

RUNNING TITLE: Old habits and weight maintenance

Breaking habits or breaking habitual behaviours?

Old habits as a neglected factor in weight loss maintenance

Benjamin Gardner

(Department of Psychology, King's College London, London, UK)

Rebecca Richards

(MRC Epidemiology Unit, University of Cambridge, Cambridge, UK)

Phillippa Lally

(Department of Behavioural Science and Health, University College London, London, UK)

Amanda Rebar,

Tanya Thwaite

(School of Health, Medical and Applied Sciences, Central Queensland University, Australia)

& Rebecca Beeken,

(Leeds Institute of Health Sciences, University of Leeds, Leeds, UK)

Corresponding author: Dr Benjamin Gardner, Department of Psychology, Room 2.11,
Addison House, Guy's Campus, King's College London, London, SE1 1UL, UK.

benjamin.gardner@kcl.ac.uk

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Abstract

Maintaining weight loss requires long-term behaviour change. Theory and evidence around habitual behaviour – i.e., action triggered by impulses that are automatically activated upon exposure to cues, due to learned cue-action associations – can aid development of interventions to support weight loss maintenance. Specifically, weight loss is more likely to be sustained where people develop new habits that support weight management, and break old habits that may undermine such efforts. Interventions seeking to break ‘bad’ weight-related habits have focused on inhibiting unwanted impulses or avoiding cues. This paper draws attention to the possibility that while such approaches may discontinue habitual behaviour, underlying habit associations may remain. We use evidence from existing qualitative studies to demonstrate that, left unchecked, unwanted habit associations can render people prone to lapsing into old patterns of unhealthy behaviours when motivation or willpower is momentarily weakened, or when returning to familiar settings following temporarily discontinued exposure. We highlight six behaviour change techniques especially suited to disrupting habit associations, but show that these techniques have been underused in weight loss maintenance interventions to date. We call for intervention developers and practitioners to adopt techniques conducive to forming new habit associations to directly override old habits, and to use the persistence of unwanted habit associations as a potential indicator of long-term weight loss intervention effectiveness.

Keywords: Weight maintenance; obesity; behavioral science; habit; intervention

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Global prevalence of overweight and obesity has increased considerably in recent years; more than 1.9 billion adults are estimated to be affected by overweight, of whom over 650 million have obesity (World Health Organisation, 2020). The health consequences of obesity place a significant burden on public health services, and incur considerable economic costs for both healthcare services and wider society (Public Health England, 2017). The identification of effective solutions to reduce the prevalence of obesity, including individual-level interventions to support long-term weight management, remains a priority for public health. The causes of obesity are multidimensional and complex (Butland et al., 2007). However, at the simplest level, obesity can be attributed to a consistent state of positive energy balance, whereby energy intake exceeds energy expenditure. Behavioural weight management interventions aim to support individuals to achieve an energy balance deficit by promoting reduced energy intake and increased physical activity. These interventions have demonstrated effectiveness in promoting weight loss over the short term, but are less successful at supporting weight loss maintenance (Hartmann-Boyce et al., 2014; Jolly et al., 2011; Parretti et al., 2016). Most participants in these programmes gradually regain lost weight, and only around 20% of participants are successful over the longer term (Wing & Phelan, 2005). This has led to the development of interventions focused on weight loss maintenance, but to date the success of these programmes has been modest (Dombrowski et al., 2014). Most such interventions have adopted similar strategies to those within interventions targeting initiation of weight loss, by for example prioritising the formation of intentions to lose weight, rather than providing support for the continued performance of actions necessary to maintain weight loss. There is a critical need to harness the

RUNNING TITLE: Old habits and weight maintenance

psychological processes that support behaviour change conducive to long-term weight loss maintenance (Kwasnicka et al., 2016; Rothman, 2000).

Habit and weight loss

The concept of ‘habit’ is often drawn on to understand and promote long-term weight management (Cleo et al., 2020; Gardner et al., 2011; Rothman et al., 2009; van’t Riet et al., 2011). Habitual behaviours are generated by impulses that are automatically triggered when people encounter contextual cues, based on activation of cue-action associations learned through repeated performance (Gardner, 2015a; Wood et al., 2014). Habit associations form through context-dependent repetition; each performance in a given context reinforces the context-action association (Lally et al., 2010), until the action becomes the most mentally accessible response within that context (Danner et al., 2008). As habit forms, action selection is transferred from effortful deliberative processes to environmental cues, so reducing dependence on conscious motivation (Neal et al., 2012). Research has highlighted the potential conflict between habit and intention as determinants of energy balance behaviours (de Bruijn et al., 2008): when people hold habits that conflict with their intentions (e.g. high-calorie snack consumption habit, and intention to avoid eating high-calorie snacks), and they lack the momentary motivation, attention or control to override habit impulses, they are likely to act in line with habits rather than intentions (Gardner, Lally, et al., 2020; Triandis, 1977).

Many energy-balance-related behaviours are habitually triggered¹, and stronger habitual responses elicit more consistent action (van’t Riet et al., 2011). Observational studies have shown that regular repetitions of dietary and physical activity behaviours rapidly increase the reported automaticity of those actions, until a plateau is reached (Gardner et al.,

¹ A distinction has been drawn between habitually instigated action, whereby habit selects and engenders a commitment to perform a given action from an array of alternatives (e.g., to eat a bag of chips), in the absence of forethought, and habitually executed action, whereby habit facilitates fluid progression through a sequence of sub-actions required to complete any act (e.g. ‘put hand in bag’, ‘put chip in mouth’, ‘chew chip’, ‘swallow chip’, and so on; Gardner et al., 2016). Most habit research in the dietary domain focuses on habitual instigation, not execution (Gardner et al., 2016). In this paper, we use the term ‘habit’ to refer to habitual instigation only.

2014; Kaushal & Rhodes, 2015; Lally et al., 2010). Predictive studies suggest that dietary consumption, physical activity and sedentary behaviour may be predominantly driven by habit rather than deliberative influences (Fürtjes et al., 2020; Gardner et al., 2011; Howlett et al., 2020). Several studies have pointed to an interaction between dietary or activity habit and intentions, such that the influence of intention on action typically lessens as habit strength increases (Gardner et al., 2011; Ouellette & Wood, 1998; but see Gardner, Lally, et al., 2020).

The potential for habits to outweigh conscious intentions in regulating behaviour underpins much of the interest in habit as a mechanism affecting weight loss maintenance. Commentators have reasoned that, if habits can override intentions, then habit formation should sustain behaviours conducive to weight loss – such as healthy eating, and physical activity – even if, as typically occurs, people lose the motivation to persist (Lin et al., 2016; Rothman et al., 2009; Verplanken & Wood, 2006). Conversely, cessation of habitual behaviours that may undermine weight loss – such as high-calorie snacking, or prolonged seated activities – will depend on disrupting automatic responding, rather than simply motivating people to want to change (Verplanken & Wood, 2006).

Weight loss intervention developers are increasingly drawing on habit theory to promote long-term change (Cleo et al., 2017, 2020). A recent systematic review identified three weight-loss interventions explicitly rooted in habit theory (Cleo et al., 2020). The ‘Ten Top Tips’ outlined ten recommendations for simple changes, designed to promote the formation of healthy eating and physical activity habits (Lally et al., 2008). The ‘Transforming Your Life’ intervention focused on developing personal environments conducive to healthy eating and physical activity habits (Carels et al, 2011, 2014). The ‘Do Something Different’ intervention sought to expand the range of behavioural responses that recipients use in everyday settings, and so discourage rigid, habitual performance of

unwanted dietary and activity behaviours (Cleo et al, 2018). All three interventions demonstrated potential for promoting weight loss via habit change (Beeken et al, 2017; Carels et al, 2011, 2014; Cleo et al, 2018; Kliemann et al, 2017; Lally et al., 2011). All three sought to break old habits, but the strategies adopted to meet this aim, and the mechanisms targeted by such strategies, varied. One intervention, for example, sought to promote momentary mindfulness, to block enactment of unwanted habit impulses (Cleo et al, 2018), while another encouraged avoidance of environments known to trigger unwanted habits (Carels et al, 2011, 2014). These strategies demonstrate that there are multiple ways in which a habit may be ‘broken’.

In this paper, we highlight an important distinction, among the range of strategies available to ‘break’ habits, between those that seek to frustrate the expression of habit impulses in action, and those that target the underlying habit association that generates such impulses. We draw attention to the possibility that, even where habitual behaviour has been discontinued, underlying habit associations can remain, and retain the potential to elicit unwanted behaviour in future, thereby undermining weight maintenance over the longer term. We argue that unwanted habit associations are a crucial concept for understanding weight loss maintenance failure, but have been overlooked in the weight loss domain.

Breaking ‘bad’ habits

The notion that a habit may persist despite the cessation of a habitual behaviour may appear contradictory. Most dietary research uses the term ‘habit’ to denote an established eating pattern or repetitive behaviour (van t’Riet et al, 2011). If habit is a form of *behaviour*, then discontinuation of performance necessarily entails discontinuation of habit. Recent psychological definitions, however, portray habit as a cognitive construct based on learned context-action associations, whereby encountering the contextual cue generates an impulse to perform the associated action (Fleetwood, 2019; Gardner, 2015a). Unless inhibited by

RUNNING TITLE: Old habits and weight maintenance

stronger, competing impulses, the habit impulse guides behaviour rapidly, efficiently, and potentially without conscious awareness, intention or volitional control. ‘Habit’ thus represents a potential determinant of behaviour, and ‘habitual behaviour’ refers to action generated by habit (Gardner, 2015a).

INSERT FIGURE 1 HERE

Figure 1 depicts the stages by which habit generates behaviour: encountering a cue activates an association, which triggers a non-conscious impulse to act, which in turn translates into action. Habit may be disrupted, or ‘broken’, by intervening at one or more stages of this process, each of which forms of intervention involves different strategies (Gardner, Rebar, et al., 2020). *Habit inhibition* refers to the wilful obstruction of an activated habit impulse, to prevent its translation in action. An observational study found that vigilant monitoring – i.e., monitoring contexts and actions for signs of an imminent habitual response, and instructing oneself not to perform the habitual act when the cue is encountered – was deemed the most effective strategy by students seeking to inhibit unwanted habits, such as eating junk food (Quinn et al., 2010). Habit inhibition underpins impulse control interventions, which seek to promote regulation of habitual responses (e.g., van Beurden et al., 2019; Lawrence et al., 2015). *Habit discontinuation* refers to preventing the activation of habitual responses by modifying exposure to associated contexts (Walker et al., 2015). Habit discontinuation may occur naturally; context changes brought about by major life events, such as a residential relocation, lead to declines in performance of unwanted, previously habitual actions, and greater uptake of desired actions (Verplanken et al., 2018). Studies have shown that getting married, becoming pregnant, and retirement can disrupt long-standing dietary or physical activity patterns (Berger et al., 2005; Forman-Hoffman et al., 2008; Kremmer et al., 1998). Habit discontinuation may be purposeful: people often seek to avoid temptations by avoiding the settings that habitually prompt unhealthy eating urges (i.e.

‘stimulus control’; Schüz et al., 2015). A third form of habit disruption involves degrading the context-action association that underpins habitual behaviour. While it is not clear whether habit associations can be truly unlearned (Bouton, 2000), forming a new, competing association can effectively overwrite old associations (Wood & Neal, 2007). For example, people who habitually eat sugary snacks at 2pm might be encouraged to eat an apple at 2pm instead (Juszczuk & Gillison, 2018; Reale et al., 2018). As the new association strengthens, the new action (eating an apple) acquires dominance over the old (eating chocolate), such that encountering the cue habitually triggers the newer, wanted behaviour. This process of *habit substitution*, or ‘habit reversal’, entails both the inhibition of old habit responses, and the formation of new habits (Gardner, Rebar, et al., 2020; Gardner & Lally, 2018).

Although inhibition, discontinuation and substitution are all forms of habit disruption (Gardner, Rebar, et al., 2020), inhibition and discontinuation target only the manifestation of habit in action, not the underlying habit association; they disrupt *habitual behaviour*, but do not directly modify the *habit* that gives rise to such behaviour. This distinction is crucial, because changing habitual behaviour may not meaningfully modify underlying associations. Suppression of activated habit impulses (i.e., habit inhibition) requires willpower and self-control (Rebar et al., 2014), but when motivational or self-regulatory resources are depleted, the unwanted habitual response may re-emerge. A diary study showed that university students were more likely to succumb to unwanted, habitually generated impulses to eat unhealthy foods during exam season, when their willpower was weakened, than during non-exam weeks (Neal et al., 2013). Similarly, temporary removal from the contexts that support habitual behaviour (i.e., habit discontinuation) can disrupt habitual performance, but re-exposure to those contexts may reactivate old habits. A qualitative review of lifestyle obesity treatment interventions for adolescents found that transitioning from the clinical setting back

to the everyday, home environment represented a key barrier to weight loss maintenance (Jones et al., 2019).

Persistent habit associations may place people who have successfully lost weight at risk of lapsing into unwanted actions that undermine weight maintenance. This speaks to the importance of distinguishing the psychological profiles of people who have successfully discontinued unwanted habitual behaviours, to discern those who no longer experience any temptations, and those with persistent habits who may have to actively inhibit habit impulses supporting unhealthy behaviours (Gardner, 2015b). The latter group would be expected to be more likely to struggle to maintain their weight due to persistent temptations generated by residual habit associations. Indeed, some models of long-term cessation of unwanted behaviours, such as the Transtheoretical Model (Prochaska & DiClemente, 1983), distinguish between maintenance and termination, the latter characterised by the complete absence of unwanted urges.

Evidence of persistent unwanted habits in weight loss maintenance experiences

To our knowledge, there are few explicit studies of the continued influence of unwanted habit associations among participants who have successfully changed their behaviour in response to weight loss interventions. Such evidence can however be derived from the reflections of people attempting to maintain intentional weight loss (Orbell & Verplanken, 2015). We conducted a scoping review of experiences of weight loss maintenance, to explore whether participants' reflections suggested that they were experiencing impulses arising from old habit associations (see Supplementary File 1 for comprehensive detail of scoping review methods). We first ran a systematic search for reviews of qualitative studies of weight loss maintenance among adults from non-clinical populations. One review was found, which synthesised evidence from 26 qualitative studies (Greaves et al., 2017). We coded the full texts of these studies for evidence of persistent habit

associations antithetical to weight loss within direct quotations from study participants. Specifically, we looked for the presence or absence of unwanted habitual responses (e.g., environmentally cued, automatically triggered) and their continued influence (e.g., urge to perform in familiar contexts, potential for relapse in familiar settings, experience of conflict between old and new urges). Using summative content analysis procedures (Hsieh & Shannon, 2005), we calculated the aggregate frequency with which each indicator was found across the 26 studies.

We found evidence in two studies of contextual cues sustaining pre-existing responses (e.g., *“family and work environments with abundant, high-calorie food made it difficult ... to lose weight”*; Barnes et al, 2007, p918). In one study, a participant described acting contrary to their conscious preferences (*“I don’t understand myself, why I eat these unhealthy foods”*; Bertz et al, 2015, p640). In five studies (19%), participants described actual relapse, or the potential for relapse, to old patterns of behaviour in familiar contexts. Thirteen studies (50%) reported participants needing willpower or self-regulation to inhibit unwanted responses, and eleven studies (42%) reported actual or potential relapse arising from stressors or diminished willpower or self-regulation (*“this past year, I have gone through a lot of family stressors and have slid back on my eating and exercise behaviors”*; Benson-Davies et al, 2013, p63).

Together, these studies demonstrate that, despite successfully modifying their behaviour, people attempting to maintain weight loss achievements struggle to overcome persistent habit associations that conflict with weight management goals, and require conscious, effortful inhibition. This testifies to the importance of weight maintenance intervention developers targeting not only unwanted habitual behaviours, but the underlying habit associations that may prompt people to lapse back into such behaviours. Notably, inspection of the Discussion section of each reviewed study indicated that none offered any

RUNNING TITLE: Old habits and weight maintenance

explicit acknowledgement of the theoretical or practical implications of persistent habit associations for weight loss maintenance.

How to break 'bad' habit associations

While habitual behaviour can be discontinued by avoiding cues or obstructing enactment of unwanted habit responses, targeting habit associations requires the displacing of an old habit association with a new one (i.e., habit substitution; Gardner, Rebar, et al., 2020; Gardner & Lally, 2018; Wood & Neal, 2007). Any technique that promotes the cessation or reduction of unwanted behaviours, or engagement in wanted behaviour, has the potential to modify habit associations, at least indirectly (Gardner, Rebar et al., 2020). Nonetheless, some techniques are uniquely needed to target habit associations, rather than encouraging cessation of old behaviours or uptake of new behaviours more broadly.

The Behaviour Change Technique (BCT) Taxonomy v1 (BCTTv1; Michie et al., 2013) sets out a comprehensive list of techniques which can be used to change any behaviour. Of the 93 BCTs specified within the taxonomy, we propose that three core techniques represent the most proximal, core strategies required to modify habit associations: '*habit reversal*'², '*behavioural substitution*' and '*context-dependent repetition*'³ (see Table 1). Definitions of these techniques can be used to explain how they combine to promote habit substitution: 'rehearsing and repeating an alternative behaviour to replace an unwanted habitual behaviour' (i.e., habit reversal) requires 'substitution of the unwanted behaviour with an alternative behaviour' (behavioural substitution) and 'the rehearsal and repetition of a behaviour in the same context repeatedly' (context-dependent repetition; Michie et al., 2013,

² The BCT Taxonomy v1 definition of 'habit reversal' - 'prompt rehearsal and repetition of an alternative behaviour to replace an unwanted habitual behaviour' (Michie et al., 2013, pS10) – does not explicitly acknowledge that the 'alternative behaviour' must be performed in response to the cue that prompts the unwanted behaviour. As defined, the 'habit reversal' technique therefore appears insufficient to achieve direct displacement of one habit association with another.

³ This technique is termed 'habit formation' in the BCT Taxonomy v1. We prefer the term 'context-dependent repetition', as it separates out the method by which habit is formed (i.e. through repetition in a consistent context) from the outcome of using that method (i.e., the formation of habit).

RUNNING TITLE: Old habits and weight maintenance

pS10). We identified a further three, secondary BCTs as supporting habit substitution, by facilitating performance of the three core techniques. ‘*Use of prompts or cues*’, and ‘*action planning*’ promote the preparation and performance of specific behaviours in specific settings, which is needed to enable ‘context-dependent repetition’ and ‘behavioural substitution’. ‘*Conserving mental resources*’, by minimising demands on mental resources, frees cognitive capacity to allow effortful engagement in a wanted behaviour or inhibition of an unwanted behaviour, which is required for ‘habit reversal’ and ‘behavioural substitution’.

INSERT TABLE 1 HERE

Use of behaviour change techniques conducive to habit substitution in weight loss interventions

We ran a scoping review to identify the frequency with which these six habit substitution techniques have been used in weight loss interventions to date (see Supplementary File 2 for comprehensive detail of scoping review methods). We conducted a systematic search of ten electronic databases to identify reviews of the content of behavioural weight loss or weight loss maintenance interventions. Reviews had to have used the BCTTv1 to identify BCTs within weight loss or weight loss maintenance promotion interventions targeting individual-level behavioural change among non-clinical adult populations. Three eligible reviews were found, of which two focused on e-health interventions (Asbjørnsen et al., 2019; Holmes et al., 2019), and one on weight management interventions among young adults (Ashton et al., 2019). Together, the three reviews summarised 94 studies, evaluating of a total of 130 discrete interventions. Next, we coded the reviewers’ secondary descriptions of the BCT content of the 130 interventions where available, or coded primary intervention descriptions where reviewer descriptions were unavailable, to identify the presence versus absence of each of the six BCTs we deem essential for breaking habit associations (Michie et al., 2013). Given the interdependence of the three core BCTs, we adopted a triaged coding

RUNNING TITLE: Old habits and weight maintenance

procedure, whereby any intervention that did not report ‘habit reversal’ was not coded further. Where ‘habit reversal’ was identified, we also coded ‘behavioural substitution’, in accordance with BCTTv1 coding guidance (Michie et al., 2013), and sought to identify the presence or absence of ‘context-dependent repetition’, ‘use of prompts or cues’, ‘action planning’, and ‘conserving mental resources’.

INSERT TABLE 2 HERE

‘Habit reversal’ was identified in only five (4%) of the 130 interventions (see Table 2). Of the five, only one explicitly included context-dependent repetition. Of secondary BCTs, action planning featured in three interventions, use of prompts or cues in two interventions, and conserving mental resources in one. Only one intervention featured all six techniques. These findings imply that intervention developers have failed to recognise the potential for unwanted habit associations to undermine long-term weight maintenance.

How to choose a ‘good’ substitute for a ‘bad’ habit association

Although the six BCTs that we have detailed provide a set of tools for promoting substitution of one habit association for another, consideration is warranted of which behaviours make the most appropriate habit substitutes. Habit substitution requires the concurrent degrading of an old habit and formation of a new habit; the unwanted existing response to a habit cue must be inhibited so that the new, desired response may be enacted. Consistent repetition of the desired response on exposure to the cue will strengthen the new cue-response association such that it begins to compete with the unwanted association for action generation (Wood & Neal, 2007). The habit substitution process can be said to be complete when the new association acquires dominance over the old, and becomes the default response.

Promoting habit substitution involves identifying cues to existing habits, and supporting performance of behaviours that offer feasible substitutes for existing habitual

RUNNING TITLE: Old habits and weight maintenance

actions. Habitual actions may, by definition, be prompted outside of awareness (Wood & Runger, 2016). People may therefore lack awareness of cues to their unwanted actions, their responses to such cues, or the relationship between cues and their responses (Hollands et al., 2016; Nisbett & Wilson, 1977). For this reason, substitution attempts can be facilitated by an initial period of monitoring focal unwanted actions (self-monitoring) and the personally-relevant contexts in which these actions are elicited (cue-monitoring), to raise awareness of likely cues and responses to such cues. One study showed that participants who kept a seven-day snacking diary recording the specific snack consumed, and the time, location, prior activity, and presence of others at the point of consumption, subsequently reported less unhealthy snacking than did those who did not keep such a diary (Verhoeven et al, 2014).

Awareness of triggering cues is vital to ensure that old habits are supplanted by new habits, rather than merely supplementing existing unwanted habits with new healthy habits. Promoting habitual fruit consumption among habitual high-calorie snackers, for example, may result in the development of new fruit consumption habits (e.g., eating a banana with breakfast) but have no effect on habitual high-calorie snacking (e.g., eating sugary snacks in the afternoon), rather than achieving direct substitution of fruit for high-calorie snacks (e.g. eating a banana *instead of sugary snacks* in the afternoon).

When cues to unwanted habits have been identified, steps must be taken to promote adoption of an action conducive to weight management to displace the existing, unwanted action. Habit forms when people repeatedly perform actions that yield positive outcomes (de Wit & Dickinson, 2009). Although habitual actions by definition persist even when the positive outcomes that they originally yielded are discontinued or decline in value (Dickinson, 1985), habits and goals are often concordant, such that habits continue to serve valued goals and yield rewards (Wood & Neal, 2007). For example, for many people, afternoon consumption of sugary snacks may have become habitual because glucose aids

RUNNING TITLE: Old habits and weight maintenance

alertness during the ‘post-lunch dip’ (Kanarek & Swinney, 1990). While the snacking habit may persist even when no such ‘dip’ is experienced, the habitual action is nonetheless rooted in its instrumentality for maintaining alertness. Identifying the ‘best’ substitute for an unwanted habitual behaviour will therefore be aided by recognising the original goal served by the unwanted action, or the rewards that led the action to become habitual, and characteristics of the action that satisfy such goals or achieve rewards. Actions must therefore serve valued purposes, or otherwise hold similar or greater momentary appeal than the unwanted habit, to offer feasible substitutes for unwanted habits.

Two main types of substitute action can be crudely identified. First, the existing behaviour, or a variant thereof, might be performed in a manner more conducive to weight management. One participant in the habit-based ‘Ten Top Tips’ intervention trial, for example, reported successfully swapping chocolate for raisins when snacking in front of the TV, thus maintaining a snacking habit while enhancing its healthfulness (Lally et al., 2011). Second, people may be encouraged to perform different behaviours directed at the goal originally served by the habitual action, or likely to achieve similar rewards. High-calorie snacking that has become habitual as a means to manage the ‘post-lunch dip’ might, for example, be substituted for alternative actions that sustain alertness, such as drinking cold water, engaging in some form of physical activity, or otherwise taking a break from the focal task (Penn & Bootzin, 1990).

Substitution is however often hindered by a lack of parity in the attractiveness of alternatives. Sedentary behaviour, for example, is often more inherently appealing than physical activity, due to the perceived effort required to be active (Brand & Cheval, 2019). High-calorie foods often hold more immediate, hedonic appeal than do healthier alternatives (Rozin et al, 1991), making it difficult to encourage people to, for example, swap sugary snacks for raw vegetables (Juszczuk & Gillison, 2018). In one study, published after our

RUNNING TITLE: Old habits and weight maintenance

syntheses of previous research were undertaken, participants received an intervention promoting substitution of sugar-sweetened beverages with either a non-caloric sweetened alternative or water (Judah et al., 2020). Habitual consumption of sugar-sweetened beverages reduced to a lesser extent among those who reported less liking of the substituted alternative. Some potential behavioural substitutes may lack attractiveness because they preclude pursuit of valued goals originally served by the unwanted habit. For example, office workers who prioritise work task completion are unlikely to replace their workplace desk-based sitting habits with forms of physical activity that reduce perceived productivity (Hadgraft et al., 2016). Attention must therefore be paid to promoting alternatives of similar value to the unwanted action.

Substitution may be further facilitated by making unwanted habitual responses less accessible. One study showed that, when offered fruit and vegetables or high-calorie snacks as a reward for completing a computer task, participants chose high-calorie foods as the default, but switched to fruit and vegetables when obtaining the high-calorie reward became more effortful (Goldfield & Epstein, 2002). The likelihood of successful habit substitution will therefore be maximised by both selecting attractive alternatives and decreasing availability of the unwanted action.

Summary and recommendations

People who successfully lose weight in the short-term often regain it over the longer-term (Hartmann-Boyce et al., 2014; Jolly et al., 2011; Kramer et al., 1989; Parretti et al., 2016). We have drawn attention to an under-recognised tenet of habit theory, which suggests that it is possible to modify a habitual behaviour without disrupting the habit that generates such behaviour. Habit associations that remain in memory despite overt changes in behaviour may be a cause of weight loss maintenance failure. Specifically, although people who avoid cues to their unwanted habits, or mindfully stop themselves acting on unwanted habit

impulses, may change their behaviour and so lose weight, persistent underlying habit associations may reactivate actions antithetical to weight loss when people are re-exposed to old environments or during momentary lapses in willpower. Indeed, our synthesis of qualitative evidence of weight loss maintenance experiences highlighted that participants sometimes describe ongoing struggles against context-specific urges to engage in unwanted behaviours antithetical to weight loss. Weight loss interventions should target habit associations directly, by promoting the consistent performance of attractive alternative actions in response to cues to existing unwanted habits, thereby not only encouraging healthy behaviours but also effectively overwriting old habit associations. Yet, few of the 130 weight loss interventions we reviewed were found to have used behaviour change techniques we deem to be core for habit substitution (i.e, habit reversal, behavioural substitution, context-dependent repetition), or secondary techniques supportive of attempts to consistently enact new responses to habit cues (i.e., use of prompts or cues, action planning, conserving mental resources; but see Judah et al., 2020). Persistent unwanted habit associations appear to be an undervalued concept within the weight loss field.

Many behaviours obstructive to weight loss – for example, snacking, drinking sugar-sweetened beverages, and sitting (Adriaanse et al., 2010; de Bruijn & van den Putte, 2009; Howlett et al., 2020) – are performed habitually. We have argued that people may successfully lose weight not because they have broken the associations that underlie such actions, but rather despite having *not* broken these associations. Avoiding the cues that trigger habit impulses, or inhibiting such impulses via self-control, frustrate the expression of habit in behaviour, but do not directly disrupt habit associations (Quinn et al., 2010; Verplanken et al., 2018). This is not to say that long-term behaviour change necessarily depends on breaking habit associations. Permanent discontinuation of cue exposure negates habit associations; habitual popcorn consumption in cinemas will be perpetually discontinued

RUNNING TITLE: Old habits and weight maintenance

if the actor never returns to the cinema, for example. Habit associations with indefinitely discontinued contexts lack relevance and do not deserve attention. However, where discontinuity is not a viable long-term strategy – i.e., cues can only temporarily be avoided or are unavoidable – and inhibition relies on effortful self-regulation, people may lapse back into old context-specific habits if the associations underpinning such responses have not been tackled. In statistical terms, residual ‘old’ habits may moderate long-term effectiveness of weight loss interventions, such that people with stronger habit associations supporting behaviours opposed to weight loss may be less likely to sustain weight loss over time. Intervention designers should therefore assess the strength of unwanted habit associations as both an intervention outcome, and as a potential moderator of intervention impact. Assessments of the frequency with which people engage in unhealthy behaviours will necessarily obscure the ongoing struggles that many people face in shielding weight loss achievements from the interference of unwanted habits. Implicit measures are available that assess habit associations indirectly, via the accuracy or speed with which habitual options are chosen upon exposure to cues (see Rebar et al., 2018).

While we have focused on habit substitution, alternative methods may also overwrite habit associations. Dissociative learning procedures such as the Go/No-Go task, in which people learn associations between either responding or inhibiting responses and healthy or unhealthy food stimuli, have the potential to change dietary behaviour by creating implicit biases towards or against target foods (Aulbach et al., 2019). Such tasks may be adapted to disrupt habit associations by promoting inhibitory responses to cues associated with unwanted habit responses. To our knowledge however, there have been no direct assessments of the potential of such tasks to modify context-dependent habitual responses.

The possibility that old habits may persist despite changes to behaviour has been overlooked in the weight loss literature, despite evidence from qualitative studies showing

RUNNING TITLE: Old habits and weight maintenance

that people who have successfully lost weight struggle against unwanted context-specific impulses. Weight loss interventions might fruitfully incorporate techniques most suited to forming new habits in direct competition with old habits, and investigate the role of unwanted habit associations in determining effectiveness.

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RUNNING TITLE: Old habits and weight maintenance

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Author contributions

RUNNING TITLE: Old habits and weight maintenance

BG and RR conceived of the paper. BG, PL and AR designed the evidence syntheses. BG, RR and TT developed protocols for the evidence syntheses, and undertook data collection and preliminary analyses. BG, RR, PL, AR and RB contributed intellectual content to the manuscript. BG analysed data and drafted the manuscript, which was revised with input from all authors. All authors read and approved the final manuscript.

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Figure 1. Habit disruption targets and strategies, mapped to the psychological process underlying habitual behaviour

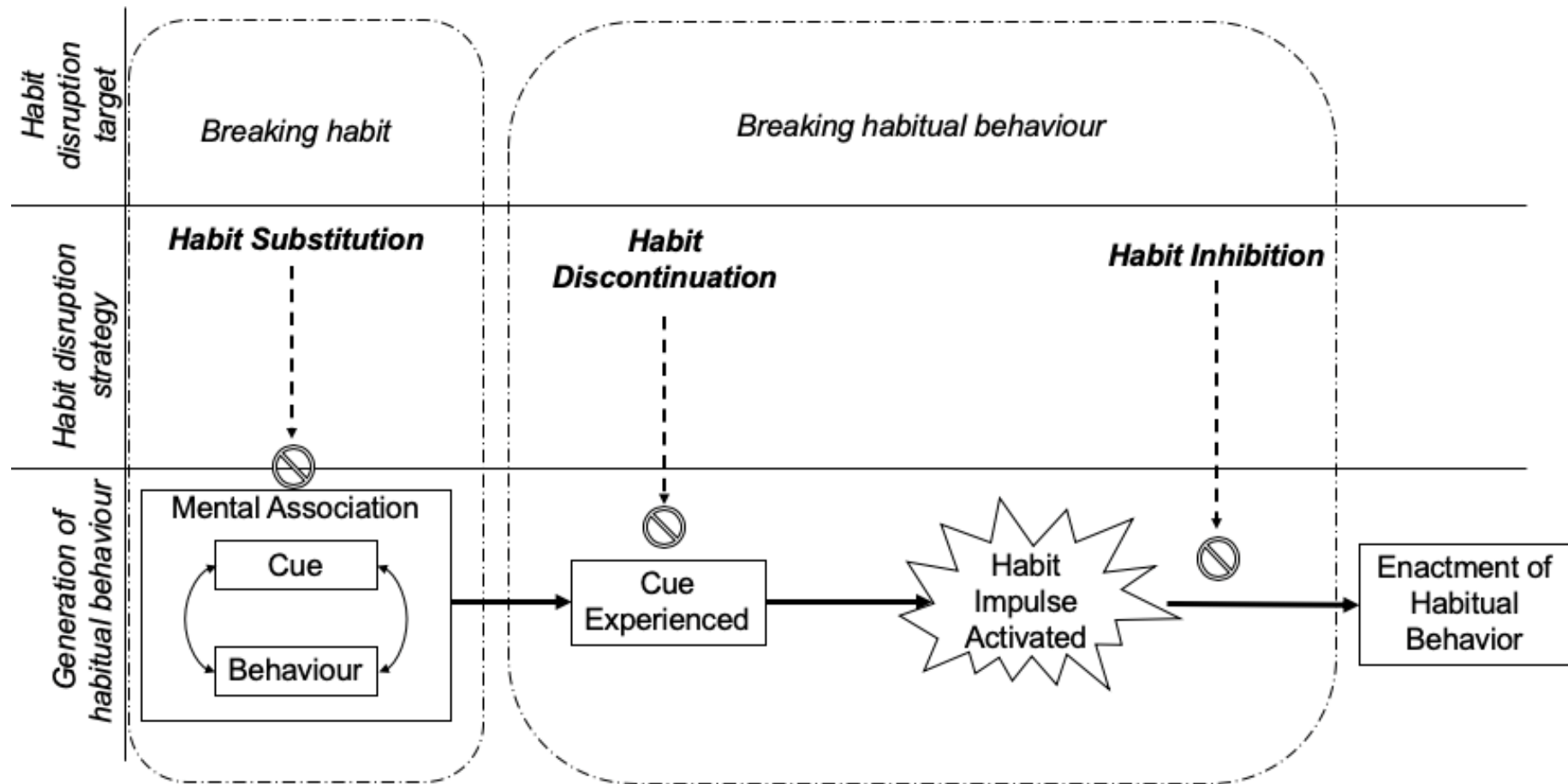


Table 1. Techniques that target the direct displacement of one habit association with another (i.e, ‘habit substitution’^a), coded according to the Behaviour Change Technique Taxonomy v1 (Michie et al., 2013)

<i>Technique</i>	<i>Description</i>
<i>Core techniques</i>	
Habit reversal	Prompt rehearsal and repetition of an alternative behaviour to replace an unwanted habitual behaviour.
Context-dependent repetition^b	Prompt rehearsal and repetition of the behaviour in the same context repeatedly so that the context elicits the behaviour.
Behavioural substitution	Prompt substitution of the unwanted behaviour with an alternative behaviour.
<i>Secondary techniques</i>	
Use of prompts or cues	Define an environmental or social stimulus that occurs at the time or place of performance of the unwanted behaviour, with the purpose of prompting or cueing an alternative behaviour in substitution for the unwanted behaviour.
Action planning	Prompt detailed planning of the alternative behaviour, to be performed in response to cues to the unwanted behaviour.
Conserving mental resources	Minimise demands on mental resources to allow for attention to be paid to performing the alternative behaviour, and inhibiting the unwanted behaviour, in response to cues to the unwanted behaviour.

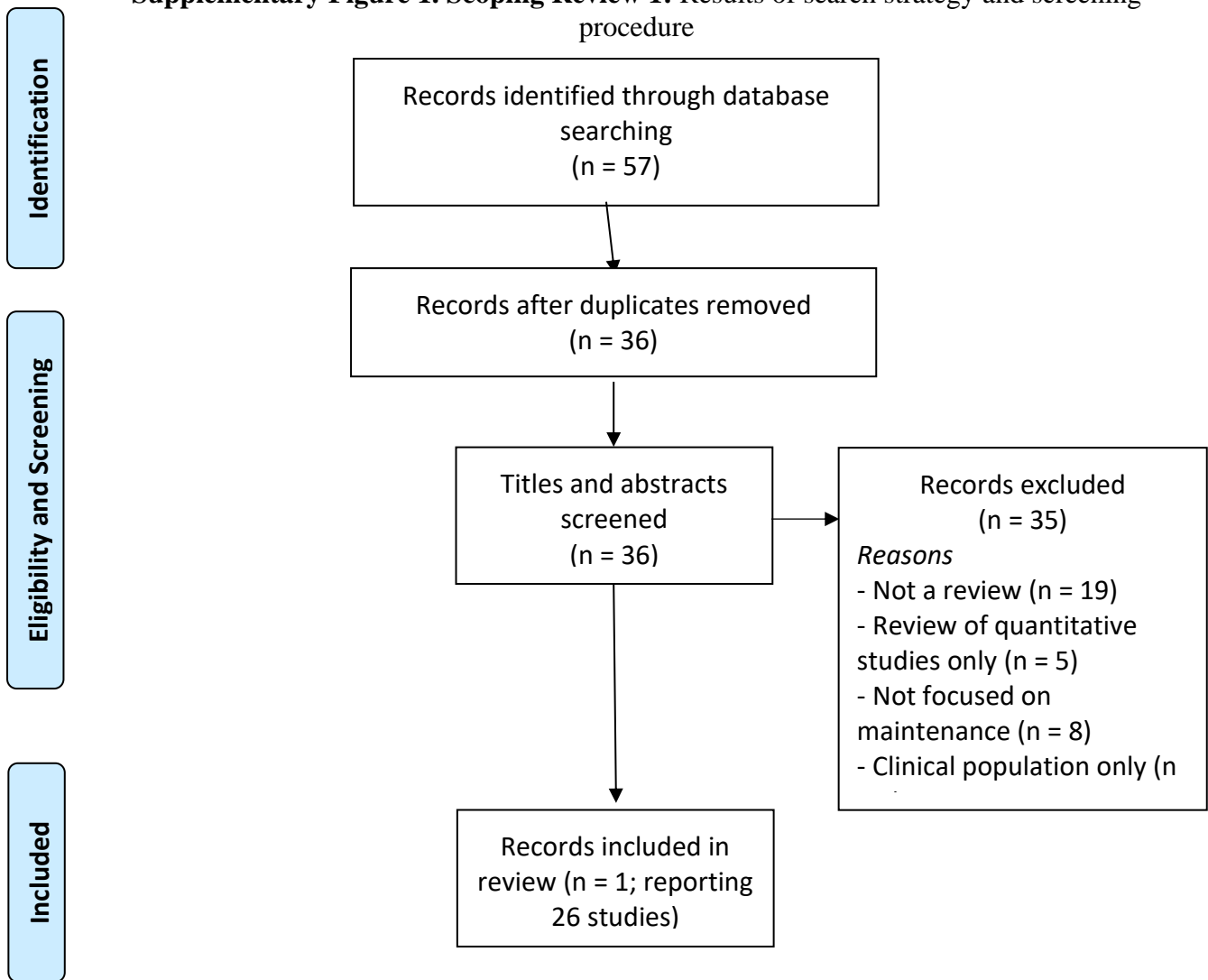
List adapted from Gardner, Rebar, et al. (2020). Technique descriptions from Michie et al., (2013).

^a Habit substitution requires (context-consistent) performance of a behaviour. All BCTs that focus on uptake of a new behaviour or cessation of an existing behaviour are potentially conducive to habit substitution, and an extensive list is not feasible here. ^b This technique is labelled ‘habit formation’ in the BCT Taxonomy v1. We prefer the term ‘context-dependent repetition’; see Footnote 1.

Table 2. Weight loss or weight loss maintenance behaviour change interventions targeting habit associations

<i>Reference</i>	<i>Brief intervention description</i>	<i>Core techniques</i>			<i>Secondary techniques</i>		
		<i>Habit reversal</i>	<i>Context-dependent repetition</i>	<i>Behavioural substitution</i>	<i>Use of prompts or cues</i>	<i>Action planning</i>	<i>Conserving mental resources</i>
Alnasser et al. (2019)	M-health application targeting physical activity and dietary consumption	Yes	No	Yes	No	Yes	No
Hebden et al. (2014)	M-health programme targeting physical activity, sedentary behaviour, and dietary consumption	Yes	No	Yes	Yes	Yes	No
Kerr et al. (2016)	M-health application providing dietary feedback, and diet tips via weekly SMS	Yes	No	Yes	No	No	No
Laska et al. (2016)	Academic course and social networking website targeting physical activity, dietary consumption, stress and sleep	Yes	No	Yes	No	No	No
Pagoto et al. (2018)	M-health application targeting physical activity and dietary consumption	Yes	Yes	Yes	Yes	Yes	Yes

Supplementary Figure 1. Scoping Review 1: Results of search strategy and screening procedure



Supplementary File 1: Evidence Synthesis Methods

Evidence Synthesis 1: Evidence of persistent unwanted habits in weight loss maintenance experiences

Aim

The aim of this synthesis was to explore whether, within qualitative studies of people attempting to maintain intentional weight loss, evidence could be found suggesting the influence of persistent ‘old’ habits. We adopted a two-stage procedure whereby we, first, sought reviews of qualitative studies of weight loss maintenance and, second, identified and extracted data from studies within those reviews.

Method

Search strategy and screening

Four electronic databases (EMBASE, PubMed, Medline, PsycInfo) were searched on 14th February 2020 to identify published reviews of qualitative studies of weight loss maintenance. Search terms were used to identify sources pertaining to weight loss, maintenance, qualitative data, and reviews, with date limits used where possible to identify sources published from 2010 onwards. Inclusion criteria specified (a) reviews (b) of qualitative evidence (c) focusing on experiences of weight loss maintenance after intentional weight loss (d) among adults (e) from non-clinical populations, and (f) published in peer-reviewed journals (g) in English (h) from 2010 onwards. No explicit operationalisation of ‘maintenance’ was adopted; all reviews of studies purporting to investigate maintenance were eligible. Reviews of studies of weight loss, but not maintenance in particular (e.g., Hartmann-Boyce et al., 2017), were excluded. Systematic searches and screening were conducted by one author (TT), with results at each stage verified via discussion with authors BG and AR.

Of 57 records found, 21 were duplicates. Of the remaining 36 records, title and abstract screening removed 35 papers, leaving one eligible review of 26 primary studies

RUNNING TITLE: Old habits and weight maintenance

(Greaves et al., 2017; see Supplementary File 1). The 26 studies reported data from one-to-one interviews (k = 17), focus groups or group interviews (k = 8), and e-mail (k = 1), from a total of 710 participants (78% female; 12 individual interviews).

Data extraction

Primary study data were extracted using a coding form to identify key indicators of an unwanted habit association for any behaviour incompatible with weight loss maintenance. These included: any explicit use of the term ‘habits’ in relation to pre-existing or previous behaviours (and if so, whether and how ‘habit’ was defined); three core characteristics of an ‘old’ habitual response (environmentally-cued; triggered automatically, defined as being initiated unintentionally, outside of conscious control, outside of awareness, or with cognitive efficiency [Bargh, 1994]; history of repetition); and five indicators of the influence of unwanted habits (urge to perform in familiar contexts; relapse, or potential relapse in familiar contexts; the need for willpower or self-regulation to inhibit an unwanted response; potential for relapse due to stressors, or diminished willpower or self-regulatory capability; experience of conflicting impulses to perform old and new behaviours in familiar contexts). The coding form was developed by BG and verified to capture features of unwanted habit influences by PL and AR, both experts in habit theory and application.

We coded for the presence versus absence of each characteristic within each study and extracted excerpts illustrative of each present characteristic. Data were extracted (by RR) from direct quotations from participants, within each of the 26 studies. Data were extracted only from Results or equivalent sections.

Analysis

Data were analysed using summative content analysis (Hsieh & Shannon, 2005). We calculated the aggregate frequency with which the presence or absence of each indicator was found across the 26 studies, and then interpretatively analysed data pertaining to each

RUNNING TITLE: Old habits and weight maintenance

indicator. To demonstrate the credibility of the analysis, direct excerpts from the participants in the reviewed studies are reported.

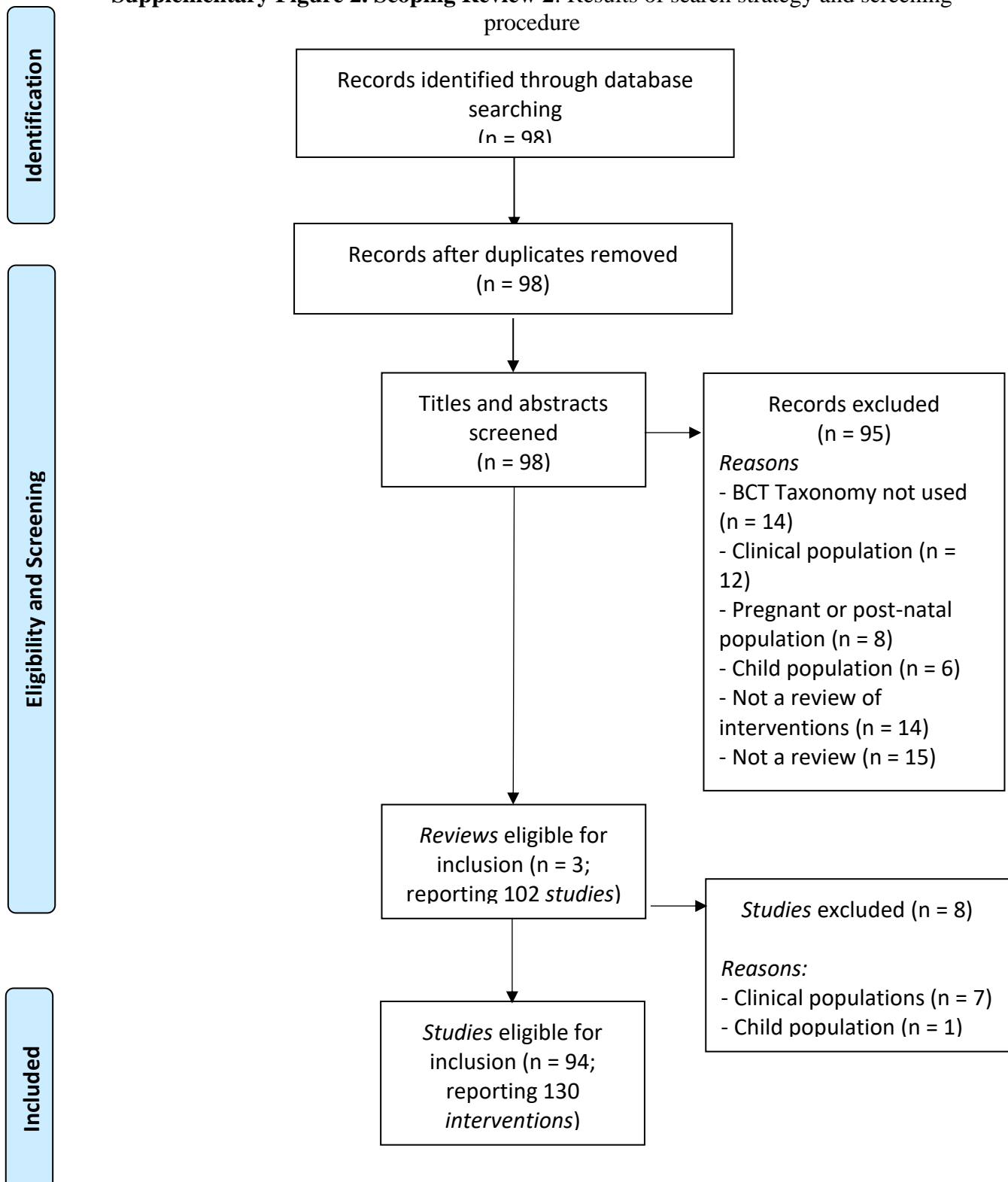
References (additional to those included in manuscript)

Bargh, J. A. (1994). The four horsemen of automaticity: Intention, awareness, efficiency, and control as separate issues. In R. S. Wyer & T. K. Srull, *Handbook of social cognition* (pp. 1–40). Psychology Press.

Hartmann-Boyce, J., Boylan, A.-M., Jebb, S. A., Fletcher, B., & Aveyard, P. (2017). Cognitive and behavioural strategies for self-directed weight loss: Systematic review of qualitative studies. *Obesity Reviews*, *18*(3), 335–349. <https://doi.org/10.1111/obr.12500>

RUNNING TITLE: Old habits and weight maintenance

Supplementary Figure 2. Scoping Review 2: Results of search strategy and screening procedure



Supplementary File 2: Scoping Review Methods

Scoping Review 2: Use of behaviour change techniques conducive to habit substitution in weight loss interventions

Aim

This scoping review was undertaken to explore the extent to which weight loss interventions have adopted strategies that target unwanted habit associations. A two-stage review procedure was followed. We first identified systematic reviews of the behaviour modification techniques used in weight management interventions, and second, extracted data relating to the content of interventions synthesised within those reviews.

Method

Search strategy and screening

The Web of Science Core Collection, comprising ten databases across a range of disciplines, was searched on 20th March 2020 using terms identifying reviews of the content of behavioural weight loss or weight loss maintenance interventions. Eligibility criteria required that sources were (a) reviews that had (b) used the BCT Taxonomy v1 to identify discrete behaviour change techniques, or clusters of techniques, within (c) weight loss or weight loss maintenance promotion interventions (d) targeting individual-level (e) behavioural change (f) among non-clinical populations of (g) adults, as (h) published (i) in English (j) in a peer-reviewed journal (k) from 2015 onwards. Reviews of interventions solely targeting pregnant or postnatal women were excluded. Reviews focusing solely on children or adolescents were excluded, but reviews that combined trials among adults and children were retained, and any interventions trialled among children were manually excluded. Our aim was to describe intervention content, so interventions that had not been trialled, as described within study protocols, were eligible. Reviews in which intervention content was coded using any other behaviour change technique taxonomy (Abraham &

RUNNING TITLE: Old habits and weight maintenance

Michie, 2008; Michie et al., 2011) were excluded, because the BCTTv1 offers the most fine-grained distinction between techniques that target habit associations and techniques that promote other forms of habit-based change (Gardner, Rebar, et al., 2020).

Of ninety-eight unique records found, 95 were removed via full-text screening, leaving three eligible reviews (Asbjørnsen et al., 2019; Ashton et al., 2019; Holmes et al., 2019), which covered 102 discrete primary intervention studies (see Supplementary File 2). Two reviews focused on e-health interventions (Asbjørnsen et al., 2019; Holmes et al., 2019), and one on weight management interventions among young adults (Ashton et al., 2019). At the study level, one intervention, included in Holmes et al.'s review, trialled among children was excluded. Additionally, on inspection, one review (Asbjørnsen et al., 2019), despite listing non-clinical populations as an exclusion criterion, included 7 studies of clinical populations, which we removed. The final dataset thus comprised 94 discrete studies, reporting a total of 130 discrete interventions. Search and screening procedures were run by TT, and verified via regular discussions with BG.

Data extraction and analysis

Data were extracted using a coding form to identify the presence versus absence of each of the six techniques we deemed necessary for habit substitution, as identified from the BCTTv1 (Michie et al., 2013). Given the interdependence of the three core BCTs (habit reversal, context-dependent repetition, behavioural substitution), we adopted a triaged coding procedure, whereby any intervention that did not report 'habit reversal' was not coded further. Where 'habit reversal' was identified, we also coded 'behavioural substitution' in accordance with BCTTv1 coding guidance (Michie et al., 2013), and sought to identify the presence or absence of 'context-dependent repetition', 'use of prompts or cues', 'action planning', and 'conserving mental resources'.

BCTs were extracted independently by two authors (TT, BG) from systematic reviewers' descriptions of BCTs within reviewed interventions where possible; otherwise, we directly coded primary descriptions of interventions. One review reported only the frequency with which discrete BCTs had been used across all studies (Ashton et al., 2019), so we contacted the review author, who sent us a list of BCTs identified within each reviewed intervention. One review reported only whether, within each intervention, one or more BCTs were present from each of the 16 BCT clusters within the BCTTv1 (Asbjørnsen et al., 2019). We directly coded only those interventions identified by reviewers as containing techniques from the 'repetition and substitution' cluster, which incorporates 'habit reversal'. Differences between coders were resolved through discussion. Inter-rater agreement was good (96.9% agreement, adjusted kappa 0.94). Data were descriptively analysed.

References (additional to those in main manuscript)

Abraham, C., & Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health Psychology, 27*(3), 379–387. <https://doi.org/10.1037/0278-6133.27.3.379>

Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. *Psychology & Health, 26*(11), 1479–1498. <https://doi.org/10.1080/08870446.2010.540664>