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# Reducing plastic waste: A meta-analysis of influences on behaviour and interventions

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ABSTRACT

Eliminating plastic waste relies, in part, on changing human behaviour. This review aimed to (a) use the AACTT (Action-Actor-Context-Target-Time) framework to identify and categorise relevant behaviours, (b) use the COM-B (Capability-Opportunity-Motivation-Behaviour) model to identify, categorise and evaluate variables that might be associated with these behaviours, (c) use the Behaviour Change Wheel and the Behaviour Change Techniques Taxonomy to identify, categorise and evaluate the nature of interventions. A systematic literature search identified 60 studies of behaviour relating to plastic waste. Meta-analysis was used to quantify (i) the strength and direction of the relationship between variables and behaviour and (ii) the impact of intervention components on changes in behaviour. Studies focused predominantly on the general public (actors), recycling (action), shopping (context), and a limited range of plastic waste items. Variables reflecting capability, opportunity, and motivation all had medium-strength associations with behaviour. The intervention types associated with the strongest changes in behaviour were 'persuasion', 'enablement' and 'environmental restructuring'. The policy options associated with strongest changes in behaviour were 'communications and marketing', 'environmental and social planning' and 'service provision'. Interventions targeting 'psychological capability' had a negative effect on plastic waste reducing behaviours while interventions targeting 'physical opportunity' and 'reflective motivation' had the strongest positive effects. All identified behaviour change techniques had medium to large effects on changes in behaviour. Taken together, the findings provide clear directions for future research and efforts to reduce plastic waste.

## 1. Introduction

### 1.1. The problem of plastic waste

The accumulation of plastic waste represents a growing threat to environmental and public health. It has been estimated that 8300 million metric tonnes of plastic have been produced over the last six decades (Geyer et al., 2017). As a result of ineffective waste management, plastic waste has become a leading cause of pollution, accounting for the vast majority of floating litter (Galgani et al., 2015). Aside from the widely documented environmental impacts on wildlife (e.g., risk of entanglement and ingestion of plastic by fish and birds (Campani et al., 2013; Wilcox et al., 2016)), microplastic particles and fibres have also been identified in tap water, beer, and salt, where the risks to human health are yet to be conclusively determined (Karami et al., 2017; Kosuth et al., 2018). If current trends continue, it is estimated that by 2050 an additional 12,000 million metric tonnes of plastic waste will be in landfill or littered, contributing to further environmental degradation (Geyer et al., 2017).

Eliminating plastic waste is therefore a global priority (Assembly, 21 October 2015; Commission, 2018). However, eliminating plastic waste requires wide-scale system changes and a shift from a linear to a circular plastics economy; that is, a system that keeps plastic flowing around a 'closed loop' system where products are re-used, re-purposed, recycled, and recovered (Neufeld et al., 2016). Achieving a circular economy is, in part, reliant on changing the behaviour of actors across all levels of the plastics system (e.g., the general public, producers, suppliers and people responsible for managing waste). For example, producers and suppliers will need to offer reusable and recyclable alternatives to single-use plastics, and citizens will need to be willing to use (and reuse) these alternatives and ensure that they are dealt with appropriately at

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**Abbreviations**

| | |
|---|---|
| **BCW** | Behaviour Change Wheel |
| **COM-B** | Capability-Opportunity-Motivation-Behaviour |
| **BCT** | Behaviour Change Technique |
| **BCTTv1** | Behaviour Change Techniques Taxonomy (version 1) |
| **OSF** | Open Science Framework |
| **AACTT** | Action-Actor-Context-Target-Time |
| **RVE** | Robust Variance Estimation |
| **PET** | Precision-Effect Test |
| **PEESE** | Precision-Effect estimates with Standard Error Test |

end-of-life. These widescale changes in behaviour also depend on developments in technological innovation and infrastructure. However, while technological innovation and changes in infrastructure are often necessary, they are not sufficient to solve the plastic waste issue. People will need to interact appropriately with these technologies and systems to enable their environmental benefits. For example, the development of novel compostable plastic packaging materials will only reduce waste if people know to compost the materials and subsequently enact the appropriate disposal behaviour (Allison et al., 2021a). Understanding behaviour and, more specifically, the factors that influence whether and how people change behaviour is therefore a fundamental part of any solution aimed at reducing plastic waste. Progress in this area is hampered by a lack of theory- and evidence-driven behavioural and behaviour change research; this hinders attempts to design effective behaviour change interventions aimed at reducing waste.

### 1.2. Behaviour change

A number of models, theories and frameworks can be used to develop such theory- and evidence-informed behaviour change interventions. The Behaviour Change Wheel (BCW), shown in Fig. 1, is an example of an integrative behaviour change framework, synthesising 19 frameworks across several domains (Michie et al., 2011, 2014). The BCW supports intervention design, starting from the inner hub of the wheel and working outwards the BCW suggests that interventionists: 1) Specify the target behaviour: Identify the precise target(s) of the intervention; 2) 'Diagnose' the behaviour: Identify what would need to change for the behaviour to change; and 3) Develop the intervention: Use the 'behavioural diagnosis' to select intervention strategies.

There are a number of different behaviours that people can engage in to reduce plastic waste e.g. those involved in reducing, reusing, recycling (Union, 2008). Interventions are more likely to be effective if they target specific behaviours following a detailed and comprehensive analysis of behaviours and their influences in their contexts (Lorencatto et al., 2018). To specify behaviour(s), the Action, Actor, Context, Target, Time (AACTT) framework (Presseau et al., 2019) can be applied. Action refers to *what* is being targeted for change (e.g., selling hot drinks in reusable cups over single-use cups); Actor refers to the person(s) *who* are part of the intervention (e.g., café staff that sell takeaway coffee); Context refers to where the behaviour is performed (e.g. in cafes); Target refers to *whom* the behaviour effects (e.g. people who buy takeaway coffee); and Time refers to *when* and for *how long* the behaviour is performed (e.g. when people are 'on the go' and want coffee).

The COM-B model (Capability-Opportunity-Motivation-Behaviour model) can help to identify – or 'diagnose' – influences on behaviour (i.e., factors that inhibit, drive or maintain behaviour) which can then serve as targets for behaviour change interventions (Michie et al., 2011, 2014). COM-B is depicted in the inner hub of the BCW shown in Fig. 1, and detailed in Fig. 2. COM-B proposes that, for behaviour to occur, there must be: Capability (which can be physical, such as stamina, or psychological, such as knowledge), Opportunity (which can be social, such as sociocultural milieu, or physical, such as the physical environment of objects and events in which people interact) and Motivation (which can be reflective, such as intentions, desires and evaluations, or automatic, such as habits, emotions and instincts that energise and direct behaviour). COM-B has been used to understand influences on a range of environmentally-relevant behaviours (e.g., (Allison et al., 2022a; Graça et al., 2019; Perros et al., 2022; Santos et al., 2022)). However, while COM-B has been applied to understand the use of reusable cups (Allison et al., 2021b) and the purchase and disposal of compostable plastic packaging (Allison et al., 2021a, 2022b), there nonetheless remains a paucity of theoretically driven research to understand behaviours related to plastic waste (Heidbreder et al., 2019).

Once factors associated with people's behaviour are identified, this information can be used to identify intervention strategies by selecting

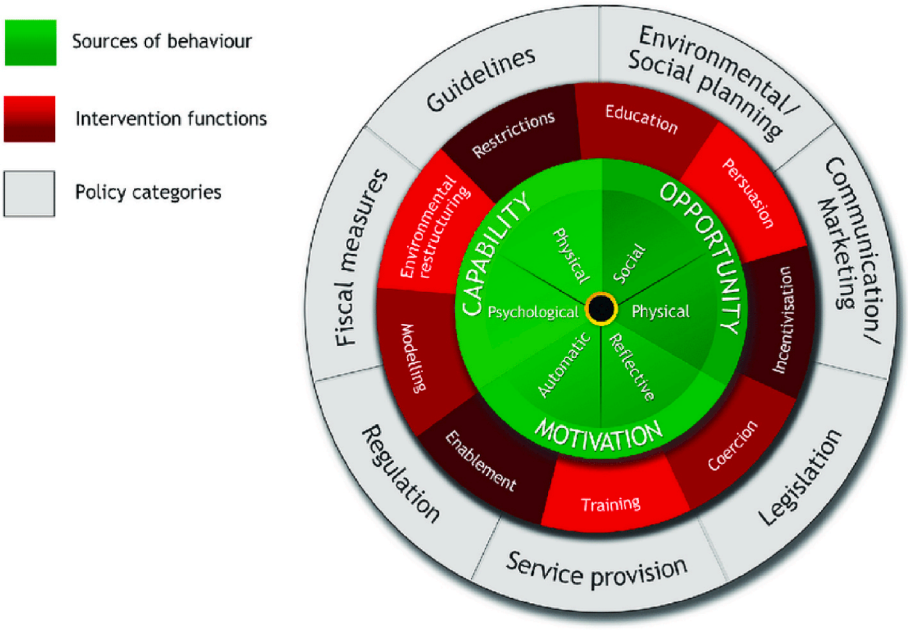


**Fig. 1.** The Behaviour Change Wheel.

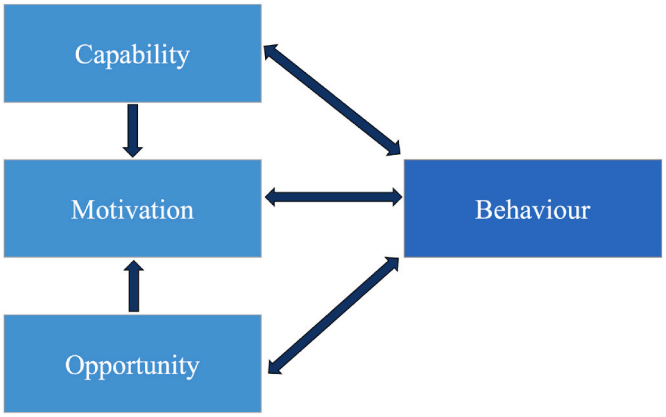


**Fig. 2.** The COM-B model.

intervention types, policy options, and specific behaviour change techniques (BCTs). The BCW delineates nine types of intervention and seven policy options (see Fig. 1). BCTs are specific strategies for changing behaviour such as goal setting and providing rewards (see the Behaviour Change Techniques Taxonomy (BCTTv1; (Michie et al., 2013)). Definitions of intervention types, policy options and BCTs can be found in Appendices A-C.

As well as informing the design of interventions, the BCW has been used in systematic reviews and evidence syntheses to integrate findings on behavioural influences and contents of interventions across diverse studies (e.g., (Anderson and Ozakinci, 2018; Arnott et al., 2014; Gardner et al., 2016; Graham-Rowe et al., 2018; Hedin et al., 2019; McDonagh et al., 2018; Samdal et al., 2017)). The evidence on citizens' behaviour relating to plastic waste is varied and multidisciplinary, including evidence from economics (Agovino et al., 2020), marketing (Muralidharan and Sheehan, 2016), psychology (Heidbreder and Schmitt, 2020), and anthropology (Braun and Traore, 2015). Using behaviour change frameworks to synthesise this research is therefore useful to identify the factors that are most strongly associated with behaviours associated with plastic waste and the types of behavioural intervention that have been most effective at reducing plastic waste. Evidence syntheses using behaviour change frameworks have been used frequently in some areas of research e.g., health; (Anderson and Ozakinci, 2018; Arnott et al., 2014; Gardner et al., 2016; Graham-Rowe et al., 2018; Hedin et al., 2019; McDonagh et al., 2018; Samdal et al., 2017); however, to the authors' knowledge, these frameworks have yet to be applied to research examining behaviours associated with plastic waste.

A narrative review of factors associated with behaviours leading to citizens' plastic waste and interventions to tackle plastic waste was conducted by Heidbreder and colleagues in 2019 (Heidbreder et al., 2019). The review found that habits, norms, and situational factors predicted citizens' plastic consumption, and that political and psychological interventions were the most common types of interventions aimed at curbing plastic consumption. However, this review was not systematic meaning that evidence may have been missed; nor was the evidence structured within a behavioural framework, meaning that it is difficult to categorise and conceptualise the various influences on behaviour and components of the interventions. Furthermore, since the review was narrative in nature, it was not possible to compute the (sample-weighted average) size of the effects of factors on behaviour and/or the interventions. Thus, a systematic review with meta-analysis is needed to provide high-quality, quantitative evidence to inform modelling and policy (Mulrow, 1994). Conducting such a review within a theory- and evidence-based behavioural framework, such as the BCW, would to help to identify and conceptualise the factors associated with behaviour, providing targets for interventions. It would also help to identify the types of interventions that are most likely to be effective at reducing plastic waste (Craig et al., 2008).

### 1.3. The present review

The aims of this review were three-fold. First, this study aimed to describe the key behaviours that contribute to plastic waste. Second, this study aimed to describe the factors that are potentially associated with these behaviours and conduct meta-analyses to identify which factors are most strongly associated with behaviour. Finally, this study aimed to describe which intervention types, policy options, targeted behavioural antecedents and BCTs have been used to modify these behaviours and conduct meta-analyses to identify the effectiveness of different behavioural change strategies on behaviours relevant to plastic waste.

## 2. Method

The review was conducted in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009) and recommendations for meta-analyses (Hedges et al., 2010; Quintana, 2015; Tanner-Smith et al., 2016). Eligible papers were identified within the peer-reviewed scientific literature. Data (i.e., text and/or numbers) were extracted from the manuscripts and coded for analysis. All papers contributed towards the narrative syntheses. A sub-group of these papers were included in quantitative meta-analyses if they met additional eligibility criteria. Evidence was synthesised within behaviour change frameworks for analysis. Fig. 3 provides an overview of the method, and directs the reader to the sections of the manuscript that provide more detailed information. A protocol was published prior to conducting the review on Open Science Framework (OSF) along with the study materials, including the raw data files and R code used for the meta-analysis (https://osf.io/53mtu/).

### 2.1. Search strategy

Two strategies were used to identify papers. First, an electronic database search of three databases was conducted in February 2020: a) PsychINFO (due to its focus on psychological and behavioural science), b) GreenFILE (due to its focus on sustainability), and c) SCOPUS (due to it being a large database of varied, multidisciplinary peer-reviewed articles). The search was restricted to English-language and peer-reviewed, published journal articles. This is because English is the only language shared by all members of the research team and non-peer reviewed studies may be of lower methodological quality than published studies (Egger et al., 2003). Each database was searched using terms relating to three filters: (i) plastic (e.g., plastic*, OR microplastic*); (ii) behaviour (e.g., behavio?r*, recycle*, reus*) and; (iii) influences or interventions (e.g., impact*, predictor*, influence*). Studies had to include at least one search term from each of the three filters in the title, abstract, or keywords. A detailed description of the electronic database search strategy can be found in Appendix D. The electronic database search was supplemented by forward and backward searching the studies cited by and citing Heidbreder et al.'s review (Heidbreder et al., 2019) in July 2020.

### 2.2. Study eligibility

Three types of studies were of interest in this review: a) studies that explored variables associated with behaviour(s) relating to plastic waste e.g., (Khan et al., 2019), b) studies that reported an intervention aimed at changing behaviour relating to plastic waste e.g., (Poortinga and Whitaker, 2018), or c) studies that did both e.g., (Holland et al., 2006). Studies were eligible for inclusion in the review if they were: a) empirical (i.e., not reviews), b) addressed plastic as a waste material in the manuscript[1] and, c) investigated citizen's behaviours, defined as:

[1] Studies on plastic surgery or plastic used within artistic contexts were therefore excluded.

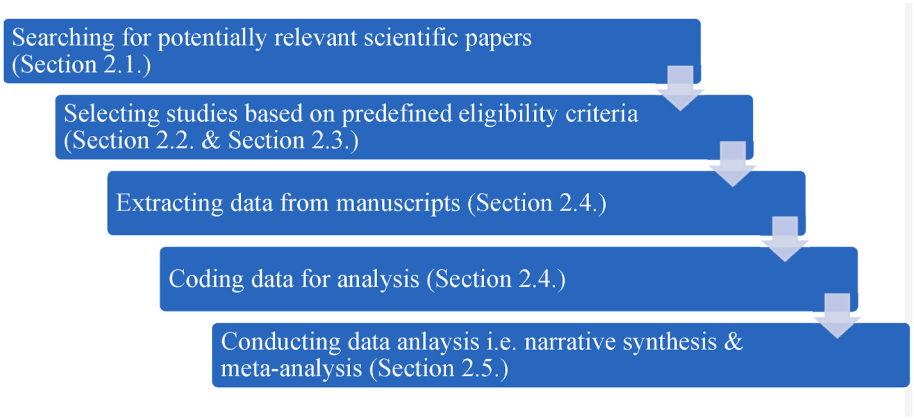


**Fig. 3.** Overview of methodology.

"*Anything that a person does in response to internal or external events. Actions may be overt (motor or verbal) and directly measurable or, covert (activities not viewable but involving voluntary muscles) and indirectly measurable; behaviours are physical events that occur in the body and are controlled by the brain*"(Davis et al., 2015)[2]. Both qualitative and quantitative studies were considered.

Meta-analytic sub-group analyses were run, for eligible quantitative studies, to identify which of the COM-B variables are most strongly associated with behaviours related to plastic waste and which BCW intervention types, policy options, targeted COM-B variables and BCTs are most effective at changing behaviour. There were additional eligibility criteria for inclusion in these two meta-analyses. If the required information was not reported, attempts were made to contact the study authors. If the required information could not be obtained after contacting the author, the study was excluded from the meta-analysis and incorporated within the narrative synthesis.

#### 2.2.1. Eligibility for meta-analysis of association between predictive variables and behaviour

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

#### 2.2.2. Eligibility for meta-analysis of intervention effectiveness

These studies had to investigate the effect of a manipulation or intervention designed to modify behaviours. Studies needed to be designed in a way that isolated the effect of the intervention (e.g., via a pre- and post-intervention assessment or via a control/comparator group). The evaluation had to be in the context of the intervention's effectiveness at changing behaviour[3]. Studies that measured changes in behaviour (e.g., asking people how often they recycle before and after a behavioural manipulation) and studies that measured changes in an outcome of behaviour (e.g., measure the volume of plastic waste produced in a waste bin before and after a behavioural intervention) were included where this was clearly an indicator of actual behaviour change e.g., (McCoy et al., 2018; Miller et al., 2016). The study also had to report, or provide sufficient information in order for us to calculate, effect size *d* representing the difference between the intervention conditions on the measure of behaviour and/or associated outcomes.

### 2.3. Study selection

The process of identifying eligible studies was conducted in two stages. First, the titles and abstracts of articles identified via the search strategies were screened to identify potentially relevant studies. 10% of studies were double screened by a second reviewer (CL) to assess for reliability (Cohen's kappa = 0.69). Discrepancies were discussed until both researchers came to a consensus. Second, the full texts of articles describing potentially relevant studies were reviewed against the inclusion and exclusion criteria to determine eligibility. The literature search identified 4904 papers, of which 60 met the inclusion criteria. Fig. 3 shows the flow of studies through each phase of the review.

### 2.4. Data extraction and coding

Data from individual studies was extracted using a form developed for the current review (available in Appendix E). The form was piloted with five studies (Holland et al., 2006; Lam, 2005; McCoy et al., 2018; Ohtomo and Ohnuma, 2014; Willis et al., 2019) by the lead author (ALA) and reviewed by a co-investigator (FL) to ensure that all relevant information was captured prior to formal data extraction. The extracted data included publication details (e.g., study title, first three authors, publication year, publication journal) and methodological details (e.g., study type [i.e., reporting factors associated with behaviour, reporting the effects of an intervention or reporting both], study design, country in which the study was conducted, mean age of the sample, gender composition of the sample [i.e., percentage female]). A data extraction 'crib sheet' outlining how each variable was coded can be found in Appendix F.

To identify the behaviours studied within the scientific literature, the extracted data included: a) the measure of behaviour (e.g., self-reported recycling behaviour) or associated outcome (e.g., volume of plastic waste in a bin), b) whether behaviour was measured using self-report or and objective measure, c) if self-report, then the reliability of the measure (if applicable) and, d) the written description of the target behaviour, which was dummy coded according to whether it specified each feature of the AACTT framework.

To identify which variables have been identified as potentially associated with these behaviours, the written description of the variable potentially associated with behaviour from the manuscript (e.g., attitudes, social norms etc.) and the reliability of the measure of this variable (if applicable) were extracted. This description of the variable was dummy coded according to which COM-B variable it reflected.

To identify which variables are most strongly associated with

[2] Studies, therefore, investigating variables associated with and interventions aimed at changing behavioural intentions/willingness were not eligible for inclusion.

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

behaviours related to plastic waste, data extracted included: a) effect size *r*, representing the strength of the relationship between the variable and the behaviour, b) how the effect size was calculated (i.e., reported in text, authors provided on contact or converted using Psychometrica (Lenhard and Lenhard, 2016)), c) the sample size for the reported effect size.

To identify what interventions have been used to try and change these behaviours, the written description of the intervention was extracted from the manuscript and dummy coded according to the intervention type, policy option, targeted COM-B variable and BCT(s) from the BCTTv1 they reflected.

To identify which interventions are most effective at changing these behaviours related to plastic waste, data extracted included: a) effect size *d*, representing the difference between the intervention conditions on the measure of behaviour and/or associated outcomes, b) how the effect size was calculated (i.e., reported in text, authors provided on contact or converted using Psychometrica (Lenhard and Lenhard, 2016), c) the sample size of the control group for the reported effect size, d) the sample size of the intervention group for the reported effect size and e) the standard error of the effect size which was calculated manually using MAVIS (v1.1.3) (Hamilton et al.) or the effect size calculator provided by the Campbell Collaboration (Wilson).

#### 2.4.1. Inter-rater reliability

Initial data extraction was conducted by the lead author (ALA) and a random 10% of studies were independently coded by another co-investigator (HMB). For continuous variables, reliability between the two coders ranged from $r = 0.95$ to 1.00. For categorical variables, Cohen's kappa ranged from 0.49 to 1.00 and percentage agreement ranged from 83% to 100%. Thus, there was a high level of agreement between the two coders. Any discrepancies were discussed until resolved. Full details of the reliability analyses can be found in Appendix G.

### 2.5. Meta-analytical approach

#### 2.5.1. Effect size index

Two different effect size metrics were used to conduct the subsequent meta-analyses: (i) effect size *r* and, (ii) effect size *d*. Effect size *r* was used to represent the strength and direction of the relationship between factors potentially associated with behaviour and Cohen's *d* was used to represent the impact of the interventions on behaviour. Where Pearson's *r* or Cohen's *d* was not available, Psychometrica (https://psychometrica.de/effect_size) was used to convert other statistics (e.g., means and standard deviations, Odds Ratios) into *r* or *d*. As some studies investigated behaviours that contribute to plastic waste while others investigated behaviours that reduce plastic waste, some effect sizes were transformed to ensure that effect sizes reflected the relationship between factors or effects of interventions on reductions in plastic waste.

#### 2.5.2. Meta-analytical procedures

Random-effects meta-analyses with Robust Variance Estimation (RVE) (Hedges et al., 2010) were conducted using the 'robumeta' and 'metafor' packages in R (Fisher and Tipton, 2015; Viechtbauer, 2010). RVE was used to address statistical dependencies at the within-study level as multiple studies contributed multiple effect sizes[4].

As Pearson's *r* is not normally distributed, Fisher's z-transformed correlation coefficients were used to represent the relationship between COM-B variables and behaviour. Results were converted back to Pearson's *r* for reporting. Cohen's *d* was used to represent the impact of the interventions on behaviour. In line with prior meta-analytic methods (5), the sample size of one study was windsorized (Rivers et al., 2017), for which the sample size ($n = 46{,}755$) exceeded three standard deviations from the mean sample size ($M = 1{,}572$, $SD = 2393$), equal to the next largest sample size ($n = 8162$). So as not to lose data, the same winsorized sample size (i.e., $n = 8162$) was used for two other population-level studies as sample size was not reported (McCoy et al., 2018; Miller et al., 2016).

Moderation analyses were conducted. Continuous moderators were entered into a regression equation as a predictor using the RVE approach. Categorical moderators which had two levels were dummy coded and entered into the meta-regression equation using RVE[5].

Although, the method of moments estimator used by the 'robumeta' package to estimate $\tau^2$ (Thompson and Sharp, 1999) and its degrees of freedom are adjusted for small sample size, this robust standard error estimation with small sample adjustment remains biased (i.e., increased type I error rate) if the adjusted degrees of freedom are $< 4$ (Tanner-Smith et al., 2016; Tanner-Smith and Tipton, 2014). Therefore, results with less than 4 degrees of freedom were not interpreted.

Finally, for each meta-analysis, the potential for publication bias was assessed using a multimethod approach. The fail-safe *N* statistic was calculated using Rosenberg's method (Rosenberg, 2005). If this value is greater than the critical value, $5n + 10$ (where *n* equals the number of effect sizes), then the probability of publication bias is low. Contour-enhanced funnel plots (Peters et al., 2008) were created which aggregated effect sizes at the study level to assess for signs of asymmetry and then formally tested the presence of asymmetry using Egger's regression (Egger et al., 1997). Whether effect sizes could be predicted by their standard errors (i.e., using the Precision-Effect Test, PET (Stanley and Doucouliagos, 2014)) was investigated using RVE methods. Whereas Egger's regression considers the intercept of the regression, PET considers the slope of the regression. Significant Egger's and PET tests are suggestive of publication bias. If results failed the fail-safe *N*, Egger's and PET publication bias tests, publication bias was corrected for via calculating PEESE (Stanley and Doucouliagos, 2014) (i.e., using the Precision-Effect estimates with Standard Error Test to test whether effect sizes can be predicted by their variances) and running Trim-and-Fill analyses (Duval and Tweedie, 2000).

## 3. Results

### 3.1. Study characteristics

Twenty-three studies reported factors potentially associated with behaviour (Agovino et al., 2020; Barnes, 2019; Braun and Traore, 2015; Dhokhikah et al., 2015; Fiorillo, 2013; Hage et al., 2009; Jahani et al., 2019; Khan et al., 2019; Klöckner and Oppedal, 2011; Lam and Chen,

[4] This estimation method permits clustered data (i.e., effect sizes nested within samples) to be meta-analysed by correcting the within-study standard errors for correlations between effect sizes. This is done by estimating the average correlation between all pairs of within-study effect sizes ($\rho$), which is then used to correct the between-study sampling variance ($\tau^2$) for these statistical dependencies. The authors set $\rho = 0.80$ because sensitivity analyses revealed that findings were invariant across different reasonable estimates of ρ. Alongside $\tau^2$, $I^2$ was also reported, which quantifies the proportion of effect size variance due to between-sample heterogeneity.

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

2006; Macusi et al., 2019; McDonald and Ball, 1998; Meng et al., 2018; Mogomotsi et al., 2019; O'Brien and Thondhlana, 2019; Ofstad et al., 2017; Oliveira et al., 2018; Romero et al., 2018; Shabanova, 2019; Taufik et al., 2020; Thanh et al., 2012; Viscusi et al., 2011; Wright and Miller, 1996) (overview in Appendix H), 27 studies reported interventions aimed at changing behaviour (Becker et al., 2014; Cheung et al., 2018; Dahlén et al., 2009; Hage et al., 2018; Hahladakis et al., 2018; He, 2012; Jacobsen et al., 2018; Lam, 2005; Luís and Spínola, 2010; Macintosh et al., 2020; Martinho et al., 2017; McCoy et al., 2018; Miller et al., 2016; Morlok et al., 2017; O'Connor et al., 2010; Poortinga and Whitaker, 2018; Rivers et al., 2017; Rubens et al., 2015; Sharp et al., 2010; Taylor and Villas-Boas, 2016; Thomas et al., 2019; Viscusi et al., 2012; Willis et al., 2019; Woodard et al., 2006; Yang and Innes, 2007; Zen et al., 2013; Zorpas et al., 2017) (overview in Appendix I), and 10 studies reported both (Bharadwaj et al., 2020; Ferronato et al., 2020; Heidbreder and Schmitt, 2020; Heidbreder et al., 2020; Holland et al., 2006; Jakovcevic et al., 2014; Muralidharan and Sheehan, 2016, 2018; Ohtomo and Ohnuma, 2014; Saphores and Nixon, 2014) (overview in Appendix J). As shown in Fig. 4, the majority of studies were conducted in mainland Europe ($k = 17$) and Asia ($k = 14$) followed by North America ($k = 12$) and the United Kingdom ($k = 6$). The studies were published between 1996 and 2020, with the majority of studies (53.4%) published between 2017 and 2020. Fig. 5.

### 3.2. Behaviours relating to plastic waste

Table 1 summarises the behaviours investigated by the primary studies, according to the AACTT framework (Presseau et al., 2019). In total, 19 different types of actions (behaviours) were identified, the most common being recycling ($k = 25$) which included recycling of unspecified plastic waste items ($k = 19$) and recycling of plastic water bottles/cups ($k = 6$). Six different actors were investigated across studies; although the majority focussed on the general public ($k = 48$). Six different contexts were investigated, including shopping ($k = 19$) or a university environment ($k = 6$). The target of the behaviour was only specified by one study; the customer being served by the retailer at the checkout (Bharadwaj et al., 2020). Six different timeframes were investigated across studies, the most common being a single shopping trip ($k = 14$).

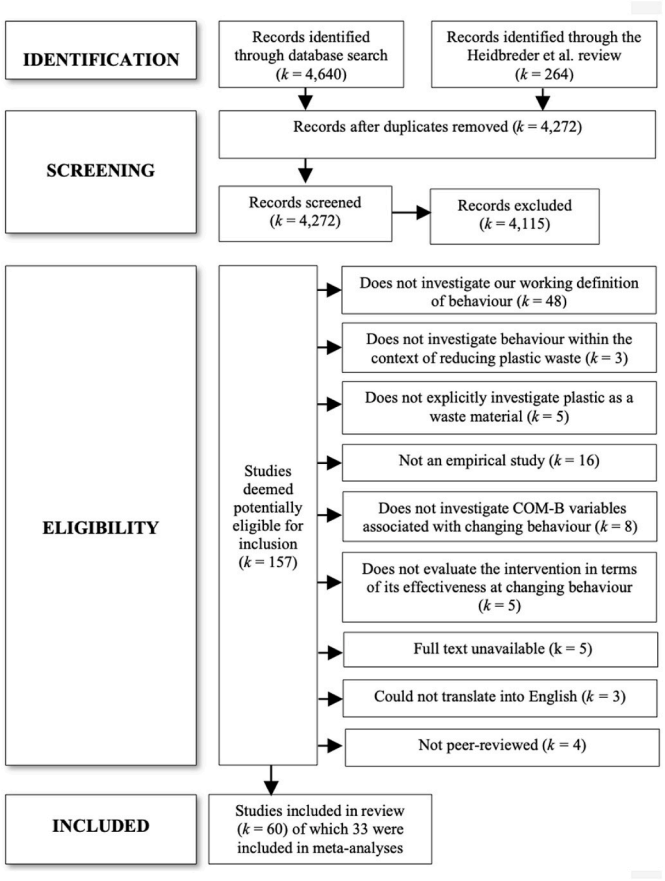


**Fig. 4.** PRISMA diagram showing the study flow.

### 3.3. Variables associated with behaviour relating to plastic waste

Thirty-three studies explored 24 variables that are potentially associated with behaviour. These variables were coded as reflecting: reflective motivation ($k = 23$); physical opportunity ($k = 16$); social opportunity ($k = 10$) and automatic motivation ($k = 8$). None of the primary studies examined variables related to physical capability.

#### 3.3.1. Psychological capability

Psychological capability was often measured in terms of awareness of the likely outcomes of behaviour ($k = 7$). For example, awareness of the environmental impact of plastic pollution was identified as an enabler of a range of behaviours related to reducing plastic waste, including recycling plastic waste (Dhokhikah et al., 2015; Ferronato et al., 2020; Klöckner and Oppedal, 2011; Ofstad et al., 2017), reducing consumption of plastic packaging (Heidbreder et al., 2020; Jahani et al., 2019) and donating, reselling, and reusing plastic items (Khan et al., 2019). Several studies ($k = 4$) also considered participants knowledge. For example, knowledge about recycling emerged as both a barrier (if knowledge was lacking) and enabler (if knowledge was present) to reducing plastic waste. This included knowledge of how to prepare waste for recycling (e.g., cleaning and sorting into the correct bin) (Dhokhikah et al., 2015; Wright and Miller, 1996) and also being able to identify whether the waste is recyclable in the first place (McDonald and Ball, 1998; Taufique et al., 2014). Two studies considered memory. For example, participants across studies reported finding it difficult to remember to save plastic containers for recycling (O'Brien and Thondhlana, 2019) and forgetting to take reusable shopping bags with them when they went shopping (Wright and Miller, 1996). Finally, one study considered participants' skills and training: specifically, education and training in sorting, recycling, and composting waste conducted by local government. Private sector or NGOs, made enacting these behaviours more likely (Dhokhikah et al., 2015).

On average, psychological capability had a small-to-medium sized relationship with behaviours related to plastic waste ($r_+ = 0.24$, $k = 6$, see Table 2).

#### 3.3.2. Physical opportunity

Physical opportunity was typically considered in terms of the convenience of the respective behaviours ($k = 9$). For example, inconvenience was considered as a barrier to enacting behaviours that reduce plastic waste including recycling (Dhokhikah et al., 2015; McDonald and Ball, 1998; Meng et al., 2018; Wright and Miller, 1996) and using reusable shopping bags (Romero et al., 2018). Similarly, using single-use plastic shopping bags was considered to be convenient (Braun and Traore, 2015; Mogomotsi et al., 2019; O'Brien and Thondhlana, 2019); thereby enabling their use. For example, women vendors in Mali spoke of how plastic bags offer easy and convenient packaging for sensitive products like medicines: "Plastic bags are very convenient for me. Before we had a lot of concerns about where to put the local medicinal products we sell; now we have the plastic bags" (Braun and Traore, 2015). Physical opportunity also encompassed consideration of the environmental context ($k = 2$) and availability of waste management facilities ($k = 7$). For example, certain activities and situations such as social gatherings (e.g., weddings, parties etc.) and going to outdoor spaces (e.g., parks) and entertainment venues presented a barrier to reducing plastic consumption (Jahani et al., 2019). Lack of bins was also

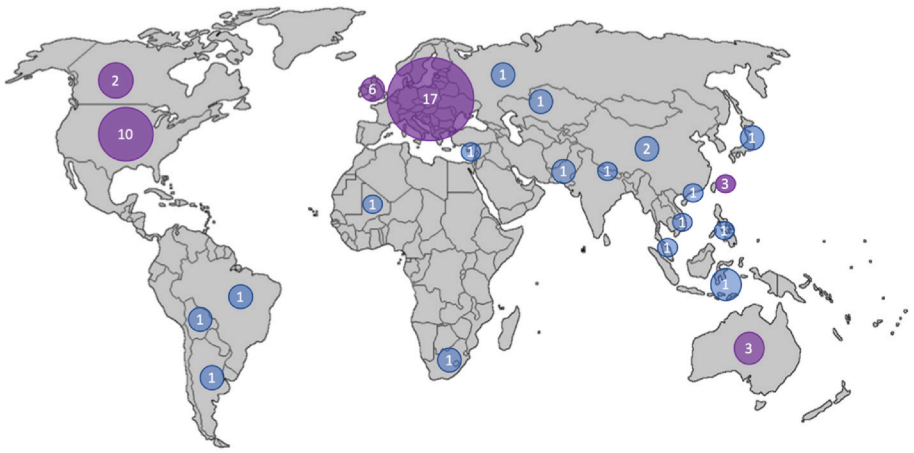


**Fig. 5.** Figure showing global distribution of study samples. Notes: Barnes et al. (Barnes, 2019) used a global dataset of data from 63 countries and so is not represented in this diagram. Romero et al. (Romero et al., 2018) is represented twice in this figure as they used two different samples: one from Brazil and one from Canada. Mainland Europe (k = 17) consists of Germany (k = 4), Portugal (k = 3), Sweden (k = 3), Italy (k = 2), Belgium (k = 1), France (k = 1) and The Netherlands (k = 1). Figure created using Microsoft PowerPoint.

**Table 1**
Behaviours investigated summarised according to AACTT framework.

| Action | *k* | Actor | *k* | Context | *k* | Target | *k* | Timeframe | *k* |
|---|---|---|---|---|---|---|---|---|---|
| Recycling plastic (unspecified) | 19 | General public | 48 | Shopping | 19 | Customer | 1 | During a single shopping trip | 14 |
| Using reusable shopping bags | 15 | University students/staff and/or visitors | 10 | University campus | 6 | | | During the past week | 2 |
| Recycling plastic water bottles/cups | 6 | Employees | 2 | Home | 5 | | | During a working day | 1 |
| Taking free single-use plastic shopping bags | 6 | School students and/or personnel | 2 | School | 2 | | | During the past fortnight | 1 |
| Buying single-use plastic shopping bags | 4 | Retailers | 1 | Work | 1 | | | Over an unspecified four-week period | 1 |
| Using plastic bags (unspecified) | 4 | | | Cafe | 1 | | | The last five instances | 1 |
| Other[a] | 18 | | | Riverside | 1 | | | Daily | 1 |

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

**Table 2**
Relationships between COM-B factors and plastic waste reducing behaviour.

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

*Note*. *k* = number of independent samples; *o* = number of effect sizes; *r*+ = weighted average effect size *r*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of *t*-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (Tanner-Smith et al., 2016), - = insufficient number of effect sizes to conduct meta-analysis.

considered as a barrier to recycling (Macusi et al., 2019), while access to recycling facilities such as bring banks and drop-off waste collection sites were considered enablers to recycling (Dhokhikah et al., 2015; Hage et al., 2009; McDonald and Ball, 1998; Oliveira et al., 2018; Saphores and Nixon, 2014; Wright and Miller, 1996).

Physical opportunity also included consideration of resources (*k* = 4), both as a barrier and enabler to reducing plastic waste. For example, the profits gained from selling upcycled goods enabled upcycling of

plastic waste items, whereas lack of time and space were identified as barriers to upcycling (Dhokhikah et al., 2015). While some studies reported the cheap cost of plastic bags as an enabler to buying them (Mogomotsi et al., 2019), other studies found that the charge for plastic shopping bags deterred people from buying them (Jakovcevic et al., 2014). Another study found that the potential profits gained from selling recyclable waste onwards promoted recycling, while the costs of excess waste generation acted as a barrier to producing waste (Meng et al., 2018). Physical opportunity also included consideration of institutional quality (i.e., the capacity of the state to protect and support its citizens) ($k = 2$). Low institutional quality was identified as a barrier to reducing citizens' plastic waste. This included corruption by those performing public functions, poor ability of the government to promote and formulate effective regulatory interventions and low freedom of press in a community (Agovino et al., 2020). Lack of supportive and codified laws to reduce the production, supply, distribution and waste management of single-use plastics was also mentioned as a barrier to reducing plastic waste (Jahani et al., 2019). Finally, physical opportunity was also reflected in the availability (or not) of single-use plastic. The ubiquity of plastic packaging was typically found to be a barrier to reducing waste. For example, participants in some studies mentioned the futility of bringing reusable bags when the grocery item is still wrapped in layers of plastic wrapping (Braun and Traore, 2015; Mogomotsi et al., 2019).

On average, physical opportunity had a medium-to-large sized relationship with behaviours related to plastic waste ($r_+ = 0.41$, $k = 3$) (see Table 2).

### 3.3.3. Social opportunity

Social opportunity included consideration of social and cultural norms ($k = 11$), manifested as both injunctive (i.e., perceptions of what behaviours are approved or disapproved by others) and descriptive norms (i.e., perceptions of which behaviours are typically performed). This included pressure to maintain traditional customs (e.g., using woven baskets at the market instead of plastic shopping bags (Braun and Traore, 2015)) and pressure to conform to internalised pro-environmental standards for recycling plastic waste items (Hage et al., 2009; Klöckner and Oppedal, 2011; Meng et al., 2018; Ofstad et al., 2017; Thanh et al., 2012; Viscusi et al., 2011), using reusable shopping bags (Romero et al., 2018), taking single-use shopping bags at checkouts (Ohtomo and Ohnuma, 2014) and donating, reusing and reselling plastic items (Khan et al., 2019). A culture of high plastic consumption and littering posed a barrier to reducing plastic waste (Jahani et al., 2019), while the perception that others recycle prompted recycling (Hage et al., 2009). The way that the media represents plastic has also been considered ($k = 2$). For example, a lack of media coverage of plastic may influence knowledge and awareness of the outcomes of behaviour (Jahani et al., 2019). Alternatively, modelling how to classify, segregate and handle different types of household waste may increase behaviours that reduce plastic waste (Dhokhikah et al., 2015). Finally, social opportunity includes consideration of social support. For example, the presence of cadres in the community providing counselling in household solid waste reduction were found to promote appropriate recycling, upcycling and composting behaviour (Dhokhikah et al., 2015).

On average, social opportunity had a small-to-medium sized relationship with behaviours related to plastic waste ($r_+ = 0.22$, $k = 6$, see Table 2).

### 3.3.4. Automatic motivation

Automatic motivation included consideration of habit ($k = 6$), both as a barrier and enabler to a range of behaviours related to reducing plastic waste, including using plastic shopping bags (Mogomotsi et al., 2019), recycling plastic items (Holland et al., 2006; Klöckner and Oppedal, 2011; Ofstad et al., 2017), and consumption of plastic packaging (Heidbreder et al., 2020; Jahani et al., 2019). Negative affect was also considered to reflect automatic motivation. For example, people associated guilt with not using reusable shopping bags (Muralidharan and Sheehan, 2018) and sadness with seeing others not recycling their plastic waste (Viscusi et al., 2011).

On average, automatic motivation had a medium sized relationship with behaviours related to plastic waste ($r_+ = 0.33$, $k = 6$, see Table 2).

### 3.3.5. Reflective motivation

Reflective motivation encompassed a wide range of beliefs, including consideration of attitudes ($k = 6$). For example, positive attitudes towards recycling were associated with subsequent recycling (Klöckner and Oppedal, 2011; Ofstad et al., 2017; Wright and Miller, 1996) while negative attitudes towards single-use plastic bags were associated with being less likely to use them (Ohtomo and Ohnuma, 2014). Positive attitudes towards plastic-waste-management behaviours were also associated with increased donation, reuse and reselling of plastic items (Khan et al., 2019). Another study found that negative attitudes towards recyclable items and multiple-use carrier bags was associated with great consumption of single-use plastic (Jahani et al., 2019). Six studies also considered participants beliefs about plastic as a material. For example, the perception that recycling is unnecessary (McDonald and Ball, 1998), and that single use plastic is more hygienic than reusable materials (Jahani et al., 2019) were associated with being more likely to use single-use plastic items. Being less likely to use single-use plastic items was associated with the beliefs that excess waste burdens waste management systems (Thanh et al., 2012) and leads to environmental degradation (Fiorillo, 2013; Hage et al., 2009; Saphores and Nixon, 2014), and that plastic packaging poses health risks (e.g., cancer, chromosomal mutations) and changes the taste of food and drink (Jahani et al., 2019).

Reflective motivation also included perceptions of the difficulty of enacting a behaviour. For example, studies investigated the relationship between perceived behavioural control and recycling plastic waste items (Klöckner and Oppedal, 2011; Ofstad et al., 2017), plastic bag use amongst shoppers (Muralidharan and Sheehan, 2016; Ohtomo and Ohnuma, 2014) and reselling, reusing and donating plastic items (Khan et al., 2019). Other studies did not refer to perceived difficulty as perceived behavioural control but still investigated its relationship with behaviour. For example, perceived obstacles to recycling were found to make it harder to recycle in one study (Saphores and Nixon, 2014), whereas perceived ease made it easier to recycle in another (Thanh et al., 2012). Another study found that participants found it rather difficult to buy products without plastic packaging (Heidbreder et al., 2020).

Reflective motivation also included consideration of personal moral norms ($k = 7$) – i.e., a sense of obligation based on the individual's personal values – and identity ($k = 3$). In one study, individualistic values were shown to be associated with increased use of plastic single-use shopping bags (Shabanova, 2019). In other studies, pro-environmental personal moral norms were found to be associated with using less plastic packaging (Heidbreder and Schmitt, 2020) and recycling (Hage et al., 2009; Klöckner and Oppedal, 2011; Ofstad et al., 2017; Saphores and Nixon, 2014; Thanh et al., 2012). With respect to identity, studies have found that pro-environmental identity was related to increased recycling (Viscusi et al., 2011) and reduced purchase of plastic packaging (Heidbreder et al., 2020). Reflective motivation also included consideration of perceived sanctions ($k = 3$) and beliefs about responsibility ($k = 3$). For example, if people believe that they will not be heavily sanctioned during a plastic bag ban, then they are more likely to continue using plastic bags (Bharadwaj et al., 2020). They are also less likely to abide by certain behaviours if there are no or minimal sanctions (Agovino et al., 2020; Hage et al., 2009). Beliefs regarding whose responsibility it is to reduce plastic waste was also associated with behaviours related to plastic waste. The more people believed that it is corporations' responsibility to reduce plastic waste, the less likely they were to recycle (Thanh et al., 2012) or use reusable bags (Romero et al., 2018). Believing that individual households should not be to blame for

the waste created by the many was also associated with reduced recycling (Saphores and Nixon, 2014).

Finally, reflective motivation included consideration of people's intentions to engage in behaviours relevant to plastic waste and plans to enact these intentions ($k = 8$). For example, the strength of participants' intentions to bring their own bags and to reuse bags (Lam and Chen, 2006), not to take plastic bags at supermarket checkouts (Lam and Chen, 2006; Muralidharan and Sheehan, 2016; Ohtomo and Ohnuma, 2014), making plans to renounce plastic packaging (Heidbreder and Schmitt, 2020), and having an active interest in recycling (Klöckner and Oppedal, 2011; McDonald and Ball, 1998; Ofstad et al., 2017; Thanh et al., 2012). The higher the intention, the more likely they were to enact that behaviour.

On average, reflective motivation had a medium sized relationship with behaviours related to plastic waste ($r_+ = 0.34$, $k = 15$, see Table 2).

#### 3.3.6. Publication biases and moderation effects

Contour-enhanced funnel plots for COM-B variables can be found in Appendix K. Publication biases (see Table 7) were not identified. Age or gender of the sample, year of publication, or the nature of the measure of behaviour (i.e., objective or self-report) was not found to moderate the size of the association between variables associated with plastic waste and behaviour (see Appendix M).

### 3.4. Interventions targeting behaviours relating to plastic waste

The studies used eight of the nine potential types of intervention (i.e., the only type of intervention that was absent was 'training'). The most common types of intervention were 'environmental restructuring' ($k = 16$) and 'coercion' ($k = 14$), followed by 'persuasion' ($k = 7$). Appendix N details the range of interventions, policy options, COM-B components and BCTs identified in the primary studies. The sample weighted average effect size for each intervention type, policy category, targeted COM-B component and BCT can be found in Tables 3–6 respectively.

#### 3.4.1. Environmental restructuring

These interventions included stocking reusable cups for sale to reduce the number of hot beverages bought in single-use cups in cafes (Poortinga and Whitaker, 2018); adding bins to promote recycling (Becker et al., 2014; Cheung et al., 2018; McCoy et al., 2018; Miller et al., 2016; O'Connor et al., 2010); adding water refill stations to reduce plastic water bottle pollution (Willis et al., 2019) and implementing recycling schemes/policies (Dahlén et al., 2009; Ferronato et al., 2020; Hage et al., 2018; Hahladakis et al., 2018; Jacobsen et al., 2018; Morlok et al., 2017; Saphores and Nixon, 2014; Viscusi et al., 2012; Woodard et al., 2006). On average, interventions involving environmental restructuring had a very large effect on behaviours related to plastic waste ($d_+ = 1.31$, $k = 23$, see Table 3).

#### 3.4.2. Coercion

Interventions involving coercion included plastic bag charges (He, 2012; Jakovcevic et al., 2014; Luís and Spínola, 2010; Martinho et al., 2017; Rivers et al., 2017; Taylor and Villas-Boas, 2016; Thomas et al., 2019; Yang and Innes, 2007; Zen et al., 2013); a 'latte levy' (i.e., charging for drinks bought in single-use cups) (Poortinga and Whitaker, 2018); mandatory recycling policies (Saphores and Nixon, 2014; Viscusi et al., 2012; Yang and Innes, 2007) and; waste handling fees based on volume and/or weight (Hage et al., 2018; Morlok et al., 2017; Saphores and Nixon, 2014; Yang and Innes, 2007). On average, interventions involving coercion had a large effect on behaviours related to plastic waste ($d_+ = 0.76$, $k = 23$, see Table 3).

#### 3.4.3. Persuasion

Interventions involving persuasion included emotive texts/images depicting plastic pollution (Heidbreder and Schmitt, 2020; Heidbreder et al., 2020); motivational/inspirational posters advocating desired behaviour (Poortinga and Whitaker, 2018); inducing guilt (Muralidharan and Sheehan, 2018); inducing positive or negative attitudes towards a plastic bag policy (Lam, 2005); inducing cognitive dissonance

**Table 3**
Effects of interventions on behaviours related to reducing plastic waste by BCW intervention type.

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

*Note*. $k$ = number of independent samples; $o$ = number of effect sizes; $d+$ = weighted average effect size $d$; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; $t$ = result of $t$-test; $df$ = degrees of freedom, $df$s < 4 should be treated with caution (Tanner-Smith et al., 2016), - = insufficient number of effect sizes to conduct meta-analysis.

**Table 4**
Effects of interventions on behaviours related to reducing plastic waste by BCW policy options.

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

*Note*. *k* = number of independent samples; *o* = number of effect sizes; *d*+ = weighted average effect size *d*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of *t*-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (Tanner-Smith et al., 2016), - = insufficient number of effect sizes to conduct meta-analysis.

**Table 5**
Effects of interventions on behaviours related to reducing plastic waste by targeted COM-B variables.

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

*Note*. *k* = number of independent samples; *o* = number of effect sizes; *d*+ = weighted average effect size *d*; *SE* = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; *t* = result of *t*-test; *df* = degrees of freedom, *df*s < 4 should be treated with caution (Tanner-Smith et al., 2016), - = insufficient number of effect sizes to conduct meta-analysis.

(Rubens et al., 2015); prompting people to commit to the desired target behaviour (Rubens et al., 2015) and; advertising messages framed as 'losses' or 'gains' (Muralidharan and Sheehan, 2016). On average, interventions involving persuasion had a very large effect on behaviours related to plastic waste ($d_+ = 1.15$, $k = 18$, see Table 3).

### 3.4.4. Enablement

Interventions that provided enablement included distributing free reusable cups/bottles to primary school (Zorpas et al., 2017) and university students (Poortinga and Whitaker, 2018); voice prompts to reduce plastic bag use at supermarkets (Ohtomo and Ohnuma, 2014) and visual prompts to promote recycling (Miller et al., 2016) and; prompting employees to form if-then plans (or implementation intentions (Gollwitzer, 1999)) to increase recycling at work (Holland et al., 2006). On average, interventions involving enablement had a very large effect on behaviours related to plastic waste ($d_+ = 1.69$, $k = 8$, see Table 3).

### 3.4.5. Education

Interventions classed as 'education' included providing information about the environmental impacts of plastic pollution (Ferronato et al., 2020; Heidbreder et al., 2020; Zorpas et al., 2017) and information to assist use of a recycling bin (e.g., the types of items that can be placed in the recycling bin) (Cheung et al., 2018; Miller et al., 2016). On average, interventions involving education had a very large effect on behaviours related to plastic waste ($d_+ = 1.69$, $k = 8$, see Table 3).

### 3.4.6. Incentivisation

Interventions involving incentivisation included a 'bottle bill' (i.e., a container deposit law) (Saphores and Nixon, 2014; Viscusi et al., 2012);

**Table 6**
Effects of interventions on behaviours related to reducing plastic waste by Behaviour Change Techniques (BCTs) from the BCTTv1.

| Behaviour Change Techniques | *k* | *o* | $d_+$ | *SE* | 95% CI | | *t(df)* | Heterogeneity | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | *LL* | *UL* | | $\tau^2$ | $I^2$ |
| **Goal setting (behaviour)** | - | - | - | - | - | - | - | - | - |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Action planning** | 2 | 2 | 0.95 | 0.53 | −5.83 | 7.72 | 1.77 (1.00) | 0.42 | 72.73 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Commitment** | - | - | - | - | - | - | - | - | - |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Feedback on behaviour** | 2 | 9 | 0.54 | 0.42 | −4.82 | 5.90 | 1.27 (1.00) | 0.77 | 91.24 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Social support (practical)** | 4 | 4 | 2.30 | 0.83 | −0.33 | 4.93 | 2.7 9 (3.00) | 2.22 | 85.72 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Instruction on how to perform behaviour** | 7 | 14 | 0.58 | 0.34 | −0.29 | 1.45 | 1.63 (5.98) | 1.00 | 94.19 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Info. about social and environmental consequences** | 17 | 17 | 1.17 | 0.39 | 0.33 | 2.00 | 2.97 (15.9) | 1.71 | 88.08 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Prompts/cues** | 20 | 27 | 1.19 | 0.31 | 0.55 | 1.84 | 3.88 (18.6) | 0.98 | 91.70 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Material incentive (behaviour)** | 6 | 6 | 1.16 | 0.54 | −0.24 | 2.56 | 2.14 (4.89) | 0.84 | 85.43 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Non-specific incentive** | - | - | - | - | - | - | - | - | - |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Future punishment** | 2 | 2 | 0.54 | 0.05 | −0.08 | 1.16 | 11.00(1.00) | 0 | 0 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Restructuring the physical environment** | 16 | 24 | 0.73 | 0.21 | 0.28 | 1.18 | 3.45(15.00) | 0.77 | 93.87 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Adding objects to the environment** | 24 | 35 | 1.33 | 0.25 | 0.81 | 1.85 | 5.33(22.40) | 0.82 | 91.61 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Incompatible beliefs** | - | - | - | - | - | - | - | - | - |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |
| **Punishment** | 23 | 29 | 0.75 | 0.15 | 0.44 | 1.05 | 5.03(21.50) | 0.45 | 86.87 |
| *Intercept only* | | | | | | | | | |
| Constant | | | | | | | | | |

Note. k = number of independent samples; o = number of effect sizes; d+ = weighted average effect size d; SE = standard error; 95% CI = the 95% confidence intervals; LL = lower limit; UL = upper limit; t = result of *t*-test; df = degrees of freedom, dfs < 4 should be treated with caution (Tanner-Smith et al., 2016), - = insufficient number of effect sizes to conduct meta-analysis.

posters providing feedback on recycling behaviour to boost a student initiative to participate in plastic recycling (Cheung et al., 2018); signs thanking people for recycling (Becker et al., 2014) and; discounts for buying drinks in reusable cups (Poortinga and Whitaker, 2018). On average, interventions involving incentivisation had a very large effect on behaviours related to plastic waste ($d_+ = 0.97$, $k = 8$, see Table 3).

#### 3.4.7. Restriction

Interventions involving restriction included plastic bag bans (complete or partial) (Bharadwaj et al., 2020; Macintosh et al., 2020; Sharp et al., 2010; Taylor and Villas-Boas, 2016). On average, interventions involving restriction had a small effect on behaviours related to plastic waste ($d_+ = 0.26$, $k = 7$, see Table 3).

#### 3.4.8. Modelling

Interventions involving modelling included providing feedback on desirable recycling behaviour for students to aspire to and imitate (Cheung et al., 2018). On average, interventions involving modelling had a medium-sized effect on behaviours related to plastic waste ($d_+ = 0.54$, $k = 2$, see Table 3).

### 3.5. Policy options

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

#### 3.5.1. Fiscal measures

Fiscal measures included levies for taking bags at supermarket checkouts (He, 2012; Jakovcevic et al., 2014; Luís and Spínola, 2010; Martinho et al., 2017; Rivers et al., 2017; Taylor and Villas-Boas, 2016; Thomas et al., 2019; Yang and Innes, 2007; Zen et al., 2013); a 'late levy' for buying drinks in a single-use cup (Poortinga and Whitaker, 2018); a discount for buying drinks in reusable cups (Poortinga and Whitaker, 2018); a 'bottle bill' (Saphores and Nixon, 2014; Viscusi et al., 2012)

**Table 7**
Results from tests of publication bias.

| COM-B factor | Failsafe N | Egger's regression | | PET using RVE | | |
|---|---|---|---|---|---|---|
| | (5n +10) | z | p | B | 95% CI | df |
| Psychological capability | 544 | 1.06 | .29 | 6.15 | −80.16-92.47 | 2.64 |
| Social opportunity | 480 | 0.06 | .95 | −10.87 | −65.96-44.23 | 2.43 |
| Physical opportunity | 406 | −0.37 | .71 | −12.56 | −278.53-253.40 | 1.00 |
| Automatic motivation | 338 | −0.53 | .59 | −6.59 | −73.48-60.30 | 2.13 |
| Reflective motivation | 45,954 | −0.59 | .56 | −15.34 | −49.14-18.45 | 9.48 |
| BCW intervention type | | | | | | |
| Education | 335 | −2.26 | .02* | −24.84 | −72.78-23.10 | 2.37 |
| Persuasion | 169 | 5.50 | <.001*** | 10.2** | 5.85–14.62 | 6.37 |
| Incentivisation | 161 | 3.72 | <.001*** | 6.14 | −2.84-15.13 | 2.49 |
| Coercion | 1413 | 1.17 | .24 | 1.67 | −1.94-5.28 | 3.57 |
| Restriction | 29a | 1.85 | .06 | 15.30 | −43.34-73.95 | 1.84 |
| Environmental restructuring | 7279 | 2.13 | .03* | 4.34* | 0.72–7.96 | 9.02 |
| Modelling | 40a | 2.05 | .04* | 160.13 | −304.3-625 | 1.00 |
| Enablement | 255 | 1.95 | .05 | 4.67 | −1.67-11.00 | 3.90 |
| BCW policy option | | | | | | |
| Fiscal measures | 1688 | 2.45 | .01* | 4.07 | −0.05-8.18 | 8.79 |
| Legislation | 968 | 0.98 | .33 | 1.32 | −1.43-4.062 | 10.8 |
| Communications & marketing | 1160 | 3.42 | <.001*** | 6.09** | 1.94–10.236 | 10.9 |
| Service provision | 93 | 1.20 | .23 | 2.03 | −12.41-16.47 | 1.91 |
| Environmental & social planning | 5850 | 2.23 | .03* | 4.3* | 0.78–7.72 | 2.75 |
| Regulation | - | - | - | - | - | - |
| Targeted COM-B variable | | | | | | |
| Psychological capability | 39a | 0.92 | .36 | 3.37 | −18.60-25.35 | 1.90 |
| Social opportunity | 40a | 2.06 | .04* | 160.13 | −304.30-625.00 | 1.00 |
| Physical opportunity | 7294 | 3.12 | .002** | 4.31* | 0.84–7.79 | 10.00 |
| Automatic motivation | 2708 | 2.76 | .006** | 3.97 | −0.01-7.94 | 9.41 |
| Reflective motivation | 256 | 4.91 | <.001*** | 10.50** | 5.26–15.73 | 5.15 |
| Behaviour Change Technique | | | | | | |
| Goal setting (behaviour) | - | - | - | - | - | - |
| Action planning | 3a | - | - | - | - | - |
| Commitment | - | - | - | - | - | - |
| Feedback on behaviour | 40 | 2.06 | .04* | 160.13 | −304.30-625.00 | 1.00 |
| Social support (practical) | 44 | 4.56 | <.001*** | 16.52* | 7.96–25.07 | 1.69 |
| Instruction on how to perform the behaviour | 351 | −1.88 | .06 | −9.58 | −48.47-29.30 | 1.66 |
| Information about social and environmental consequences | 114 | 5.50 | <.001*** | 10.37*** | 6.49–14.24 | 6.25 |
| Prompts/cues | 966 | 3.42 | <.001*** | 5.45* | 1.57–9.33 | 10.07 |
| Material incentive (behaviour) | 35 | 2.51 | 0.01* | 7.03 | −4.31-18.37 | 2.38 |
| Non-specific incentive | - | - | - | - | - | - |
| Future punishment | 3a | - | - | - | - | - |
| Restructuring the physical environment | 1617 | −2.22 | 0.03* | −15.91 | −34.70-2.88 | 6.62 |
| Adding objects to the environment | 6769 | 2.08 | 0.04* | 3.82* | 0.24–7.39 | 12.00 |
| Incompatible beliefs | - | - | - | - | - | - |
| Punishment | 1308 | 1.10 | 0.27 | 2.51 | −2.17-7.19 | 8.09 |

*Note.* *a* = Failsafe N does not exceed Rosenberg's critical value; significance codes: $p < .001$ ***, $p < .01$ **, $p < .05$ *; *B* = unstandardized beta coefficient; 95% CI = the 95% confidence intervals; PET = Precision Effect Test; RVE = robust variance estimation. A significant PET and/or *z*-value in the Egger's regression test indicates risk of bias (Egger et al., 1997). Tests of Failsafe N and Egger's regression were conducted using meta-analytic random/mixed-effects models, whereas PET was conducted using RVE; *df* = degrees of freedom, *df*s < 4 should be treated with caution (Tanner-Smith et al., 2016), - = insufficient number of effect sizes to conduct meta-analysis.

and; volume/weight based waste handling fees (Hage et al., 2018; Morlok et al., 2017; Saphores and Nixon, 2014; Yang and Innes, 2007). On average, interventions employing fiscal measures had a large effect on behaviours related to plastic waste ($d_+ = 0.89$, $k = 26$, see Table 4).

### 3.5.2. Legislation

Legislation included mandatory recycling policies (Saphores and Nixon, 2014; Viscusi et al., 2012; Yang and Innes, 2007); 'bottle bills'(Saphores and Nixon, 2014; Viscusi et al., 2012); laws banning plastic carrier bags (Bharadwaj et al., 2020; Macintosh et al., 2020; Sharp et al., 2010; Taylor and Villas-Boas, 2016) and; laws mandating a charge for plastic carrier bags (He, 2012; Jakovcevic et al., 2014; Martinho et al., 2017; Muralidharan and Sheehan, 2018; Rivers et al., 2017; Taylor and Villas-Boas, 2016; Thomas et al., 2019; Yang and Innes, 2007). On average, interventions employing legislation had a medium-sized effect on behaviours related to plastic waste ($d_+ = 0.55$, $k = 27$, see Table 4).

### 3.5.3. Communications and marketing

Communications and marketing included using print media such as motivational posters/signs advocating the desired behaviour (Poortinga and Whitaker, 2018); educational information on a campaign to reduce plastic waste (Ferronato et al., 2020; Heidbreder et al., 2020; Zorpas et al., 2017); persuasive/emotive messaging (Heidbreder and Schmitt, 2020; Lam, 2005; Muralidharan and Sheehan, 2016, 2018; Rubens et al., 2015); educational information on the types of items that can be recycled (Cheung et al., 2018; Miller et al., 2016) and rewarding signs to promote desired behaviour (Becker et al., 2014). On average, interventions employing legislation had a large effect on behaviours related to plastic waste ($d_+ = 1.00$, $k = 24$, see Table 4).

### 3.5.4. Service provision

Service provision included implementation of waste management and recycling services (Dahlén et al., 2009; Ferronato et al., 2020; Hage et al., 2018; Hahladakis et al., 2018; Jacobsen et al., 2018; Morlok et al., 2017; Saphores and Nixon, 2014; Woodard et al., 2006); support for recycling in the workplace (Holland et al., 2006) and the distribution of free reusable cups to university students (Poortinga and Whitaker, 2018) and; reusable water bottles to primary school students (Zorpas et al., 2017). On average, interventions providing services had a large effect on behaviours related to plastic waste ($d_+ = 1.64$, $k = 7$, see Table 4).

#### 3.5.5. Environmental and social planning

Environmental and social planning included stocking reusable cups for purchase in cafés (Poortinga and Whitaker, 2018); implementing water refill stations (Willis et al., 2019); adding recycling bins within the environment (Becker et al., 2014; Cheung et al., 2018; McCoy et al., 2018; Miller et al., 2016; O'Connor et al., 2010) and adding behavioural voice prompts within the environment (Ohtomo and Ohnuma, 2014). On average, interventions employing environmental and social planning had a large effect on behaviours related to plastic waste ($d_+ = 1.41$, $k = 21$, see Table 4).

#### 3.5.6. Regulation

Regulation included voluntary plastic bag charges at retailer checkouts without support from legislative frameworks (Luís and Spínola, 2010; Zen et al., 2013). Only one study had quantitative data that could be used for the meta-analysis so the sample weighted average effect size for the effectiveness of interventions employing 'regulation' as a policy category could not reliably be calculated.

### 3.6. Targeted COM-B components

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

#### 3.6.1. Psychological capability

Interventions targeting psychological capability included reminders directing attention towards the desired behaviour (e.g. via visual/auditory prompts (Becker et al., 2014; Cheung et al., 2018; Ohtomo and Ohnuma, 2014) and colourful recycling bins to increase their saliency (O'Connor et al., 2010)); increasing procedural knowledge on how to perform the target behaviour (e.g., providing information on what items can be recycled (Miller et al., 2016)) and; increasing awareness of campaigns (e.g., via highlighting the consequences of plastic pollution (Ferronato et al., 2020; Heidbreder et al., 2020; Zorpas et al., 2017)). On average, interventions targeting psychological capability had a small negative effect on behaviours related to plastic waste ($d_+ = -0.28$, $k = 10$, see Table 5).

#### 3.6.2. Physical opportunity

Interventions targeting physical opportunity included increasing the availability of resources (both objects and services) within the physical environment to reduce barriers to the desired target behaviour; for example, distributing free reusable cups/bottles and making them available for purchase (Poortinga and Whitaker, 2018; Zorpas et al., 2017), adding water refill stations (Willis et al., 2019) and recycling bins within the environment (Becker et al., 2014; Cheung et al., 2018; McCoy et al., 2018; Miller et al., 2016; O'Connor et al., 2010), increasing availability of local waste management and recycling services (Dahlén et al., 2009; Ferronato et al., 2020; Hage et al., 2018; Hahladakis et al., 2018; Jacobsen et al., 2018; Morlok et al., 2017; Saphores and Nixon, 2014; Woodard et al., 2006). Interventions targeting physical opportunity also manifested as decreasing the availability of resources that promote undesired behaviour (e.g., plastic carrier bag bans (Bharadwaj et al., 2020; Macintosh et al., 2020; Sharp et al., 2010; Taylor and Villas-Boas, 2016)). On average, interventions targeting physical opportunity had a large effect on behaviours related to plastic waste ($d_+ = 1.08$, $k = 30$, see Table 5).

#### 3.6.3. Automatic motivation

Interventions targeting automatic motivation included inducing feelings of guilt (Muralidharan and Sheehan, 2018); reinforcement via feedback on behaviour (Cheung et al., 2018); incentivisation (e.g., via discounts (Poortinga and Whitaker, 2018) and deposit-return schemes (Saphores and Nixon, 2014; Viscusi et al., 2012)); the prospect of punishment (e.g., additional charges, levies and taxes (Hage et al., 2018; He, 2012; Jakovcevic et al., 2014; Luís and Spínola, 2010; Martinho et al., 2017; Morlok et al., 2017; Poortinga and Whitaker, 2018; Rivers et al., 2017; Saphores and Nixon, 2014; Taylor and Villas-Boas, 2016; Thomas et al., 2019; Yang and Innes, 2007; Zen et al., 2013)) and sanctions (e.g., a threatened penalty for disobeying the law (Bharadwaj et al., 2020; Macintosh et al., 2020; Taylor and Villas-Boas, 2016; Yang and Innes, 2007)). On average, interventions targeting automatic motivation opportunity had a large effect on behaviours related to plastic waste ($d_+ = 0.77$, $k = 32$, see Table 5).

#### 3.6.4. Reflective motivation

Interventions targeting reflective motivation included arousing cognitive dissonance and encouraging people to commit to the target behaviour (Rubens et al., 2015); increasing pro-environmental attitudes and values (e.g., via motivational posters/messaging (Lam, 2005; Poortinga and Whitaker, 2018)) and increasing self-efficacy (e.g., via setting implementation intentions to recycle (Holland et al., 2006)) and being invited to participate in a challenge to reduce plastic waste (Heidbreder et al., 2020). Interventions targeting reflective motivation also manifested as targeting personal moral norms and perceived behavioural control (Heidbreder and Schmitt, 2020). On average, interventions targeting reflective motivation had a large effect on behaviours related to plastic waste ($d_+ = 1.34$, $k = 17$, see Table 5).

#### 3.6.5. Social opportunity

Interventions targeting social opportunity included targeting people's perceptions of descriptive social norms (i.e., perceptions about how others are recycling to promote recycling behaviour (Cheung et al., 2018)). On average, interventions targeting social opportunity had a medium-sized effect on behaviours related to plastic waste ($d_+ = 0.54$, $k = 2$, see Table 5). However, the effect size should be interpreted with caution as only two interventions targeted social opportunity.

### 3.7. The effect of specific behaviour change techniques on behaviour

Fifteen of the 93 BCTs in the BCTTv1 (Michie et al., 2013) were identified at least once in the studies reporting interventions. 'Restructuring the physical environment' and 'punishment' and were the most commonly used BCTs ($k = 16$ and $k = 15$ respectively), followed by 'adding objects to the environment' ($k = 9$), 'information about social and environmental consequences' ($k = 7$) and 'prompts/cues' ($k = 6$). 'Instruction on how to perform the behaviour' was delivered in five studies while 'material incentive (behaviour)' was delivered in four. 'Future punishment' was delivered twice while the other seven BCTs that were employed were each used in just one study each. Table 6 summarises the results of the meta-analyses examining the effect of the BCTs that were used in two or more studies on behaviours related to plastic waste. Below, only results where the degrees of freedom were greater than four are reported on (Tanner-Smith et al., 2016).

BCTs with medium-to-large effects included: Providing instructions on how to perform a behaviour ($d_+ = 0.58$, $k = 7$, see Table 6), restructuring the physical environment ($d_+ = 0.73$, $k = 16$, see Table 6) and punishment ($d_+ = 0.75$, $k = 23$, see Table 6). BCTs with very large effects included: Providing a material incentive to change behaviour ($d_+ = 1.16$, $k = 6$, see Table 6), information on social and environmental consequences ($d_+ = 1.17$, $k = 17$, see Table 6), prompts/cues ($d_+ = 1.17$, $k = 20$, see Table 6) and adding objects to the environment ($d_+ = 1.33$, $k = 24$, see Table 6).

### 3.8. Publication biases and moderation effects

Contour-enhanced funnel plots for each intervention type, policy category, targeted COM-B component and BCT can be found in

Appendix L. There was risk publication bias for all intervention types except for 'coercion' and 'enablement', all policy options except for 'legislation' and service provision', all targeted COM-B components and all BCTs except for 'punishment' and 'instruction on how to perform the behaviour' (see Table 7). Bias adjusted effect sizes from trim-and-fill analyses ranged from −0.79 to +0.18 (Table 8).

The only variable found to significantly moderate (some) of the effects of interventions on behaviours related to plastic waste, was how the behaviour was measured. The nature of the measure of behaviour significantly and positively impacted effect sizes for interventions targeting 'physical opportunity', the intervention type 'persuasion' and the policy category 'communications and marketing' such that effect sizes were higher when behaviour was objectively measured vs self-reported (see Appendix M).

## 4. Discussion

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

### 4.1. Behaviours related to plastic waste

Recycling was the most commonly specified action for reducing plastic waste, the general public were the most commonly specified actors, and in-person shopping was the most commonly studied context. The only plastic waste-related items specified in the primary studies were packaging, shopping bags, cups and water bottles; otherwise, studies focused on unspecified, generic plastic waste. As plastic waste is the result of multiple behaviours of multiple actors across various contexts, empirical investigation into a wider range of actions, actors and contexts is likely to be needed to make progress in this space. For example, while recycling is important, there is a consensus that focusing on waste prevention strategies are more optimal than waste processing strategies, exemplified by the EU waste hierarchy, which prioritises waste management options in terms of resource efficiency (Union, 2008). For example, repair can prevent waste (Nazlı, 2021) as can reuse (Greenwood et al., 2021); however these types of behaviours are rarely studied and so less is known about peoples' engagement with them or interventions to promote them (Kunamaneni et al., 2019). 'Individualising' behaviour, through a focus on the general public's consumption,

**Table 8**
Effect sizes as a function of different interventions following correction for publication bias.

| BCW intervention type | Trim-and-fill | | | | | PEESE using RVE | | |
|---|---|---|---|---|---|---|---|---|
| | Observed *o* | Unadj. d+ | Imputed o | Adj. d+ | Change | B | 95% CI | df |
| Education | 13 | 0.68 | 0 | 0.51 | −0.17 | −170.02 | −674.83-334.79 | 2.06 |
| Persuasion | 21 | 1.15 | 0 | 1.01 | −0.14 | 17.40*** | 13.55–21.25 | 5.22 |
| Incentivisation | 15 | 0.97 | 0 | 0.69 | −0.28 | 13.31 | −2.89-29.50 | 1.65 |
| Coercion | 30 | 0.76 | 0 | 0.78 | +0.02 | 2.51 | −17.48-22.70 | 1.37 |
| Restriction | 14 | 0.26 | 2 | 0.17 | −0.09 | 98.51 | −355.74-552.76 | 1.72 |
| Environmental restructuring | 37 | 1.31 | 0 | 1.14 | −0.17 | 11.06** | 6.23–15.89 | 5.15 |
| Modelling | 9 | 0.54 | 0 | 0.40 | −0.14 | 1195.40 | −2271.3-4662.1 | 1.00 |
| Enablement | 8 | 1.69 | 0 | 1.71 | +0.02 | 11.31 | −1.20-23.82 | 2.38 |
| BCW policy option | | | | | | | | |
| Fiscal measures | 32 | 0.89 | 0 | 0.90 | +0.01 | 11.54* | 2.54–20.54 | 3.13 |
| Legislation | 36 | 0.55 | 9 | 0.27 | −0.28 | 5.09 | −4.44-14.62 | 8.72 |
| Comms & marketing | 34 | 1.00 | 0 | 0.21 | −0.79 | 14.31*** | 9.23–19.38 | 6.00 |
| Service provision | 7 | 1.64 | 0 | 1.65 | +0.01 | 0.95 | −24.53-26.43 | 1.41 |
| Env & social planning | 34 | 1.41 | 0 | 1.18 | −0.23 | 10.82** | 6.03–15.61 | 5.72 |
| Regulation | - | - | - | - | - | - | - | - |
| Targeted COM-B variable | | | | | | | | |
| Psychological capability | 17 | −0.28 | 5 | −0.39 | −0.11 | 6.91 | −142.51-156.34 | 0.78 |
| Social opportunity | 9 | 0.54 | 0 | 0.40 | −0.14 | 1195.40 | −2271.3-4662.1 | 1.00 |
| Physical opportunity | 48 | 1.08 | 0 | 0.93 | −015 | 9.84* | 3.00–16.69 | 6.36 |
| Automatic motivation | 48 | 0.77 | 0 | 0.70 | −0.07 | 11.60* | 2.92–20.29 | 3.24 |
| Reflective motivation | 19 | 1.34 | 0 | 1.22 | −0.12 | 17.43*** | 13.26–21.60 | 4.67 |
| Behaviour Change Technique | | | | | | | | |
| Feedback on behaviour | 9 | 0.54 | 0 | 0.40 | −0.14 | 1195.40 | −2271.3-4662.1 | 1.00 |
| Social support (practical) | 4 | 2.30 | 0 | 2.31 | +0.01 | 20.50* | 2.87–38.13 | 1.65 |
| Instruction on how to perform the behaviour | 14 | 0.58 | 0 | 0.47 | −0.11 | −29.65 | −263.78-204.48 | 1.38 |
| Information about social and environmental consequences | 17 | 1.17 | 0 | 1.19 | −0.02 | 18.05*** | 14.46–21.64 | 5.26 |
| Prompts/cues | 27 | 1.19 | 0 | 0.99 | −0.20 | 13.48*** | 8.10–18.85 | 5.95 |
| Material incentive (behaviour) | 6 | 1.16 | 0 | 1.23 | +0.07 | 13.97 | −3.02-30.96 | 1.69 |
| Restructuring the physical environment | 24 | 0.73 | 0 | 0.91 | +0.18 | −95.27 | −257.18-66.64 | 4.78 |
| Adding objects to the environment | 35 | 1.33 | 0 | 1.21 | −0.12 | 10.58** | 5.17–16.03 | 6.06 |
| Punishment | 29 | 0.75 | 0 | 0.78 | +0.03 | 9.29 | −7.86-26.45 | 3.18 |

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

can also shift focus away from the socioeconomic and commercial drivers of plastic waste behaviours. Because the actions of businesses and governments shape the social, economic and environmental contexts within which citizens interact (Kelly and Barker, 2016), behaviour change research should explore the behaviour of a wider range of actors including government and industry.

### 4.2. Variables associated with behaviours related to plastic waste

All identified COM-B variables had medium-strength associations with behaviour, although more data is required to draw conclusions about the impact of 'physical opportunity'. 'Reflective motivation' had the strongest association with behaviour followed by 'automatic motivation'. This is unsurprising as waste management behaviours, and specifically recycling (which constituted the majority of the target behaviours studied), are often habitual and emotionally- and morally-significant behaviours (Chan and Bishop, 2013; Fang et al., 2021; Principato et al., 2021; Robina-Ramírez et al., 2020; Russell et al., 2017). 'Psychological capability' and 'social opportunity' had the weakest associations with behaviour. This could be explained by waste management behaviours, and particularly recycling, being comparatively less socially influenced behaviours than other environmentally-significant behaviours, such as dietary behaviours (Conklin et al., 2014; Horgan et al., 2019). The study findings support the notion that while knowledge and awareness are associated with behaviour, they are neither sufficient nor the strongest drivers of behaviour. The findings also demonstrate that a combination of capability, opportunity and motivation are required to enact behaviour, suggesting that holistic approaches are needed for intervention design.

### 4.3. Interventions targeting behaviours related to plastic waste

The approach that behaviour change is about 'getting the message across' or providing knowledge and information has been identified as two of the main errors that policy makers make (Kelly and Barker, 2016). The findings show that citizens must have not only the capability but also the motivation and opportunity to adopt behaviours that reduce plastic waste – indeed, interventions targeting psychological capability typically had a negative effect on behaviours that reduce plastic waste. This further suggests that interventions should consider all of these factors simultaneously, rather than focusing only on providing information.

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

### 4.4. Strengths and limitations

While prior evidence reviews have been conducted (Heidbreder et al., 2019), this is the first review to use behaviour change theory to categorise the nature of interventions designed to reduce plastic waste and use meta-analysis to quantify the effect of intervention types, components, and strategies on behaviours related to plastic waste. In many cases, however, this approach represents 'post-hoc' application of theory to understand interventions that were not informed by theory. Evidence suggests that explicit application of theory can improve intervention design, facilitate the evaluation of intervention effectiveness, and enhance learning within health behaviour change contexts (Davidoff et al., 2015); for a review see (Prestwich et al., 2015). It is therefore suggested that behaviour change theory could be used to inform the design of interventions targeting plastic waste. This study also highlight clear evidence gaps which, alongside the development of open-access coding manuals, can be used to guide future research efforts.

Many target behaviours and interventions were poorly described which hindered the ability to extract and code study components. This is an issue that has been raised by other behavioural scientists (Crayton et al., 2020; Hoffmann et al., 2014; Michie and Abraham, 2008; Webb et al., 2010). Poor behavioural specification is problematic as it prevents understanding exactly what is being targeted or investigated and measured. To improve evidence synthesis, better reporting of target behaviours is required. In addition, some sub-group meta-analyses were not able to be computed due to lack of data, limiting conclusiveness of study findings. For example, no data on the potential effectiveness of some of the BCW policy options (i.e., guidelines), intervention types (i.e., training) and most BCTs from the BCTTv1 were identified as they have not yet been studied with respect to their effects on behaviours related to plastic waste. In addition, many interventions were multi-faceted, involving multiple intervention types and policy options and targeting several COM-B components. Factorial designs would help to disentangle the effect of intervention components from each other.

A final limitation is that the effects of some of the interventions may have been confounded with the target behaviour being investigated. For example, the sample-weighted average effect size for the intervention type 'restriction', which consisted of partial or complete plastic bag bans, was unexpectedly low when compared with the other types of intervention. It is likely the bans were more effective at changing single-use plastic bag use, but less effective at changing behaviour relating to bringing one's own bags to the supermarket. Restriction laws are also only as effective as their perceived enforcement (Bharadwaj et al., 2020). The meta-analysis was unable to take these potential contextual moderating variables into account.

## 5. Conclusion

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

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## CRediT authorship contribution statement

**Ayşe L. Allison:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Harriet M. Baird:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing, Supervision. **Fabiana Lorencatto:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing, Supervision. **Thomas L. Webb:** Conceptualization, Methodology, Supervision, Writing – review & editing, Funding acquisition. **Susan Michie:** Conceptualization, Methodology, Supervision, Writing – review & editing, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The study materials, including the raw data files and R code used for the meta-analysis can be found at: https://osf.io/53mtu/

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## Appendix A. Supplementary data

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