Study Protocol

Reducing Disposable Diaper Waste: Protocol for a Behavioural Science Workstream

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Abstract: Disposable diapers contribute to the generation of plastic waste globally, with more than 8 million tonnes of diapers ending up in landfills or incinerated each year. One strategy for reducing this waste while maintaining child and parent health and well-being is to increase reusable diaper use and reduce delays in toilet training. We outline a protocol for applying behavioural science to understand the factors influencing these behaviours and to generate intervention recommendations. The research will be conducted in two stages. Stage 1 involves semi-structured interviews and surveys, guided by the Capability, Opportunity, Motivation-Behaviour (COM-B) model, to explore factors influencing reusable diaper use and toilet training at 18–30 months. Data will be analyzed using quantitative (regression and ANOVA) and qualitative (deductive and inductive) methods. Stage 2 involves triangulating findings to identify key barriers and enablers. Intervention frameworks (Behaviour Change Wheel and BCT Taxonomy) will help identify potential behaviour change intervention strategies to target key barriers and enablers identified within COM-B domains. Interventions will be presented to multidisciplinary stakeholders and nominal group technique process will be used to agree on the most promising, feasible, and acceptable options for development and piloting. The findings will help generate recommendations for supporting UK government policy and practice change in this area.

Keywords: absorbent hygiene product; circular economy; intervention; nappy; potty training; public health; sustainability; waste management

1. Introduction

The widespread use of disposable diapers presents a significant environmental problem. Primarily made of polymers, including cellulose, polypropylene, polyester, and polyethylene [1], millions of tonnes of disposable diapers predominantly end up in landfills or are incinerated every year making them a major contributor to global plastic waste [2,3]. While recycling methods such as mechanical processing or composting exist, they are rarely implemented due to cost, lack of infrastructure, and logistical factors. Until these issues are resolved, an environmentally favourable approach to dealing with diaper waste is to increase resource efficiency [4]. Such a strategy focuses on minimising disposable diaper usage before they become post-use waste. Reducing delays in toilet training and increasing reusable diaper use are two behaviours that can enable the source reduction in disposable diapers.

A 2023 Life Cycle Assessment (LCA) commissioned by the Department for Environment, Food and Rural Affairs (DEFRA) in the UK highlighted that both disposable and reusable diapers have environmental impacts [5]. The primary environmental impact of

disposable diapers comes from their materials and production, followed by end-of-life treatment which is landfill or incineration. Separate waste collections of disposable diapers to allow recycling of the plastic materials, urine, and faeces are technically possible. However, the implementation of this system increases costs and is currently carried out only in a small number of UK local authorities (e.g., Wales). In contrast, the largest environmental impact of reusable diapers occurs during the use phase, particularly due to energy consumption for washing, drying, and the environmental impact of detergents. Ongoing initiatives aimed at decarbonising the electricity grid should reduce the environmental impact of the use phase of reusable diapers over time [6]. Additionally, reusable diapers can offer significant cost savings for parents. The UK Government's Money Advice Service estimated that parents could save up to GBP 1475 or more, including laundry costs, by using reusable diapers over home-brand disposable diapers in 2021 [7]. Nevertheless, reusable diapers represent only about 5% of the UK nappy market [8] indicating that there are many factors other than cost and plastic waste that influence parental choices of diaper products.

In parallel, there is a growing trend for delayed toilet training completion and increased diaper use, especially in the Global North [9–16]. In the UK, the average age for toilet training completion has increased from 28.5 months in the 1950s [17] to 36.8 months in the 2000s [13]. This trend contrasts with the Global South, where toilet training ages remain lower, such as 22.3 months in Turkey [18] and 23.8 months in Jordan [19]. While perceptions of the right age for toilet training and practices vary between different generations, countries and cultures [20–23], in the UK, the Children's Bowel and Bladder Society (ERIC) recommends that most children are ready for toilet training between 18 and 30 months of age [24]. Yet, in 2024, 91% of UK teachers reported having at least one school starter in class (compulsory school age in the UK is 48 months) who was not yet toilet trained [25]. Toilet training delays raise concerns not only about increased diaper waste but also about health and social impacts. Prolonged use of diapers beyond the recommended toilet training age can increase the risk of urinary tract infections [26] and have negative effects on the child's mental health and quality of life [27]. It can also create an emotional burden for caregivers, leading to stress, frustration, and tension between parents and children [28,29]. Additionally, it increases the economic burden on parents who must purchase diaper products for longer.

To address the behavioural challenge of disposable diaper waste reduction, it is essential to understand the barriers and enablers related to reusable diaper use and toilet training at 18–30 months. Currently, research on the factors influencing both behaviours are limited. For reusable diaper use, studies based in England identify some barriers to the adoption of reusable diapers. These include a lack of knowledge and misinformation, limited availability, perceived inconvenience, high upfront costs, and negative stereotypes associated with reusable diapers [30,31]. A 2011 study in Scotland explored the impact of providing financial and environmental information through a health website [32]. It found that 73.4% of parents were prompted to consider reusable diapers, highlighting the potential of informational campaigns in influencing behaviour. More recently, a 2023 study conducted in Indonesia investigated the factors influencing the intention to use alternatives to disposable diapers [33]. This study identified perceived benefits such as environmental impact, financial savings, and social status and identity affirmation, along with perceived threats such as health concerns for their children, as determinants of pro-environmental intentions. Surprisingly, motivation and subjective norms showed no significant relationship with the intention to adopt alternatives. These findings demonstrate the interplay of environmental awareness, financial considerations, and health perceptions in shaping parental choices regarding diaper use.

For toilet training, the literature highlights the importance of convenience (e.g., waiting to start toilet training until holidays), routines, and social pressures (e.g., starting school, shame and taboo in peer groups) as key factors [34]. Findings suggest many parents do not regard delayed toilet training as a problem issue or do not prioritise early toilet training, citing time constraints and disposable diapers as reasons [16,35]. On a broader societal scale,

delays have been attributed to various changes in modern lifestyles which have changed the characteristics of the caregiving environment. Examples include less authoritarian and more child-centred attitudes towards the child [11,14,36], both parents working outside the home [11], and the use of day-care services for working parents [37,38]. All of these factors can lead to parents having less time to toilet train [36] and later age at initiation of toilet training [13,16] leading to later completion. The widespread use of disposable diapers has also been associated with delays in toilet training [11,12,14,36,39]. It has been suggested that the high absorbency levels of disposable diapers might inadvertently reduce the sensory feedback that helps some children learn bladder and bowel control, potentially delaying the appearance of 'readiness signs' for toilet training [40]. Supporting this notion, the UK's National Health Service recommends folding kitchen paper inside the diaper or using 'pull-up pants' which have lower absorbency during toilet training. This approach helps children become aware of wetness, facilitating an easier and potentially earlier transition during toilet training [41].

Taken together, reducing disposable diaper waste will rely on strategies that support parents and other caregivers with reusable diaper use and earlier toilet training, whilst also delivering convenience, health, and comfort. Behavioural science offers valuable frameworks for addressing these issues by understanding and influencing behaviour change. Nonetheless, there are numerous behavioural change theories that often overlap conceptually, making it challenging to choose the most appropriate one for a specific context [42]. To address this, researchers have developed integrated, overarching frameworks and models that synthesise these theories. One example, shown in Figure 1, is the COM-B model [43]—and associated Theoretical Domains Framework (TDF) [44]—which posits that for a behaviour to occur (i.e., reusable diaper use or toilet training at 18–30 months), one must have the capability, opportunity, and motivation to enact it (links between COM-B and TDF shown in Figure 2). Both frameworks integrate various behaviour change theories into a set of domains that reflect the individual, socio-cultural, and environmental factors influencing behaviour. Capability refers to the physical and psychological capacities to enact behaviour such as skills, knowledge, attention, and memory. Opportunity refers to how the physical and social environment shapes behaviour, including factors such as time, resources, infrastructure, and the social context (e.g., norms, support). Motivation encompasses the automatic and reflective internal processes that drive behaviour, such as habits, emotions, priorities, and beliefs.
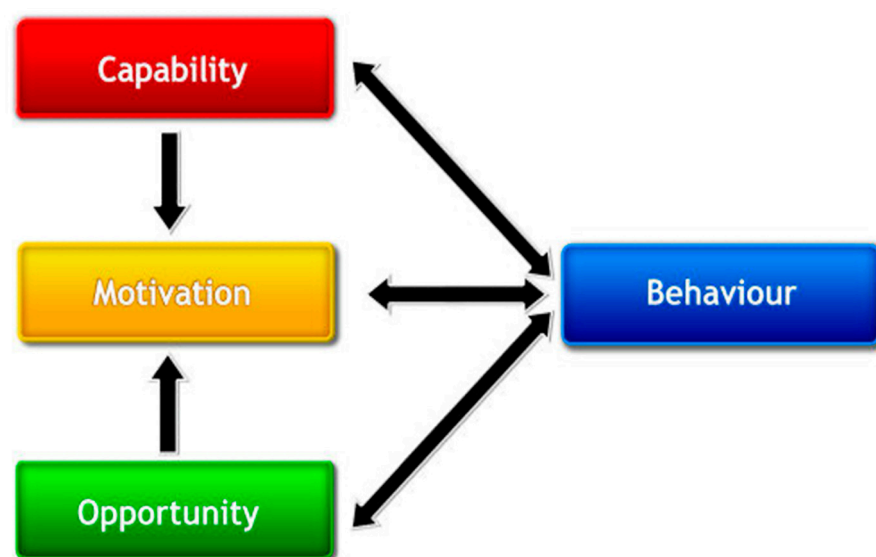
Figure 1. The COM-B model (reproduced with permission from [43]).
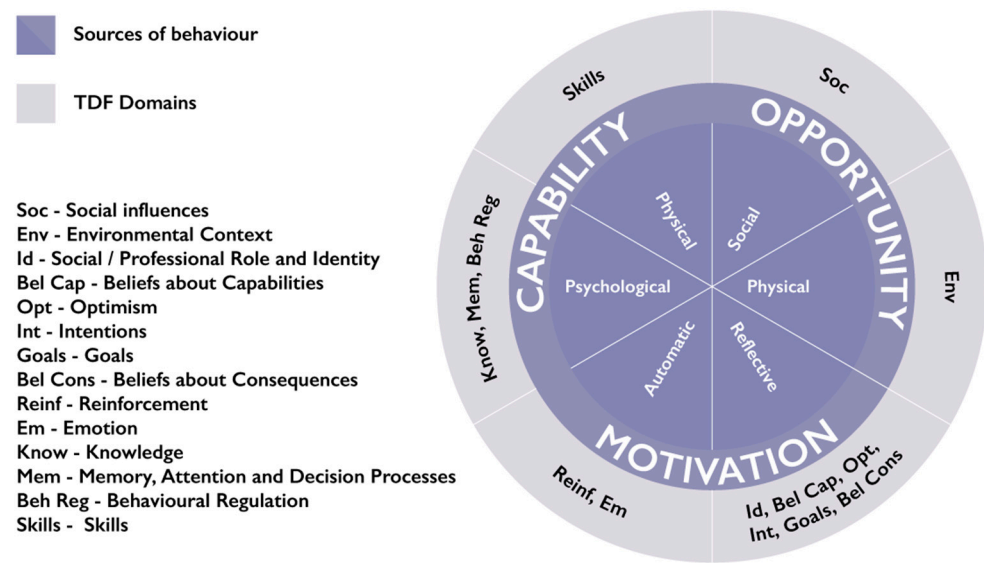
Figure 2. Link between TDF and COM-B categories (reproduced with permission from [45]).

Both the COM-B model and TDF have been previously utilised to examine the barriers and enablers to behaviours related to waste management and other sustainability practices, such as gardening [46]. An advantage of these frameworks is their connection to two intervention development tools: the Behaviour Change Wheel [43,47], which identifies nine broad intervention types (such as education, modelling, incentivisation, and environmental restructuring), and the Behaviour Change Technique Taxonomy, which specifies ninety-three detailed techniques for changing behaviour [48]. Published matrices are available that pair COM-B and TDF domains with interventions in both the Behaviour Change Wheel and the Behaviour Change Technique Taxonomy, making these tools valuable for guiding systematic, targeted, and theory-based intervention development [47].

In our research, we will employ the COM-B model and TDF as the overarching frameworks to direct our data collection and analysis, focusing on factors that influence reusable diaper use and earlier toilet training. These frameworks will help in triangulating and comparing findings across different research methods. Furthermore, we will refer to the Behaviour Change Wheel and the Behaviour Change Technique Taxonomy to identify potential intervention strategies aimed at overcoming key barriers and promoting the desired behaviours, such as increased reusable diaper use and toilet training between 18 and 30 months.

The overall aim of this research is to advance understanding of behaviour concerning disposable diaper waste reduction. To this end, the specific objectives are as follows:

(1) Identify barriers and enablers to reusable diaper use and earlier toilet training as they relate to capability, opportunity, and motivation to reduce disposable diaper waste.

(2) Identify and come to a consensus with interdisciplinary stakeholders (parents, early years staff, health professionals, etc.) on the interventions that support reusable diaper use and earlier toilet training without impacting the health and well-being of children or caregivers.

2. Methods

The proposed research consists of a two-stage mixed-methods study, with Stage 1 addressing Objective 1 and Stage 2 addressing Objective 2. An overview can be found in Figure 3. Each stage is described below.
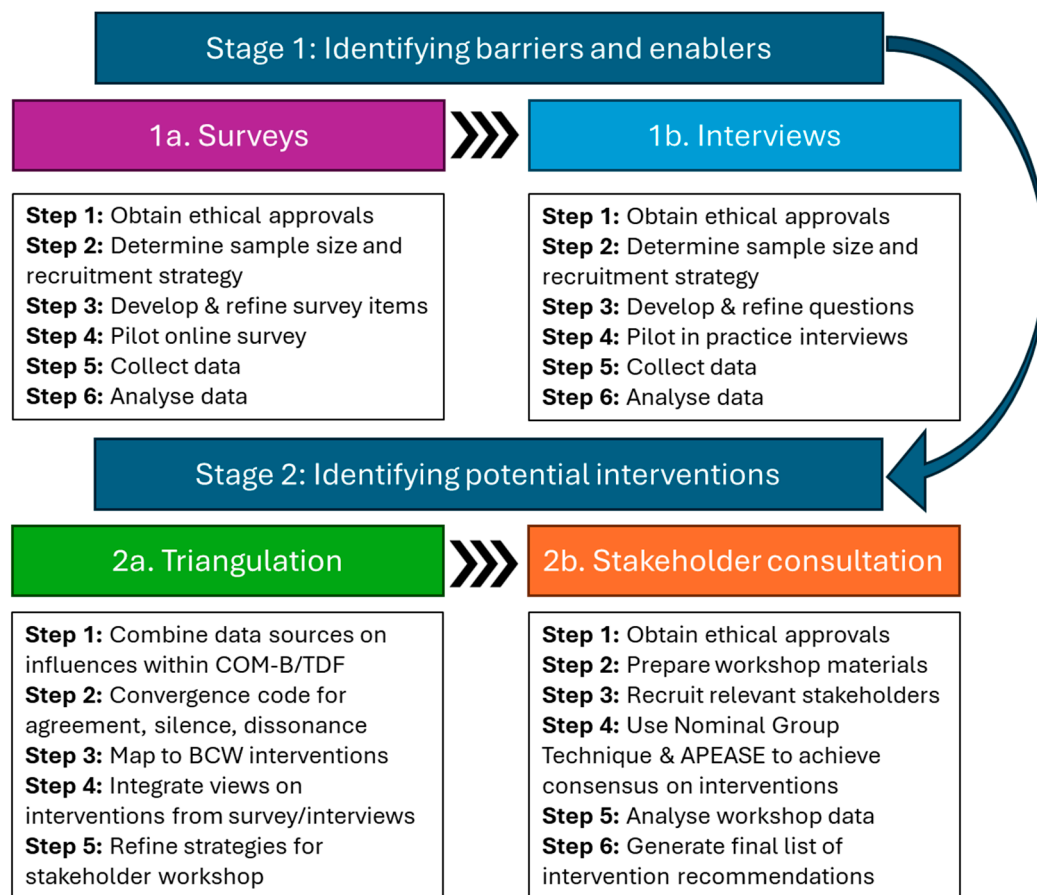
Figure 3. Overview of proposed research. BCW = Behaviour Change Wheel.

This work is approved under UCL Ethics (CEP/2020/579), with each sub-study requiring separate registration and approvals. Stage 1 involves three sub-studies, which were registered with and approved by UCL's local Data Protection Office: the survey (Z6364106/2024/03/35), interviews on diaper use (Z6364106/2024/05/169), and interviews on toilet training (Z6364106/2024/06/75). For Stage 2, we will apply for research registration for the stakeholder workshop before conducting the study.

In our data collection materials, we use the terms 'nappy' and 'potty training' to refer to diapers and toilet training, respectively. These terms will be used to engage research participants, aligning with the commonly used terminology in the UK, the context of this research.

ChatGPT (version GPT-4) by OpenAI was employed in the final stages of manuscript preparation to enhance the readability, clarity, flow, and conciseness of the text. Additionally, it was used to assist in refining language, including spelling and grammar, ensuring the manuscript meets high standards of written communication.

2.1. Stage 1: Identifying Barriers and Enablers

Stage 1 involves two sets of semi-structured interviews and online surveys, one each focussed on diaper use and toilet training.

2.1.1. Online Survey
Participants

For the surveys, the inclusion criteria include being a parent or primary caregiver to a child currently in diapers or who has recently (i.e., in the last year) stopped using diapers due to toilet training. Participants will need to be over 18, ordinarily resident in the UK and have sufficient English to participate.

Recruitment

The online survey will be hosted by Qualtrics (https://www.qualtrics.com/uk/, accessed on 25 July 2024) and we will recruit participants using Prolific (https://www.prolific.com/, accessed on 25 July 2024), a data collection service where they will be reimbursed for their time. First, we will conduct a pre-screener survey of Prolific's pool of participants who have children, with their youngest born between 2019 and 2024 to identify eligible survey participants. This pre-screener survey will also assess participants' diaper use behaviour (primarily disposable, hybrid or primarily reusable) and toilet training status (soon to start, currently toilet training and recently completed toilet training). We plan to take a phased approach to data collection whereby an initial 500 responses will be collected and assessed for the spread between the different diaper users and toilet training statuses. Then, if necessary, we will selectively invite more participants to the main survey to ensure spread between groups.

Prolific and Qualtrics both have mechanisms in place to minimise bots and fraudulent responses, ensuring higher data quality in our research study. Prolific offers a pre-screened, human-verified participant pool, while both platforms monitor response timing to detect irregularities. We will match Prolific responses to unique Prolific IDs, allowing us to review participant answers in Qualtrics. This process enables us to identify and reject suspicious entries on Prolific before data collection is complete, ensuring that only high-quality responses are retained and allowing additional participants to join. To maintain data integrity, we will issue unique completion codes through the integration of Prolific and Qualtrics, including only those participants who fully complete the survey in our analysis. We will exclude participants who provide inconsistent answers, such as discrepancies between their Prolific sign-up information, pre-screening survey, and main survey responses, or those with extremely short or excessively long response times. This approach ensures that only high-quality data are included in the final analyses. Prolific also includes a built-in chat function that allows participants to communicate directly with researchers. To ensure fairness, if a participant believes their response was unfairly or mistakenly rejected and it was not a bot or fraudulent response, they can contest the decision through this chat. In such cases, participants will be reimbursed for their time and/or given the option to return their submissions, preventing a rejection from appearing on their Prolific accounts.

Sample Size

We aim to recruit between 500 and 1000 survey participants. This is based on a G* Power calculation. A priori power analyses were conducted using G*Power (version 3.1.9.7) [49] to determine the necessary sample size for a multiple linear regression analysis. The analyses were based on an anticipated small to small-to-medium effect size $f^2 = 0.2$–0.5, an alpha level of 0.05, and a desired power of 0.95. The analysis assumed 6 predictors in the regression model (each COM-B variable). The power analysis indicated that a total sample size of 424–1050 participants would be required to detect the expected effect size with 95% power.

Materials

The survey broadly consists of six sections. The full survey instrument can be found in the Supplementary Materials (S1).

The first section collects data on behavioural patterning of different types of diaper use, e.g., which diaper products, their frequency of use, and the different contexts in which they are used. The second section collects data on influences on reusable diaper use. A third section collects data on the patterning of toilet training behaviour, e.g., whether they have yet to start toilet training, are currently toilet training, or have recently completed toilet training including their child's age at the time of planned, current, and completed toilet training depending on which group they belong to. The fourth section collects data on influences on toilet training. The fifth section collects data on support for intervention strategies promoting reusable diaper use and earlier toilet training. The sixth section

collects demographic information such as age, gender, UK region, etc. An additional final section, which will only appear for reusable diaper users, will collect data on patterns associated with reusable diaper use, e.g., total number of diapers in rotation, laundering practices, and plans for diapers when no longer needed, etc.

To explore the influences on reusable diaper use and earlier toilet training, participants will be asked to rank, on a 5-point Likert scale, in agreement with statements representing different types of barriers and enablers. We will include at least one barrier or enabler statement corresponding to each domain of COM-B. Participants will also be able to provide additional influences on their behaviour through an open-ended survey question. These frameworks have been employed similarly to identify barriers and enablers to food waste recycling [50]. Table 1 summarises example COM-B statements from the survey.

Table 1. Examples of survey COM-B statements for influences on behaviour.

COM-B Domain	Diaper Use	Toilet Training
Capability	- I do not know what reusable nappy products are available - Disposable nappies are easier to assemble and put on that reusable nappies - Disposable nappies lead to better child sleep, ensuring more rest for parents	- I did not know what the recommended age for potty training initiation and completion is - I have enough energy to potty train my child earlier - I know how to potty train
Opportunity	- I do not know many other people using reusable nappies - Healthcare providers recommend disposable nappies - The upfront costs of reusable nappies are too expensive	- I feel pressure from nursery/school to complete potty training earlier - I am able to be physically present for consistent potty training at 18–30 months - Disposable nappies make it easier to delay potty training past 30 months
Motivation	- I prioritise sustainability in other aspects of my life, so I am not overly concerned about the types of nappies I use - Reusable nappies look better than disposable nappies - Reusable nappies are a bit gross	- I am motivated to potty train earlier by the potential financial savings from no longer needing to buy nappies - I want to potty train earlier to reduce my impact on the environment from using nappies - Potty training at 18–30 months can fit into my household's routine

Note: The terms 'nappy' and 'potty training' refer to diapers and toilet training, respectively. These terms will be used to engage research participants, aligning with the commonly used terminology in the UK, the context of this research.

To explore support for interventions, participants will be asked to rank, on a 5-point Likert scale, their support for statements representing different types of intervention strategies that would help promote more reusable diaper use and earlier toilet training. As shown in Table 2, we include at least one intervention corresponding to each Behaviour Change Wheel intervention type (e.g., education, training, environmental restructuring).

The initial set of survey items was developed as a 'paper' version in Microsoft Word (365 suite) to facilitate easier feedback and comments. This version established the survey's broad structure, including items that explored behavioural patterns, potential influences, and possible interventions. Initial items were developed through a combination of literature review, ongoing discussions with interdisciplinary research team members (e.g., an LCA expert to identify necessary data on reusable nappy usage), and informal consultations with key stakeholders, including parents, child healthcare professionals, and toilet training educators. The content was cross-referenced with COM-B, TDF, and the Behaviour Change Wheel to ensure comprehensive coverage. Any relevant influences or intervention types that were missing were added to cover those domains. The wording and framing of items were iteratively refined with input from stakeholders and the research team, and free-text options were included to capture any additional influences or interventions that might have been overlooked.

Table 2. Examples of potential Behaviour Change Wheel (BCW) intervention types.

BCW Intervention Type	Supporting Reusable Diaper Use	Supporting Toilet Training at 18 to 30 Months
Education Increasing knowledge and understanding by informing, explaining, showing and correcting	- Informational campaigns raising awareness of reusable nappies and how to use them	- Campaigns to educate, encourage, and show the health benefits of earlier potty training for parent and child (e.g., via social media content, podcasts, healthcare-backed content)
Persuasion Changing the way people feel about a behaviour by generating cognitive dissonance and showing how changing behaviour can reduce it	- Media campaigns showing the impacts of plastic waste from disposable nappies on the environment	
Modelling Showing examples of the behaviour for people to imitate	- Parenting-focussed social media content to encourage and show the benefits of using reusable nappies (e.g., podcasts, influencer content, NHS content)	
Coercion Changing the attractiveness of a behaviour by creating the expectation of an undesired outcome or denial of a desired one	- Raise the financial cost of disposable nappies (e.g., via tax) to incentivise the use of reusable alternatives	- Raise the financial cost of disposable nappies (e.g., via tax) to incentivise earlier toilet training completion
Training Increasing psychological or physical skills, or habit strength by explanation, demonstration, practice, feedback and correction	- Healthcare professional-delivered training for parents on how to use reusable nappies (e.g., assemble, launder)	- Healthcare professional-delivered training for new parents and caregivers on when and how to potty train
Enablement Providing support to improve ability to change in a variety of ways not covered by other intervention functions, e.g., through medication, surgery, encouragement, moral support	- Provision of affordable nappy 'libraries' where reusable nappies can be borrowed/rented and returned - Provision of affordable and reliable reusable nappy laundering services	- Paid parental leave to support parents and caregivers to potty train
Environmental restructuring Constraining or promoting behaviour by shaping the physical or social environment	- Reusable nappies as the standard nappies used in healthcare and nursery settings	- Have early year practitioner (e.g., nursery staff) support with potty training by incorporating skills-based potty training into what children are taught at pre-school and nursery
Restrictions Constraining behaviour by setting rules	- Restricting the heavy marketing of disposable nappies	- Only admit children to school that are potty trained (unless the child has special educational needs)
Incentivisation Changing the attractiveness of a behaviour by creating the expectation of a desired outcome or avoidance of an undesired one	- Vouchers to support with the upfront and/or laundering costs of reusable nappies	- Charge additional fees for children that childminders and nursery workers must regularly change (unless the child has special educational needs)

Note: The terms 'nappy' and 'potty training' refer to diapers and toilet training, respectively. These terms will be used to engage research participants, aligning with the commonly used terminology in the UK, the context of this research.

The survey was then transitioned to an online format using Qualtrics, where further revisions were made based on user experience feedback from online piloting. Extensive rounds of testing for content, accessibility, and usability were conducted with the research team and parents experienced in nappy use and toilet training (i.e., the target population), ensuring the survey was comprehensive, user-friendly, and effective.

A summary, along with suggestions for adapting our approach to different contexts, is provided below. It is important to note that this process is not strictly linear; movement between stages may occur. Continuous literature review and ongoing discussions with the research team and stakeholders are likely to take place throughout the process, informing decisions at each stage. The general steps taken were as follows:

1. **Identify Key Behaviours**: Start by defining the specific behaviours you want to explore within the problem context. Regularly reviewing the relevant literature, collaborating with your research team, and holding informal discussions with stakeholders will help refine these behaviours.
2. **Conduct a Literature Review**: Identify relevant influences and interventions related to the target behaviour(s) from the existing evidence base.
3. **Consult Stakeholders**: Engage key stakeholders (e.g., experts, practitioners, target population) to gather diverse insights and assess the relevance of potential survey items. This also includes integrating various perspectives (e.g., interdisciplinary) through regular research team discussions.
4. **Map to Frameworks**: Cross-reference your items with relevant behavioural frameworks or other models suitable for the new context to ensure comprehensive coverage.
5. **Iterative Refinement**: Continuously refine the survey items based on feedback from stakeholders and the research team. We found that most refinements are best performed using a 'paper' version in Word, as this simplifies tracking and incorporating feedback before transitioning to an online format.
6. **Incorporate Flexibility**: Include free-text options to capture unanticipated influences, interventions, or general insights specific to the new context.
7. **Pilot Testing**: Transition the survey to an online format and conduct pilot testing rounds (ideally with members of the target population) to ensure accessibility and usability, including aspects like language and survey length.

Procedure

Informed consent will be collected before any data collection begins. The survey will take between 10 and 15 min to complete. It is fully anonymous, and participants have the option to skip open-ended questions and those asking for demographic information. Participants can withdraw their data at any time during the survey and up until they receive payment. If they do not complete the survey, their data will be deleted and excluded from analysis.

Analysis

For the survey, data will be analysed using R 4.4.1. Current behaviour concerning diaper use and toilet training will be analysed descriptively using frequencies and percentages. Barriers and enablers to reusable diaper use and earlier toilet training, as they relate to capability, opportunity, motivation, and behaviour, will be analysed using ANOVAs and regression analyses to assess differences between diaper user groups and toilet training statuses. The mean scale scores will be computed for each COM-B domain. Internal consistency of COM-B scales will be assessed before grouping them for entering them into the regression. In addition, relevant demographic variables that might moderate these relationships will be explored through moderator analyses. Open-ended survey responses on other potential behavioural influences will be analysed via thematic analyses and organised according to COM-B. Participants' support for the different types of intervention strategies will be analysed descriptively. Their views on potential intervention strategies to support more reusable diaper use and earlier toilet training will be analysed thematically and organised according to the Behaviour Change Wheel intervention types.

2.1.2. Semi-Structured Interviews

Participants

The participant inclusion criteria for the diaper use interviews will include being the following: (1) the parent or carer of a baby or young child who uses diapers during the day; (2) the main or joint decision maker in the household regarding which diapers are used; and (3) a current reusable diaper user, a past reusable diaper user, or someone who has not used them but is aware of and has considered them.

The participant inclusion criteria for the toilet training interviews will be parents and primary caregivers of pre-school-aged children (1–5 years old) who are planning to toilet train, are currently toilet training, or have toilet trained the last child they toilet trained within the last 12 months. Interviewees need to be the main (or joint) toilet trainer in the household.

Purposive maximum variation sampling will be employed [51]. For the diaper interviews, we will include three groups of participants and aim for an equal split: (a) those who do not currently use reusable diapers (but are aware of and have considered them), (b) those who currently use a mix of reusables and disposables, and (c) those who exclusively use reusables.

For the toilet training interviews, we will include three groups of participants and aim for an equal split: (a) those who have not yet started toilet training, (b) those who have started but not completed toilet training, and (c) those having recently completed toilet training in the last 12 months, as well as an equal split between (a) earlier potty trainers (18–30 months of age) and (b) later potty trainers (after 30 months).

For both sets of interviews, interviewees should be over 18, ordinarily resident in the UK, and have sufficient English to conduct the interview.

Recruitment

For both sets of interviews, participants will be recruited via social media posts in closed parenting groups. Interviewees will be reimbursed for their time with a GBP 20 voucher for participation.

Sample Size

For the interviews, we will aim for 15–20 participants based on guidance for reaching thematic saturation in qualitative research [52]. We will aim for maximum diversity in terms of age, UK region, ethnicity, number of children (e.g., first and non-first-time parents), and socioeconomic status where possible.

Materials

Two separate interview topic guides were developed for each behaviour using Atkin's et al.'s guidance for using TDF in implementation research [53]. Interview guides were created in Microsoft Word to facilitate easier feedback and comments The structure of the interview topic guides largely mirrors the structure of the survey, covering areas such as current behaviour, influences on behaviour, and potential interventions to support behaviour change. However, the interviews ask questions in a more open and exploratory manner. To develop the interview guides, an initial set of questions starting with higher-level open questions, followed by prompts and more specific questions was created. The interview questions are guided by the COM-B model and the TDF, ensuring all relevant potential influences on behaviour are addressed. These were then refined through rounds of review within the research team and piloting via practice interviews with parents and primary caregivers experienced in using diapers and toilet training. Relevant changes to the wording and order of questions were made accordingly.

The interview guides for diaper use and toilet training can be found in the Supplementary Materials (S2 and S3, respectively).

Procedure

Interviews will be conducted online via MS Teams at a time convenient to the interviewee. Interviews will last between 30 and 60 min. The interviews will be recorded and transcribed verbatim. The interview transcripts will be anonymised so that any identifiable information is removed and the audio recording will be destroyed.

Analysis

To analyse interview data, combined deductive and inductive thematic analyses will be conducted using Atkin et al.'s guidance for using TDF in qualitative implementation research [53]. First, 'utterances' from transcripts will be organised according to domains from the TDF. Second, inductive thematic analyses will be conducted within each TDF domain. Similar reported influences will be grouped and a label summarising the shared meaning the theme plays in influencing behaviour will be created. This exercise will generate broad content themes and where applicable, sub-themes describing more detailed content. To encourage the reliability and validity of coding, a sub-set of findings will be reviewed by another co-investigator to assess whether each theme level accurately reflects the shared meaning of the grouped responses and whether each theme label was allocated to the appropriate TDF domain. Any discrepancies will be discussed until an agreement is reached and theme labels and TDF allocations revised accordingly.

2.2. Stage 2: Identifying Potential Interventions

The design of this stage includes a triangulation of findings to identify potential interventions and stakeholder consultations to agree on and prioritise interventions.

2.2.1. Triangulation and Mapping to Intervention Frameworks

There will be no data collected during this phase. As such, there will be no research participants, recruitment strategy, or sample size.

Procedure and Analysis

Data triangulation is a methodology used to enhance the credibility and validity of research findings by combining multiple data sources, methods, theories, or investigators. This approach helps to cross-verify information and reduces bias, providing a more comprehensive understanding of a research problem. To triangulate our research findings, we will be informed by the methods, guidance, and key learnings from others following triangulation protocols within healthcare research [54–56].

We will be triangulating across data sources, such as surveys and interviews, to identify barriers and enablers to reusable diaper use and earlier toilet training. This analysis will be conducted separately for each behaviour within the TDF and the COM-B model. We will then use convergence coding to identify areas of agreement, silence, and dissonance between the different data sources and methods [56]. This exercise will highlight key barriers and enablers for each target behaviour. Using the Behaviour Change Wheel guide [47], we will map these barriers and enablers (organised according to COM-B) to appropriate intervention types, policy categories, and behaviour change techniques that could effectively address them. The intervention recommendations will also be shaped by insights from survey and interview findings, specifically focusing on participants' ideas, views, and support for various intervention strategies. Examples of similar mapping exercises can be found in the contexts of promotion of front gardening [46] and compostable plastic packaging disposal [57].

The final output will be descriptions of intervention strategies likely to be relevant and effective in addressing the key barriers and enablers to reusable diaper use and toilet training. These strategies will be presented and discussed at stakeholder workshops.

2.2.2. Stakeholder Consultation

Participants

Stakeholders will include diaper users, such as parents and other primary caregivers, as well as other stakeholders within the diaper system, such as industry and waste management representatives. We also aim to hear from stakeholders who might deliver interventions, including local authorities, healthcare professionals (e.g., health visitors), educators (e.g., school and nursery staff), and policymakers. The final profile of the stakeholders consulted will depend on the findings from the previous step, specifically the preliminary intervention recommendations developed from data triangulation.

Recruitment

Participants for the stakeholder consultations will be recruited via the researchers' professional networks. Participation will be voluntary.

Sample Size

We will aim to recruit at least one stakeholder per stakeholder category.

Materials and Procedure

Informed consent will be obtained before the workshop. The workshop will be conducted online and last approximately three hours. The workshop will involve presenting the proposed intervention recommendations and introducing the APEASE evaluative framework. Each intervention will be discussed against APEASE criteria.

APEASE stands for affordability (how costly the proposed intervention is), practicability (how feasible the intervention is), effectiveness/cost-effectiveness (how effectively the intervention will change the target behaviour), acceptability (how appropriate the intervention is deemed by recipients and key stakeholders), safety/side-effects (a consideration of potential side-effects and unintended consequences of the intervention), and equity (how fair and just the intervention is and whether it might instigate disparities between groups).

The primary goal of the APEASE framework is to improve the relevance, usefulness, fairness, and practicality of an intervention. Recognising the importance of incorporating contextual factors to maximise effectiveness during the design process, the authors of the Behaviour Change Wheel guide [47] developed APEASE to provide structured guidance throughout this process.

Participants will use break-out rooms to discuss and evaluate each intervention in terms of APEASE and generate ideas for additional interventions if relevant. We will use the Nominal Group Technique process to reach a consensus on which to take forward [58]. For the selected interventions, we will discuss how best to design and deliver them considering the parameters of the TiDIER checklist—a framework designed to enhance transparency, reproducibility, and clarity in the reporting of interventions [59].

To close the workshop, participants will be directed to a short online survey, hosted by Qualtrics, where they will rate each intervention on each APEASE criterion on a 5-point Likert scale. The workshop will be audio-recorded, and transcribed verbatim, with chats from the main session and break-out sessions logged.

Analysis

The stakeholder workshop will yield both qualitative (transcripts of the session and logged chats) and quantitative (interventions ranked from 1–5 for each APEASE criteria) data. The transcripts of the session and logged chats will be analysed thematically. The inductive thematic findings for each proposed intervention will be deductively mapped to APEASE. The intervention APEASE rankings will be descriptively summarised.

3. Discussion

This proposed research program outlines a systematic approach to identifying barriers and enablers to reusable diaper use and earlier toilet training, and to collaborating with

interdisciplinary stakeholders to develop interventions that reduce disposable diaper waste. Utilising behaviour change theories, methods, and frameworks, the research aims to conceptualise the determinants of these behaviours and generate intervention recommendations with stakeholder input.

In line with open science principles, we are documenting our research protocol to increase transparency in the behaviour change research process. In doing so before conducting our studies, we ensure greater openness and accountability. The present protocol also serves as a valuable stand-alone resource, offering an adaptable template with guidance for other practitioners and researchers to conduct theoretically informed behaviour change research and design interventions with stakeholder input. Additionally, this makes the present work useful outside of the UK context on which it focusses, as the principles and methods are transferable.

The research outlined has significant implications for policy and practice. The application of integrative behaviour change tools and frameworks to the issue of disposable diaper waste is a novel approach, providing structure to research findings and facilitating the design of evidence-based interventions. Our study will contribute insights into the barriers and enablers of reusable diaper use and earlier toilet training and evaluations of the types of interventions that could be used to change these behaviours. This will offer an evidence base for informing the development of policies and strategies that effectively support these behaviours, ultimately helping to reduce disposable diaper waste. This is crucial for the UK Government to meet its national waste management targets, as outlined in the 25-Year Environment Plan, which aims to eliminate avoidable plastic waste [60]. Additionally, supporting earlier toilet training can improve school readiness in the UK, addressing a growing public health concern [25,61]. By advancing the understanding of how to support reusable diaper use and toilet training at the recommended age, this work will support the UK Government's environmental and public health goals and contribute to practical and policy improvements in waste management and child health and development.

The findings from this research program have significant implications for further research. This work is part of a larger interdisciplinary project, the Comfort Loop, which aims to create a sustainable system for absorbent hygiene products, including diapers, incontinence products, and menstrual products [62]. Diapers are the first product category under investigation. Insights from this research will inform future behavioural studies on reducing waste from incontinence and menstrual products and a citizen science project on reducing waste from absorbent hygiene products. Additionally, the findings will contribute to Life Cycle Assessments (LCAs) of different diaper products conducted within the project. Specifically, the survey data on current reusable diaper practices, such as sourcing, usage, laundering, and end-of-life plans, as well as average toilet training ages based on diaper type, will enhance the LCA analyses. For products such as reusable diapers where the use phase significantly impacts the total environmental footprint, understanding usage variations is crucial [63]. Currently, there are limited data on how they are used in practice. By improving our understanding of how reusable diapers are used in practice, we can create more accurate LCA models and realistic use-case scenarios.

The use of mixed methods (i.e., qualitative and quantitative) within and across studies is a strength of the work outlined. By leveraging the strengths of different research methods, we anticipate being able to conduct a comprehensive, rigorous, and nuanced investigation into behavioural influences and the types of interventions that could support parents and caregivers reduce disposable diaper waste. The involvement of a wide range of stakeholders in the intervention development process is another strength. Involving people who are representative of those who might deliver (e.g., healthcare professionals), receive (e.g., parents), or otherwise be impacted (e.g., nursery and school staff) by interventions enhance their likely relevance, equity, and acceptability [64–66]. Using behaviour change theories, models and frameworks in combination with stakeholder engagement is another strength of this work. These frameworks can effectively engage stakeholders by providing a structured approach that streamlines discussions and maximises their time,

leading to efficient and focused participation. Researchers have previously found that the Behaviour Change Wheel enhances this process by offering a clear framework, which not only makes stakeholder involvement more productive but also builds confidence in the interventions [46]. Stakeholders can trust that the proposed interventions are well-founded, grounded in rigorous research, and based on solid theoretical principles, ensuring both the efficiency and credibility of the intervention development process.

The limitations of this study include the restriction of research participants to English speakers. This limitation may skew the research findings and reduce their overall representativeness, potentially weakening the evidence from an equity, diversity, and inclusion (EDI) perspective. Another limitation is the reliance on self-reported quantitative data, particularly regarding the usage, washing, and drying practices of reusable diapers. Participants may under- or over-report their behaviour. To minimise this risk, we have restricted survey participants to those who have a child currently in diapers or only recently stopped so that the behaviour they are reporting on is in recent memory. A further limitation of this study is its focus on the behavioural analysis of a single group of people and in one context—parents and primary caregivers within the household. To more comprehensively understand the barriers and enablers to reusable diaper use and earlier toilet training, it would be beneficial to conduct similar analyses for other key actors within the system such as diaper producers, diaper suppliers, policymakers, and healthcare providers. It would also be useful to understand the behaviour of early years staff in contexts such as schools and nurseries, whose insights could provide a more comprehensive understanding of the factors concerning diaper use and toilet training. To address this limitation, we will be engaging these other key actors within the stakeholder consultations for their input on the types of interventions that could work to support reusable diaper adoption and earlier toilet training.

4. Conclusions

In line with open science principles, we have documented our research protocol to enhance the transparency and accountability in the behaviour change research process. This protocol serves as an adaptable template for other researchers, facilitating the design of theoretically informed interventions with stakeholder input and ensuring the transferability of our methods beyond the UK context. The research method outlined will systematically identify barriers and enablers to reusable diaper use and toilet training delay prevention through the application of behaviour change theories and frameworks. It will help to develop a set of intervention recommendations aimed at reducing disposable diaper waste based on this evidence and stakeholder input. The findings from this proposed research will enhance the existing evidence base in this area, offering critical insights for future research, policy, and practice. The strengths of the method proposed include its mixed-methods approach, involvement of diverse stakeholders, and application of behavioural science models and frameworks. Despite potential limitations, such as self-reported data bias, a focus on English-speaking participants, and a focus on parent and primary caregiver behaviour only, this research has significant implications for waste reduction and improving school readiness. This aligns with the UK Government's environmental and public health goals.

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