approach to intervention development reporting, which, in turn enhances the quality of interventions and improves learning about intervention development research and practice.

In line with the UK Medical Research Council’s guidance for developing complex interventions, the next stage of this project is to pilot the prototype labels developed (Craig et al., 2008). This is likely to involve user testing. For instance, this could include exposing people to the newly developed disposal instruction labels and observing which bin they sort the waste into (e.g., a general waste, food waste or recycling bin). This will help to identify the type(s) of wording and logos that are most effective at getting people to put different types of compostable plastic packaging in the desired bin. This study could initially be piloted online to assess the approach and testing procedures as the labels are likely to require further refining prior to conducting an in-person study.

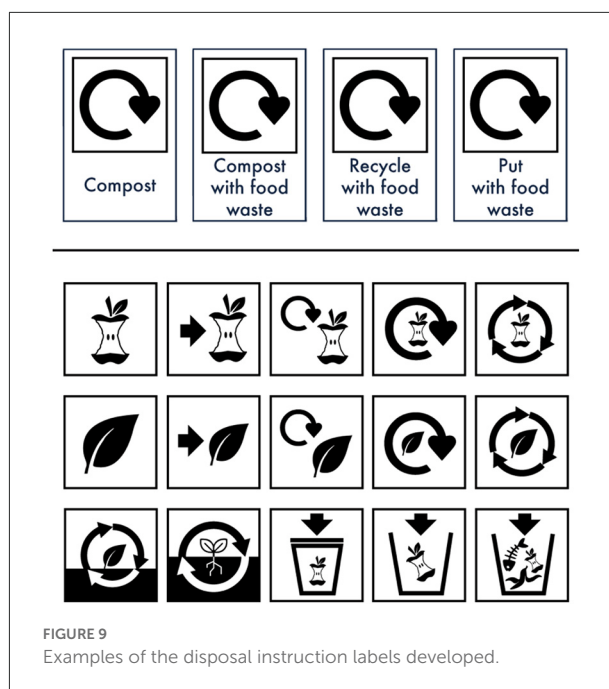


FIGURE 9
Examples of the disposal instruction labels developed.

At the conclusion of the intervention development process, we were able to describe the rationale, theoretical basis, content and delivery of the intervention. However, we were not able to investigate in detail the potential impacts of other aspects of product packaging e.g., branding, color, imagery, material texture, packaging/product format. These are very likely to influence the delivery of our disposal instruction labels and so their potential impacts in the specific context of our developed disposal instruction labels should be explored in any user testing. Existing rules and regulations (or lack, thereof) relating to package labeling and imagery are also important contextual factors to take into consideration. There is much “greenwashing” and false advertising in the area of biodegradable and compostable plastic products (Aparsi et al., 2020; Allison et al., 2021a). The introduction of a disposal instruction label is unlikely to be sufficient as an intervention strategy until products that are not compostable but claim to be are banned from the market. While focusing on regulation or legislation as policy options was deemed out of scope for the current intervention, we recommend future interventions to consider this as it will be instrumental in preventing potentially misleading imagery and claims to be put on packaging.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AA, DP, SM, and MM: conceptualization, methodology, and validation. AA: data curation, formal analysis, investigation, project administration, and writing—original draft. MM and DP: funding acquisition. AA and DP: resources and visualization. SM, MM, and FL: supervision. AA, DP, MM, SM, and FL: writing—review and editing. All authors contributed to the article and approved the submitted version.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/frsus.2022.968152/full#supplementary-material>

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