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# Does self-control modify the impact of interventions to change alcohol, tobacco, and food consumption? A systematic review

Kaidy Stautz<sup>a</sup>, Zorana Zupan<sup>a</sup>, Matt Field<sup>b</sup> and Theresa M. Marteau<sup>a</sup>

<sup>a</sup>Behaviour and Health Research Unit, University of Cambridge, Cambridge, UK; <sup>b</sup>Department of Psychological Sciences, University of Liverpool, Liverpool, UK

## ABSTRACT

Low self-control is associated with increased consumption of alcohol, tobacco, and unhealthy food. This systematic review aimed to assess whether individual differences in self-control modify the effectiveness of interventions to reduce consumption of these products, and hence their potential to reduce consumption amongst those whose consumption is generally greater. Searches of six databases were supplemented with snowball searches and forward citation tracking. Narrative synthesis summarised findings by: consumption behaviour (alcohol, tobacco, food); psychological processes targeted by the intervention (reflective, non-reflective, or both); and study design (experiment, cohort, or cross-sectional). Of 54 eligible studies, 22 reported no evidence of modification, 18 reported interventions to be less effective in those with low self-control, and 14 reported interventions to be more effective in those with low self-control. This pattern did not differ from chance. Whilst self-control often influenced intervention outcomes, there was no consistent pattern of effects, even when stratifying studies by consumption behaviour, intervention type, or study design. There was a notable absence of evidence regarding interventions that restructure physical or economic environments. In summary, a heterogeneous, low-quality evidence base suggests an inconsistent moderating effect of low self-control on the effectiveness of interventions to change consumption behaviours.

## ARTICLE HISTORY

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## KEYWORDS

Self-control; impulsivity; alcohol; smoking; diet; systematic review

Excessive alcohol use, smoking, and an unhealthy diet are key risk factors for numerous non-communicable diseases (World Health Organization, 2017). A vast number of interventions to reduce unhealthy consumption are available to policy-makers and practitioners (Jepson, Harris, Platt, & Tanahill, 2010; Michie, van Stralen, & West, 2011), yet a growing evidence base suggests that certain interventions show differential effectiveness according to participants' characteristics (McGill et al., 2015; Mizdrak, Scarborough, Waterlander, & Rayner, 2015). Self-control is one such characteristic that could be particularly useful in understanding differences in intervention outcomes.

Self-control is a trait individual difference reflecting the capacity to exert control over one's thoughts, actions, emotions, and impulses, and to prioritise distal motives over proximal motives (Fujita, 2011; Tangney, Baumeister, & Boone, 2004). It involves the ability to alter habitual or dominant responses and to replace these with non-dominant responses to achieve longer term goals, rewards,

**CONTACT** Kaidy Stautz  [ks704@medschl.cam.ac.uk](mailto:ks704@medschl.cam.ac.uk)

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or standards (Fujita, 2011; Inzlicht, Schmeichel, & Macrae, 2014). In other words, it is the capacity for voluntary self-governance (Duckworth & Kern, 2011).

Self-control is related to, and easily conflated with, many other psychological constructs. It reflects the top-down aspects of self-regulation, a term used to refer to broader processes of managing behaviour to set and pursue goals and maintain individual standards (Nigg, 2017). Self-control is the aspect of self-regulation used to resolve goal conflict, particularly when immediate gratification would jeopardise a longer term goal (Fujita, 2011). Self-control largely relies on executive functions (e.g., Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012), a set of higher order cognitive processes involved in goal-directed behaviour. The most relevant executive function component for self-control is response inhibition, defined as 'the deliberate overriding of dominant or prepotent responses' (Miyake & Friedman, 2012, p. 9; see also Bari & Robbins, 2013). Other processes related to executive functioning, such as attentional control and the capacity to value future events, are also involved in self-control, with deficits in these abilities manifesting as attention-deficit impulsiveness and delay discounting, respectively (Bickel et al., 2012).

Self-control is also related to a set of behavioural tendencies termed impulsivity in the individual differences literature, defined as the non-reflective selection of stimulus-evoked responses, or non-reflective preference for immediately rewarding responses (Nigg, 2017). Whilst self-control reflects more than just low levels of impulsivity, impulsive individuals are likely to find it difficult to exercise self-control (De Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012). Trait impulsivity is thought to result from at least three 'impulsigenic' processes, each related psychometrically to broader traits within the five-factor model of personality (McCrae & Costa, 1990): (1) impaired capacity to exert constraint over one's actions or to consider their negative consequences (reflected in measures assessing lack of premeditation and related to trait conscientiousness); (2) seeking short-term rewards, sensations, and/or novelty in preference to longer term rewards and without consideration of their potential cost or harm (reflected in sensation seeking, risk-taking, and reward sensitivity, and related to trait extraversion); and (3) responding rashly to emotions (reflected in measures of urgency, and related to trait neuroticism) (Dawe, Gullo, & Loxton, 2004; Sharma, Markon, & Clark, 2014; Whiteside & Lynam, 2001).

Given the multidimensional nature of self-control and its operationalisation across many research fields, it has been measured with a cornucopia of assessment tools. These measures can be broadly organised into four domains (Duckworth & Kern, 2011): self-reported questionnaires, other-reported questionnaires, executive function behavioural tasks, and delay of gratification tasks. Within these broad domains there is further fractionation, reflecting the range of subtraits and abilities that self-control is thought to encompass (Sharma et al., 2014). Duckworth and Kern (2011) used meta-analysis to assess correlations within and between broad measurement domains, finding that whilst self- and other-reported scales correlated strongly, associations between other domains were typically weak. Other investigators have reached similar conclusions (Cyders & Coskunpinar, 2011; Dick et al., 2010). This lack of convergence may reflect differences in what is being tapped by each type of measure. Whereas self- and other-reported scales assess long-term patterns of behaviour, executive function and delay of gratification tasks measure specific abilities or aspects of behaviour, which, whilst thought to reflect relatively stable individual differences, are also more susceptible to fluctuation in response to environmental or psychological factors (Jones, Christiansen, Nederkoorn, Houben, & Field, 2013). In the current review, we employ the grouping of self-control measures used by Duckworth and Kern (2011) so that readers can consider differences between measurement domains. Supplementary material S1 presents an overview of major domains and subdomains of self-control measurement, and a list of example measures.

Individual differences in self-control are reliably associated with health-harming consumption behaviours (De Ridder et al., 2012; Sharma et al., 2014; Stevenson, 2017; Vainik, Dagher, Dubé, & Fellows, 2013). Self-reported low self-control is associated with typical and problematic levels of alcohol use, increased body mass index, and a higher likelihood of initiating smoking (Coskunpinar, Dir, & Cyders, 2013; Jasinska et al., 2012; Kvaavik & Rise, 2012; Stautz & Cooper, 2013). Performance on

executive function tests of self-control is typically worse amongst individuals who are alcohol dependent, heavy drinkers, smokers, or obese (Fitzpatrick, Gilbert, & Serpell, 2013; Lavagnino, Arnone, Cao, Soares, & Selvaraj, 2016; Reinert, Po'e, & Barkin, 2013; Smith, Mattick, Jamadar, & Iredale, 2014). These differences are thought to result from two reciprocal processes: low self-control causing increased consumption of alcohol, tobacco, and unhealthy food; and consumption of these products having a detrimental impact on self-control (de Wit, 2009; Field & Jones, 2017; Jones et al., 2013; Volkow, Wang, Fowler, & Telang, 2008).

Two previous reviews concluded that heightened impulsivity (implying reduced self-control) is a risk factor for poorer treatment outcomes amongst alcohol and tobacco-dependent individuals and substance-dependent patients more broadly. Loree, Lundahl, and Ledgerwood (2015) concluded that impulsivity assessed before treatment is a 'key predictor of substance-use treatment outcomes'. Stevens et al. (2014), who limited their review to studies using behavioural measures, concluded that delay discounting and impulsive decision-making were associated with less successful treatment outcomes. Whilst valuable, these narrative reviews were limited in three ways. First, they focused only on main effects of impulsivity on treatment outcomes in a specific population subgroup – substance-dependent patients. It is, therefore, not known which interventions, if any, might be better options for individuals with low self-control in wider populations. Second, they combined evidence from different study designs (e.g., experimental and cohort studies). Effects in certain study designs, namely cohort studies, are at greater risk of confounding from unmeasured third variables. Effects of impulsivity found in such studies may not be related to any specific intervention, and could merely reflect that individuals with higher impulsivity are more likely to consume more in general. Third, these reviews did not formally assess the quality of included studies, meaning that conclusions could have been based on low-quality evidence. These limitations will be addressed in the current review.

There are many ways in which low self-control might moderate the effectiveness of behaviour change interventions. Individuals with low self-control may experience stronger urges or impulses to consume unhealthy products, have a weaker capacity to resist those impulses, and/or a reduced ability to act on the requirements of an intervention. A recent review of the relationship between self-control and well-being highlights subtler but perhaps more pervasive ways in which self-control could influence goal-directed behaviour. Moving beyond the idea that those with high self-control simply have greater resources for effortful inhibition of impulses, De Ridder and Gillebaart (2017) suggest that having high self-control is associated with a better ability to initiate goal pursuit and engage in goal-directed behaviour. In other words, those with high self-control are better able to set goals, act in ways that will help achieve these goals, and experience pleasure from doing so. Furthermore, those high in self-control seem better able to set adaptive routines in pursuit of long-term goals, such that behaviour is automated away from temptations or potential self-control conflicts.

These mechanisms clearly have implications for health behaviour change interventions. Indeed, of five overarching themes identified in theories of behaviour change maintenance (motives, self-regulation, resources, habit, and environment – Kwasnicka, Dombrowski, White, & Sniehotta, 2016), three pertain to self-control. Behaviour change maintenance is thought to be more likely in those who can monitor and *regulate* their behaviour, have the psychological *resources* to do so, and are able to form new *habits*. Individuals with low self-control tend to be less able to regulate aspects of their behaviour, have weaker resources such that their behaviour is more easily influenced by factors such as impulses, emotions, and the environment, and may find it difficult to change existing habits due to dependence on existing automatic response tendencies (Frieze & Hofmann, 2009; Hofmann, Frieze, & Strack, 2009; Strack & Deutsch, 2004). Nevertheless, interventions vary in how reliant they are on these processes to be effective. For example, an intervention that simply provides information about healthy food still requires all of these processes to elicit a long-term change in diet. In contrast, an intervention that restructures the environment to remove unhealthy cues, such as banning smoking in public places, is less likely to depend on these processes to be effective.

To summarise, there is a clear cross-sectional link between low self-control and increased consumption of alcohol, tobacco, and unhealthier food. Furthermore, self-control may influence treatment outcomes in substance-dependent individuals. However, less is known about whether self-control moderates the effectiveness of interventions to reduce consumption of health-harming products, in wider populations. Low self-control likely impacts upon the capacity to maintain sustained behaviour change in response to interventions, particularly if intervention effectiveness depends on processes such as self-monitoring and restraint, which are likely to be more difficult for those with low self-control.

## The present study

This systematic review extends previous reviews of the impact of impulsivity on substance-use treatment outcomes by assessing whether the broader construct of self-control moderates the effectiveness of interventions to reduce alcohol consumption, smoking, and healthier food consumption, in any population. The review includes four domains of self-control measurement. Furthermore, whilst previous reviews did not distinguish evidence obtained from different research methodologies, the current review separates findings from experimental studies with and without control groups, cohort studies, and cross-sectional studies.

*Review question.* Does self-control moderate the effect of interventions designed to reduce consumption of alcohol, tobacco, and unhealthier food?

## Method

This systematic review is reported in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). The review protocol was prospectively registered in the PROSPERO database (ID: CRD42016036115).

## Eligibility criteria

Studies eligible for inclusion were empirical studies of any design that reported: (i) an intervention or policy designed to reduce consumption of alcohol, tobacco, or unhealthy food, or promote consumption of healthy food; (ii) an alcohol, tobacco, or diet/weight-related outcome, and (iii) analysis of a measure of self-control as a potential moderator of intervention effectiveness. Eligible participants were humans of any age. In experimental studies, eligible comparators were control groups not exposed to any intervention or groups exposed to alternative interventions. Eligible self-control measures were informed by a previous review of self-control assessment (Duckworth & Kern, 2011) as well as reviews of impulsivity assessment (Dick et al., 2010; Sharma et al., 2014). Any measure purported to assess self-control or related constructs such as impulsivity, inhibitory control, executive control, and delay discounting was deemed eligible. For experimental and cohort studies, only those that assessed self-control before implementation of the intervention were eligible. We excluded studies where the measure of self-control included cues specific to the outcomes of interest, such as a Go-no/go task that included images of snack foods (e.g., Brockmeyer et al., 2016). These tasks are better viewed as assessing the influence of motivationally salient cues on self-control, rather than self-control capacity *per se*.

## Eligible outcomes

**Alcohol.** Self-reported typical quantity or frequency of alcoholic beverage consumption; frequency of heavy episodic drinking episodes (binge drinking); intensity of hazardous or harmful alcohol consumption, such as number of dependence symptoms or number of negative consequences experienced from alcohol; objectively measured alcohol consumption, such as amount (e.g., in millilitres or containers) of alcoholic beverages consumed; initiation/onset of alcohol use, heavy

drinking, or problematic use (binary variables); maintenance of abstinence from alcohol, measured either as a binary variable or as number of days to relapse; and selection or purchasing of alcohol products.

**Tobacco.** Quantity or frequency of consumption of tobacco products; self-reported current smoking status (i.e., smoker versus non-smoker); objectively measured smoking intensity (e.g., number of puffs of a cigarette); initiation/onset of smoking (binary); smoking cessation, or maintenance of abstinence from smoking/tobacco products (binary, compared to relapse); biological measures of tobacco consumption (e.g., carbon monoxide breath test, cotinine saliva test; typically used to generate a binary variable indicating smoking status); and selection or purchasing of tobacco products.

**Food.** Self-reported quantity or frequency of healthy (e.g., fruit and vegetables) or unhealthy (e.g., energy dense snacks) food consumption; observed intake of food, nutrients, or energy, for example, grams of food consumed in a laboratory-based taste test; change in weight over time; maintenance of weight loss/diet (binary); and selection or purchasing of food products.

### **Search strategy**

Six electronic databases were searched: PsycINFO, PubMed, EMBASE, ASSIA, Web of Science, and Scopus. There were no restrictions on language or publication date. The search comprised four domains of keywords/terms reflecting: (i) self-control, (ii) consumption, (iii) intervention, and (iv) effect modification. Supplementary material S2 presents the search terms used.

Database searches were completed up to April 2017. Title-abstract records retrieved by the searches were imported into Endnote X4 reference management software. Duplicate records were identified using the automatic de-duplication feature and by manual checking. Two researchers (KS and ZZ) independently screened title-abstract records for eligibility. Screening discrepancies were resolved by discussion. Full-texts of provisionally eligible records were retrieved via electronic library resources, screened independently by two researchers (KS and ZZ), and coded as eligible or excluded with reasons recorded. Original searches were supplemented with snowball searches and forward citation tracking (using Google Scholar) of eligible articles, reference list searches of relevant review articles, and requests for unpublished data.

### **Data extraction**

One researcher (KS) extracted data on study characteristics. Two researchers (KS and ZZ) extracted outcome data in duplicate. A data extraction form was trialled on five studies before extraction of remaining studies. Discrepancies in extracted outcome data were resolved by discussion. The following study information was extracted: authors, publication status, country, setting, design, eligibility criteria, sample characteristics (age, gender, socioeconomic position, attrition, recruitment method), details of intervention, details of comparator, details of outcome variables (description, pre- and post-intervention means, intervention main effect), details of self-control measure, method of analysis, details of effect modification, and data required for quality assessment. In studies that assessed outcome measures at multiple time points, we extracted data relating to the longest follow-up.

### **Quality assessment**

The Quality Assessment Tool for Quantitative Studies (Effective Public Health Practice Project, 1998) was used to provide a methodological rating for each eligible study on the following categories: selection bias, study design, confounders, blinding, data collection methods, withdrawals and drop-outs, intervention integrity, and analysis. Two researchers (KS and ZZ) carried out independent assessments of each included study. Ratings were compared with differences resolved through discussion.

## Synthesis of results

Heterogeneity in study designs, populations studied, types of interventions, comparisons made, and measures used precluded quantitative synthesis through meta-analysis. Results of the quality assessment also suggested a high likelihood of bias in many included studies, most commonly due to non-representative sampling and the use of study designs that did not account for unmeasured confounding variables. Meta-analyses of diverse studies at risk of bias can produce misleading results that do not accurately represent differences between studies (Higgins & Green, 2011). We, therefore, present results in a narrative synthesis, with studies grouped according to target consumption behaviour, the psychological processes targeted by the intervention (see below), and study design.

Heterogeneity across studies also precluded tests of publication bias, which are typically used in quantitative synthesis and are conducted on a set of comparable effect sizes. As an alternative, we utilised the fact that many studies conducted tests of modification with multiple measures of self-control, and assessed whether the percentage of modification effects reported at the study level differed from the percentage reported at the individual test level (i.e., total number of contrasts). If the percentage of significant effects reported at the study level was an accurate marker of true effects, we would expect these two values to be similar. However, a higher percentage of study-level significant effects compared to test-level significant effects may be evidence of bias, in that studies reporting any significant moderating effect may be more likely to be published.

Interventions were categorised into two groups, representing the psychological processes targeted by the intervention. We based our groups on distinctions set out by authors guided by dual-systems theory (Frieze, Hofmann, & Wiers, 2011; Hollands, Marteau, & Fletcher, 2016; Strack & Deutsch, 2004), who distinguish interventions that largely target reflective (or conscious) processes from those that largely target non-reflective (non-conscious or impulsive) processes. These distinctions are pertinent to the current review, as we would expect individual differences in existing self-control to influence responses to these categories of intervention in different ways.

Interventions that target reflective processes are those that provide information only, or that depend on planning, self-monitoring, behavioural restraint, or identifying situations where unhealthy products are desired. We would expect these types of intervention to be more beneficial for those with higher self-control, as they depend on existing skills in self-regulation and sufficient psychological resources to consistently monitor one's behaviour (Kwasnicka et al., 2016). They are also dependent on a high degree of individual agency, meaning that individuals must rely on their personal resources to benefit (Adams, Mytton, White, & Monsivais, 2016).

Interventions that target non-reflective processes are those that aim to reduce impulsive responses to unhealthy cues through pharmacological (e.g., nicotine replacement) or psychological (e.g., cognitive bias modification) means, or attempt to make unhealthy products less prevalent, prominent, or desirable (e.g., making unhealthy products less available or more expensive). These interventions should be more, or at least equally, beneficial for those with lower self-control (Marteau, Hollands, & Fletcher, 2012), as they do not depend on self-regulation or psychological resources, or any existing ability to set new habits. They also require low or no individual agency to be effective.

Using this framework, three researchers (KS, ZZ, and TMM) categorised 21 archetypal interventions through discussion. The remaining interventions were classified by two researchers (KS and ZZ), who reached 93% agreement. There was disagreement regarding four studies involving incentive schemes for remaining abstinent from smoking. Based on recent discussion of this intervention type in relation to reflective and non-reflective processes (Regier & Redish, 2015), these were eventually categorised as targeting reflective processes. Table 1 displays how interventions were categorised and provides further rationale for specific interventions. Six eligible studies investigated interventions that targeted both reflective and non-reflective processes through a combination of psychotherapy and pharmacotherapy. These are presented separately in our narrative synthesis.

Evidence from four types of study design was considered separately to reflect differences in the evidence that each can offer regarding effect modification (Corraini, Olsen, Pedersen, Dekkers, &



**Table 1.** Included interventions, categorisation by target psychological processes, and rationale.

Target	Behaviour change principles	Interventions	Rationale
Reflective (conscious) processes	Provide information	<ul style="list-style-type: none"> <li>– Menus labelling food/drink as high or low calorie</li> <li>– Posters with nutritional information</li> <li>– Information about symptoms of smoking abstinence</li> <li>– E-learning modules about alcohol and tobacco use</li> </ul>	Dependent on aligning information with personal goals/standards
	Goal-setting and/or self-monitoring	<ul style="list-style-type: none"> <li>– Instruction to ‘Eat as little as possible’</li> <li>– Implementation intentions to change diet</li> <li>– Interactive Voice Response self-monitoring</li> <li>– Brief motivational interview</li> </ul>	Require restraint and self-regulation
	Identify internal/external behavioural cues	<ul style="list-style-type: none"> <li>– Psychotherapy</li> <li>– Counselling</li> <li>– Cognitive behavioural therapy</li> <li>– Acceptance-based behavioural therapy</li> </ul>	Require reflection on past behaviour
	Train new skills and behaviours	<ul style="list-style-type: none"> <li>– Personality-specific skills training</li> <li>– Residential treatment with diet and exercise encouragement</li> </ul>	Require reflection on past behaviour and learning new habits to align behaviour with goals
	Incentivise healthy behaviour	<ul style="list-style-type: none"> <li>– Vouchers provided after remaining abstinent from smoking</li> </ul>	Require restraint to earn reward
Non-reflective (non-conscious) processes	Reduce craving for unhealthy products	<ul style="list-style-type: none"> <li>– Pharmacotherapy (e.g., nicotine replacement)</li> </ul>	Should reduce physiological desire for product
	Reduce impulsive/associative responses to unhealthy cues	<ul style="list-style-type: none"> <li>– Implicit association training</li> <li>– Approach/avoidance training</li> <li>– Evaluative conditioning</li> </ul>	Changes automatic affective associations such that unhealthy products become less desirable
	Strengthen self-control	<ul style="list-style-type: none"> <li>– Training inhibitory responses to unhealthy products</li> <li>– Immediate monetary reinforcement for not smoking</li> </ul>	Develops or conditions ability to automatically resist unhealthy cues
	Restructure physical or economic environment to reduce influence of unhealthy cues	<ul style="list-style-type: none"> <li>– Workplace smoking ban</li> <li>– Taxes on unhealthy products</li> <li>– Change proximity of snack food placement</li> <li>– Exposure to healthy food advertising</li> </ul>	Remove options for unhealthy behaviour or make healthy options more prominent

Vandenbrouke, 2017). Experimental studies with a control group (including randomised controlled trials) offer the strongest level of evidence, indicating whether self-control influences effectiveness *only* in an intervention group and not in a control group. Experimental studies comparing different interventions but without a control group can indicate whether self-control influences responses to one intervention compared to another (i.e., an interaction). In cohort studies where intervention success or failure is measured (e.g., maintained abstinence versus relapse), it can be ascertained whether those with lower self-control have a higher or lower likelihood of achieving intervention success, but it is not possible to attribute this to an interaction between self-control and the intervention. Finally, cross-sectional studies offer the weakest level of evidence as they provide limited insight into the direction of any observed associations. However, they can provide preliminary evidence on possible interactions between self-control and the degree of intervention exposure (e.g., amount of health information received) on an outcome.



Chi-squared tests were used to assess whether the pattern of modification findings found in included studies differed to what would be expected by chance, differed by target behaviour, or differed by intervention type. An alpha level of .05 was used for significance testing. Studies were weighted by their quality rating such that weak = 1, moderate = 1.5, and strong = 2. *Post hoc* power calculations indicated that these tests were substantially underpowered (average power around 20%).

## Results

### Results of search

We identified 4571 unique records for title-abstract screening. Full-text screening of 246 articles judged potentially eligible resulted in 52 articles being retained. Two of these articles contained multiple eligible studies. Two articles pertained to the same study and were linked. In total, 54 studies were eligible for the review. Supplementary material S3 illustrates the flow of studies through the systematic review process, whilst S4 lists the included studies.

### Study characteristics

Fifty-one of the 54 included studies had been published in peer-reviewed journals, whilst two were from dissertations and one was unpublished. Year of publication of published studies ranged from 1997 to 2017. Seventeen studies assessed alcohol, 19 assessed tobacco, and 19 assessed food (one study assessed both alcohol and tobacco). There were 31 experimental studies (17 with a control group and 14 without), 21 cohort studies, and 2 cross-sectional studies. The majority of studies were conducted in the USA (19 studies), the Netherlands (7 studies), Germany, and the UK (4 studies each). The mean sample size was 435, though this dropped to 151 if excluding five studies with samples over 1000. A total of 36 measures of self-control were used (21 self-reported questionnaires, 2 other-reported questionnaires, 11 executive function tasks, and 2 delay of gratification measures). Detailed study characteristics are presented in supplementary tables S5–S7.

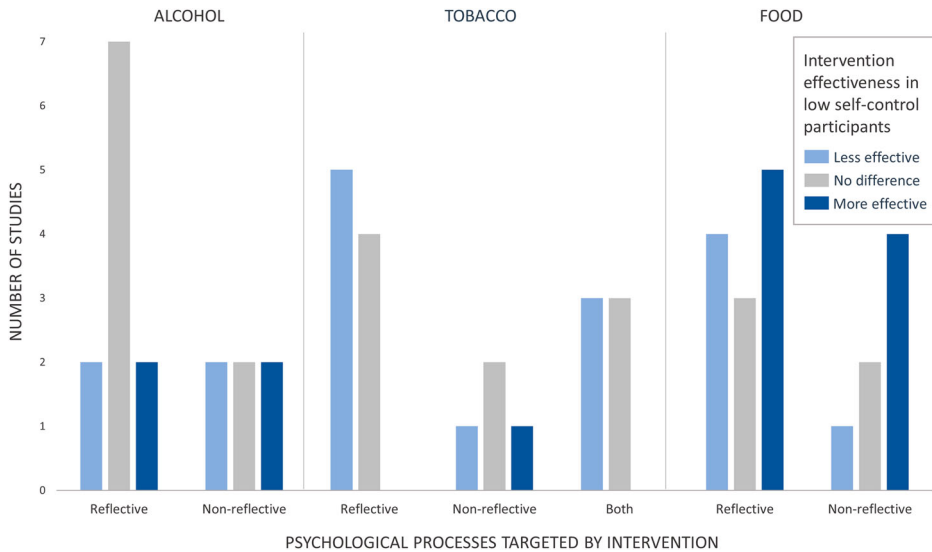
### Quality assessment

Overall quality ratings for each study are reported in supplementary tables S5–S7. A full list of decisions for each aspect of the quality assessment is provided in supplementary table S8. Study quality was rated as weak in 29 studies, moderate in 23 studies, and strong in 1 study. One study could not be assessed for quality as only an abstract was available.

### Modification effects

Of 54 studies, 32 (59.3%) reported modification of intervention effects by at least one measure of self-control. In 18 of these studies, interventions were less effective in those with low self-control, whilst in 14 studies interventions were more effective in those with low self-control. [Figure 1](#) shows the number of studies reporting interventions to be less, more, or no different in effectiveness amongst those with low compared to high self-control.

A one sample chi-squared test, with three cells representing (i) no modification, (ii) intervention less effective in low self-control participants, and (iii) intervention more effective in low self-control participants, indicated that the study-level pattern of modification findings was not significantly different than what would be expected by chance,  $\chi^2(2) = 1.78$ ,  $p = .41$ . A chi-squared independence test with cells representing three levels of modification result and the three consumption behaviours, indicated no significant difference in the pattern of modification findings between consumption behaviours,  $\chi^2(4) = 9.59$ ,  $p = .05$ . A further test with cells representing three levels of modification



**Figure 1.** Number of studies finding interventions to be more effective, less effective, or no different in effectiveness in those with low self-control compared to those with high self-control (sum of studies is 55 due to one study [Malmberg et al., 2015] assessing two consumption behaviours).

result, as above, and the two types of intervention (i.e., targeting reflective or non-reflective processes) indicated no significant difference by intervention type,  $\chi^2(2) = 2.47$ ,  $p = .29$ .

Twenty-one studies tested more than one measure of self-control as an effect modifier. Ninety possible modification effects were tested in total, 42 (46.7%) of which showed a modification effect. This proportion is lower than that found at the study level (32 of 54 studies – 59.3%), perhaps indicating that the study-level pattern of modification effects is inflated compared to true effects. For 28 of these 42 effects, interventions were less effective in those with low self-control, whilst in 14 interventions were more effective. Testing whether this pattern differed from chance was not possible due to non-independence of observations.

### *Modification by self-control measurement domain*

Supplementary material S9 shows the results of modification tests for each measure of self-control. The majority of tests were conducted with self-reported questionnaires (51 tests) or executive function tasks (25 tests). For self-reported questionnaires, 26 tests found no modification, 17 found interventions to be less effective in low scorers, and 8 found interventions to be more effective in low scorers. For executive function tasks, 15 tests found no modification, 4 found interventions to be less effective in low scorers, and 6 found interventions to be more effective in low scorers. A chi-squared test comparing the percentage of tests finding no modification across the two domains showed no significant difference,  $\chi^2(1) = 0.54$ ,  $p = .46$ . Notably, performance on two commonly used executive function tasks, the Stroop and go/no-go tasks, did not modify intervention effectiveness in any of eight separate tests. In contrast, performance on the stop signal task modified intervention effectiveness in five of six tests, all of which showed greater intervention effectiveness in poorer scorers.

### *Narrative synthesis*

#### *Alcohol*

The seventeen studies examining alcohol-use sampled patients with an alcohol-use disorder ( $n = 11$ ), heavy drinkers ( $n = 1$ ), adolescents ( $n = 3$ ), and young adults ( $n = 2$ ). Ten experimental studies (eight

with a control group and two without), six cohort studies, and one cross-sectional study were included. Ten studies were rated weak in quality, five as moderate, and one as strong. One study could not be assessed for quality as only an abstract was available.

### *Interventions targeting reflective (conscious) processes*

**Experimental studies with control group.** Lammers et al. (2017) investigated whether individual differences in impulsivity and sensation seeking moderated the (overall null) impact of personality trait-specific coping skills training in a large sample of Dutch adolescents, selected for the intervention for being high in these traits. High sensation-seeking participants in the intervention condition showed a blunted increase in binge drinking over the course of a year, compared to those in the control condition. No such effects were found for impulsivity. This was the only included study to be rated strong in quality. Malmberg et al. (2015) investigated whether impulsivity or sensation seeking moderated the null effect of either a self-directed learning intervention or this intervention combined with a parental participation, monitoring, and counselling intervention in a sample of Dutch adolescents. No moderating effects were found. Tucker, Roth, Huang, Scott Crawford, and Simpson (2012) found no moderating effect of delay discounting on an interactive voice response intervention in patients with alcohol-use disorder.

**Experimental studies without control group.** Capone and Wood (2009) investigated whether sensation seeking moderated the effect of a brief motivational interview and/or an alcohol expectancy challenge intervention, both of which were found to be effective overall, on alcohol consumption and problems in a heavy drinking student sample. No moderation was found. Koning, Verdurmen, Engels, van den Eijnden, and Vollebergh (2012) investigated whether scores on the Self-Control Scale moderated the effect of adolescent skills training, parent skills training or a combined intervention on the onset of weekly drinking and heavy weekly drinking in a sample of Dutch adolescents. The combined intervention was effective in delaying the onset of weekly drinking in adolescents with low self-control. No such effect was found for the onset of heavy weekly drinking. No effects were found for the other intervention conditions.

**Cohort studies.** Of six studies that compared alcohol-dependent participants who abstained or relapsed following psychotherapy (Charney, Zikos, & Gill, 2010; Czapla et al., 2016; Manning, Teo, Guo, Wong, & Li, 2016; Müller, Weijers, Boning, & Wiesbeck, 2008; Pitel et al., 2009; Sellman, Mulder, Sullivan, & Joyce, 1997), two found baseline differences in self-control. Charney et al. (2010) found that those with higher impulsivity at baseline were more likely to relapse. Müller et al. (2008) found that participants who relapsed following six weeks of motivational counselling sessions reported higher levels of baseline impulsivity and novelty seeking, though not sensation seeking.

### *Interventions targeting non-reflective (non-conscious) processes*

**Experimental studies with control group.** Two studies investigated whether self-control moderated cognitive bias modification training to reduce approach and increase avoidance to alcohol-related cues in patients with an alcohol-use disorder. Whilst Staiger et al. (2017) found that participants scoring higher on the Eysenck I7 measure of impulsivity were more likely to reduce their alcohol consumption following training, Eberl et al. (2013) found that Stroop task performance did not impact upon effectiveness.

Three studies investigated pharmacological interventions, using medication thought to strengthen self-control. Bold et al. (2017) found that urgency scores from the Urgency, Premeditation, Perseverance, Sensation Seeking, and Positive Urgency (UPPS-P) Impulsive Behaviour Scale did not moderate the effectiveness of naltrexone on reduced drinking in a sample of young adults. Joos et al. (2013) found that modafinil had a protective effect on increased abstinence and reduced heavy drinking only amongst participants with poor response inhibition, assessed with the stop signal task. In those with strong inhibition, the drug showed a detrimental effect. Impulsivity and

delay discounting did not modify the effectiveness of modafinil. Meszaros et al. (1999) compared novelty seeking scores of participants who relapsed with those who remained abstinent following treatment with fluvoxamine, in a sample of patients with an alcohol-use disorder. Baseline novelty seeking was higher in males who relapsed, but not in females.

**Cross-sectional studies.** A study of 5701 young adult males in Switzerland found that negative associations between alcohol policy strength in the local region and individual levels of binge drinking and alcohol-use disorder were present only amongst those that reported low sensation seeking, and not in those that reported high sensation seeking (Foster, Held, Estévez, Gmel, & Mohler-Kuo, 2015).

## Summary

Overall, 8 of 17 studies reported evidence of effect modification, with 4 finding interventions to be less effective in those with low self-control and 4 finding them to be more effective. The evidence base is mostly weak in quality and most studies sampled individuals with an alcohol-use disorder. Of 11 studies investigating interventions targeting reflective processes, 2 reported less effectiveness amongst low self-control participants, 2 reported greater effectiveness, and 7 reported no differences. Of six studies assessing interventions targeting non-reflective processes, two reported less effectiveness amongst low self-control participants, two reported greater effectiveness, and two reported no differences.

## Tobacco

The 19 studies examining smoking as an outcome sampled adult smokers ( $n = 11$ ), adults from the general population ( $n = 1$ ), adolescent smokers ( $n = 3$ ), adolescents from the general population ( $n = 1$ ), pregnant adult smokers ( $n = 1$ ), adults with schizophrenia ( $n = 1$ ), and heavy drinkers who also smoked ( $n = 1$ ). Eight experimental studies (6 with a control group and 2 without) and 11 cohort studies were included. Eight studies were rated weak in quality, 11 as moderate, and 0 as strong.

## Interventions targeting reflective (conscious) processes

### Experimental studies with control group

Cui, Tang, Lam, Cinciripini, and Robinson (2016) reported no baseline differences in novelty seeking between participants who were abstinent or non-abstinent participants following brief psychotherapy. Conversely, Helstrom, Hutchison, and Bryan (2007) found that sensation seeking moderated the effectiveness of motivational enhancement therapy on cigarettes smoked per day, such that the intervention was only more effective than control amongst those low in sensation seeking. For those high in sensation seeking, the control condition was more effective. Malmberg et al. (2015) investigated whether impulsivity and sensation seeking moderated the null effect of either a self-directed learning intervention or this intervention combined with a parental participation, monitoring, and counselling intervention, in Dutch adolescents. No moderating effects were found. Lopez (2014) investigated a contingency management intervention whereby participants were given retail vouchers for abstinence and found no interaction between intervention condition and delay discounting on relapse.

### Experimental studies with no control group

One study examined an incentive-based intervention (Morean et al., 2015), finding that adolescent smokers high in trait impulsivity that received contingency management were around 11 times more likely to achieve abstinence than were those that were high in impulsivity and received cognitive behavioural therapy.

### **Cohort studies**

Krishnan-Sarin et al. (2007) found higher baseline delay discounting and poorer performance on the continuous performance task in those who relapsed compared to those who did not following an incentive-based intervention in a small sample of adolescent smokers. There were no differences in self-reported impulsivity. Powell, Dawkins, West, Powell, and Pickering (2010) found that participants who relapsed to smoking following the provision of information about abstinence and coping strategies showed poorer performance on the antisaccade task and continuous performance task (assessed at acute withdrawal) than those who abstained. There were no moderating effects of impulsivity, sensation seeking, and novelty seeking. Sheffer et al. (2012) found that higher self-reported impulsivity (on one of three measures) and delay discounting, though not scores on the go/no-go task or balloon analogue risk task, in those who relapsed compared to those who maintained abstinence following cognitive behavioural therapy with relapse prevention. Yoon et al. (2007) also reported that baseline delay discounting was higher amongst those who eventually relapsed compared to those who did not following an incentive-based intervention, in a sample of pregnant smokers.

### **Interventions targeting non-reflective (non-conscious) processes**

#### **Experimental studies with control group**

Dallery and Raiff (2007) found that participants who smoked during a laboratory-based reinforcement intervention, whereby not taking a puff of a cigarette was immediately rewarded, had higher baseline delay discounting than those who abstained.

### **Cohort studies**

Two studies reported no differences in measures of baseline self-control between participants who relapsed and those who maintained abstinence following pharmacotherapy (Carton, Houezec, Lagrue, & Jouvent, 2000; Dolan et al., 2004). One study examined the impact of population-level policy interventions. Daly, Delaney, and Baumeister (2015) found that a decline in heavy smoking following a national workplace smoking ban and a 20% tax increase on cigarettes in the Netherlands was only evident amongst those with low trait self-control, and not those with high self-control. This effect was temporary, however, as many participants with low self-control resumed heavy smoking within two to three years following the legislation.

### **Interventions targeting both reflective and non-reflective processes**

#### **Experimental studies with control group**

Bailey, Bryson, and Killen (2011) found no differences in Behavioural Activation System scale scores in those who relapsed compared to those who abstained following selegiline plus cognitive behavioural therapy.

#### **Experimental studies with no control group**

Kahler, Spillane, Metrik, Leventhal, and Monti (2010) investigated whether sensation seeking interacted with treatment condition to predict likelihood of relapse following nicotine replacement therapy plus smoking cessation counselling (with or without an alcohol brief intervention) in a sample of heavy social drinkers that also smoked. No significant interactions were found. In a secondary analysis of a subset of participants from this study, MacKillop and Kahler (2009) reported no differences in baseline delay discounting between those who relapsed and those who abstained at 26 weeks following nicotine replacement plus counselling.

### **Cohort studies**

Bishry et al. (2012) reported no differences in measures of baseline self-control between participants who relapsed and those who maintained abstinence following psychotherapy with unspecified medication. Lopez-Torrecillas, Perales, Nieto-Ruiz, and Verdejo-Garcia (2014) found that participants who relapsed following treatment with varenicline plus counselling showed higher impulsivity and poorer scores on the Iowa gambling task, but no differences in delay discounting or go/no-go task performance, compared to those who maintained abstinence. Nieva et al. (2011) found that those who relapsed to smoking following pharmacotherapy (nicotine replacement, bupropion, or varenicline) plus cognitive behavioural therapy had higher impulsivity and sensation seeking. There were important gender differences, however: in females, baseline sensation seeking was higher amongst those that eventually relapsed compared to those that abstained. In males, baseline impulsivity was higher in those who relapsed compared to those who abstained. Sheffer et al. (2012) found that delay discounting, but not impulsivity, was higher amongst those who relapsed than those who abstained following nicotine replacement plus cognitive behavioural therapy.

### **Summary**

Overall, 10 of 19 studies reported evidence of effect modification, with nine finding interventions to be less effective in those with low self-control and one finding an intervention to be more effective. Evidence is mostly moderate or weak in quality, with zero studies rated as strong. Of nine studies investigating interventions targeting reflective processes, five reported less effectiveness in those with low self-control and four found no differences. Of four studies assessing interventions targeting non-reflective processes, one reported less effectiveness in those with low self-control, one reported greater effectiveness, and two found no differences in effectiveness. Of six studies assessing interventions targeting both reflective and non-reflective processes, three reported less effectiveness amongst low self-control participants and three reported no differences.

### **Food**

The 19 studies examining food interventions sampled undergraduate students ( $n = 11$ ), adults from the general population ( $n = 3$ ), overweight or obese adults ( $n = 2$ ), children/adolescents ( $n = 2$ ), and overweight or obese children/adolescents ( $n = 1$ ). Fourteen experimental studies (four with a control group and ten without), four cohort studies, and one cross-sectional study were included. Eleven studies were rated as being weak in quality, eight as moderate, and zero as strong.

### **Interventions targeting reflective (conscious) processes**

#### **Experimental studies with control group**

Churchill and Jessop (2011) found that implementation intentions to increase fruit and vegetable consumption were effective only amongst participants with low scores on the UPPS urgency scale. No moderation effects were found for the other UPPS scales (lack of premeditation, lack of perseverance, and sensation seeking). Rising and Bol (2017) examined whether self-control moderated the impact of menus adapted to show calorie information on the selection of a range of salads and beverages. Whilst no moderation by self-control was found, conditional effects indicated that calorie information influenced selection of lower calorie salads (but not beverages) only amongst participants with low impulsivity and high restraint (two subscales of the Self-Control Scale). Hall et al. (2015) reported no moderating effect of Stroop and flanker task scores on the impact of exposure to a healthy food guidelines poster on snack food consumption.

### *Experimental studies with no control group*

In two studies, one with undergraduates and one with older adults, Hall, Lowe, and Vincent (2014) and Hall et al. (2015) found no moderating impact of several behavioural measures of self-control on the effectiveness of an instruction to 'eat only the bare minimum' versus 'eat as much as you like' on snack food consumption in a taste test.

One study investigated acceptance-based behavioural treatment for weight loss, compared with standard behavioural treatment, in overweight/obese adults (Manasse et al., 2017). Inhibitory control assessed with the stop signal task was found to interact with treatment condition. Those in the acceptance-based treatment condition with weaker inhibitory control lost more weight than those with stronger inhibitory control. This effect was reversed in the standard behavioural treatment condition. No moderating effect was found for delay discounting.

In three studies, Mukhopadhyay, Sengupta, and Ramanathan (2008) consistently found that asking participants to remember a time when they had resisted tempting food in the past led, counterintuitively, to increased snacking during a break period, but only amongst participants with high impulsivity. Conversely, asking participants to remember a time when they had succumbed to tempting food led to reduced snacking, again only in participants with high impulsivity.

### *Cohort studies*

Churchill and Jessop (2010) found that implementation intentions to avoid high-calorie snack foods were effective in reducing intake only amongst participants with low or moderate, but not high, urgency. Dalle Grave et al. (2015) found that overweight/obese women low in novelty seeking were more likely to successfully complete a lifestyle modification weight loss programme than were those high in novelty seeking. Success was defined as losing  $\geq 10\%$  of initial body weight. Conversely, Pauli-Pott, Albayrak, Hebebrand, and Pott (2010) investigated a weight loss behavioural modification intervention in overweight/obese children, and found that those with high impulsivity, inferred from performance on a go/no-go task and an interference task, had a higher likelihood of success, defined as losing  $\geq 5\%$  of BMI.

## *Interventions targeting non-reflective (non-conscious) processes*

### *Experimental studies with control group*

Houben (2011) found that training inhibitory motor responses (versus either approach responses or neither) towards images of unhealthy snack food using a modified stop signal task led to reduced snack food consumption only in participants with weaker baseline performance on an unmodified stop signal task.

### *Experimental studies with no control group*

Giesen, Havermans, Nederkoorn, and Jansen (2012) examined the impact of taxes and subsidies for high- and low-calorie foods, respectively, on purchasing decisions. It was found that participants with weaker inhibitory control were particularly responsive to both interventions, showing reduced total calorie purchasing compared to those with strong inhibitory control in the tax condition and increased calorie purchasing (though not limited to low-calorie items) in the subsidy condition. In an evaluative conditioning intervention, Haynes, Kemps, and Moffitt (2015a) found that training female undergraduates to associate unhealthy snack food images with negative words led to reduced snack food consumption in a taste test only amongst participants with weaker stop signal task performance. Haynes, Kemps, and Moffitt (2015b) reported a similar interaction effect with an implicit association retraining intervention in which female undergraduates were trained to associate images of unhealthy snack food with negative or positive images. Training involving aversive images led to reduced snack food consumption, but only for participants with lower scores on the Inhibitory Self-control Scale. One study reported no moderating effect of Stroop performance on the effect of



changing the proximity of snack food consumption (Hunter, Hollands, Couturier, & Marteau, unpublished).

### **Cohort studies**

Rollins (2013) looked at the effect of restricting the availability of snack food and then lifting the restriction on intake amongst 3–5-year-olds at a day-care centre. It was found that children rated as having weak inhibitory control by their parents ate more snack food when the restriction period was lifted than did those rated as having strong inhibitory control.

### **Cross-sectional studies**

In a large sample of children and adolescents from three European countries, Giese et al. (2015) did not find an interaction between self-reported exposure to advertisements for healthy food products and scores on the Brief Self-Control Scale on fruit and vegetable intake.

### **Summary**

Available evidence suggests that self-control often modifies the effect of interventions to encourage healthy food consumption. However, this evidence is weak to moderate in quality, largely based on findings from experiments without control groups and cohort studies, and largely based on studies of undergraduate students. Overall, 14 of 19 studies reported evidence of effect modification, with 5 studies finding interventions to be less effective in those with low self-control and 9 studies finding them to be more effective. Of 12 studies assessing interventions targeting reflective processes, 4 reported less effectiveness in participants with low self-control, 5 reported greater effectiveness in participants with low self-control, and 3 reported no differences. Of seven studies assessing interventions targeting non-reflective processes, one reported less effectiveness in participants with low self-control, four reported greater effectiveness in participants with low self-control, and two reported no differences.

## **Discussion**

### **Principal findings**

This systematic review assessed whether individual differences in self-control modify the effectiveness of interventions to reduce consumption of alcohol, tobacco, and unhealthy food. Evidence from 54 eligible studies, mostly rated weak or moderate in quality, indicated an inconsistent modifying effect of self-control on intervention effectiveness. Thirty-two of 54 (59%) eligible studies reported differential effectiveness of interventions by at least one measure of self-control. Of these, 18 reported that interventions were less effective and 14 reported that they were more effective in those with low self-control. This pattern of findings did not differ from what would be expected by chance.

Our findings go beyond those from previous reviews that have identified main effects of heightened impulsivity on poorer treatment outcome in substance-dependent patients (Loree et al., 2015; Stevens et al., 2014), expanding the number of measures and consumption behaviours, and highlighting three important caveats. We show that whilst the broader construct of self-control often moderates the effectiveness of interventions to change unhealthy consumption behaviours in wider populations, this effect is not consistent (i.e., self-control moderates intervention effectiveness in different directions), evidence for the effect is not of strong quality, and the pattern of significant effects does not differ to chance.

### **Which interventions are more effective for those with low self-control?**

We categorised interventions based on theoretical considerations regarding whether the intervention targeted reflective (conscious) or non-reflective (non-conscious) processes, and tested

whether either of these types of intervention was of greater or lesser benefit for those with lower self-control compared to those with higher self-control. We did not find any differences in the pattern of moderation effects between these two types of intervention, although this finding was based on an underpowered analysis. The prediction that interventions targeting non-reflective processes would be more or equally beneficial for those with low self-control was, therefore, not supported. However, the evidence base regarding these interventions is limited. Much of the evidence on training cognitive biases away from unhealthy cues comes from laboratory-based studies using small samples of female undergraduate students. There is also a dearth of research regarding interventions that attempt to restructure the environment to change the prominence of unhealthy cues. We identified only one study each for alcohol and tobacco and two for food that studied such interventions. Collectively, these studies showed that higher taxes on cigarettes and unhealthy food could have a greater impact on the consumption of low self-control participants; more restrictive policies relating to alcohol availability are less effective in young males high in sensation seeking; and that self-control does not influence any effect of increasing the distance one has to reach for snack foods on consumption.

### ***Does the measure matter?***

Included studies used a disparate set of self-control measures. Of 36 included measures, most were self-reported questionnaires or executive function tasks. We did not observe differences between these measurement domains in the likelihood of finding modification effects. At the individual test level, the stop signal task appears to be particularly sensitive to identifying modification effects, doing so in five of six tests. However, it is not clear whether this is due to the specifics of the task, the interventions, or other study characteristics.

The high number of eligible measures resulted from our broad definition of self-control, which encompassed aspects of self-regulation, executive function, and impulsivity. This informed our decision to incorporate measures that assessed both general tendencies and specific behavioural abilities. As has been reported previously, associations between domains of self-control measurement are typically weak (Duckworth & Kern, 2011). The use of a diverse range of often weakly related measures to assess a single, albeit complex, construct therefore raises issues with validity. Many eligible measures were not designed to measure self-control *per se*, but specific aspects of the broader construct. It is certainly possible that a more consistent pattern of results might be found with a smaller set of eligible measures. That said, a more restrictive range of measures could exclude relevant evidence. There is, therefore, a trade-off to be made, both in reviews and in individual studies, between a smaller, less informative, more homogeneous set of measures and a larger, more informative, more heterogeneous set. We decided on the latter for this review to establish a comprehensive state of the literature on this topic. Previous reviews of self-control measurement have recommended the use of multiple measures in individual studies to further understanding of the nature of self-control and how it impacts upon behaviour (Sharma et al., 2014). It may be a useful endeavour for health psychologists interested in self-control to develop a recommended set of measures that can adequately tap the various aspects of self-control relevant for health behaviour in a systematic manner. The Self-Control Scale, UPPS-P Impulsive Behaviour Scale (developed from a factor analysis of many impulsivity questionnaires), the stop signal task, and the delay discounting task would be useful additions to such a battery.

### ***Strengths and limitations***

Strengths of this systematic review include its novel focus on self-control as a moderator of the effectiveness of interventions to change health-harming consumption behaviours. The review synthesises a large and complex literature, assessing three consumption behaviours, four domains of self-control measurement, and a wide range of interventions. Furthermore, the separation of studies by their

design and the assessment of individual study quality allowed for a thorough assessment of the strength of available evidence.

The review was limited, however, by a generally low-quality evidence base with high heterogeneity in participants, interventions, and measures. This precluded estimation of effect sizes using quantitative synthesis. Our analysis focused on categorical outcomes (i.e., moderation in different directions or no effect), and can therefore only provide an indication of the general direction of effects observed in the literature, but not the size of these effects. Included studies typically had small sample sizes and rarely reported power calculations for any moderation analysis. There is an indication that the number of modification effects at the study level may be inflated relative to true effects. The proportion of studies reporting modification effects (59%) was slightly higher than proportion of individual tests findings effects (47%), perhaps indicating a publication bias toward significant findings. A further limitation was that our search strategy could only identify studies that explicitly stated testing the hypothesis that self-control would modify the effect of an intervention. It is likely that this hypothesis was also tested in many other studies but not reported in the final study report, particularly if no effect was found. In future, we hope that such studies will be easier to identify via pre-registration of studies that includes proposed analyses. A further limitation was the lack of observed power in our analysis, which reduces confidence in our findings regarding the pattern of differences in moderation findings overall, by consumption behaviour, and by intervention type. Finally, we included studies that assessed weight loss interventions with weight change as the outcome variable. Weight loss interventions typically included components not limited to changing food consumption, for example, encouraging physical activity. Any observed relationships between self-control and weight change may therefore not be due only to intervention effects on food consumption.

### **Implications for research and policy**

This systematic review has identified a gap in the literature regarding whether interventions that attempt to restructure environments to change consumption behaviours, which theoretically should be less likely to favour those with higher existing self-control, show differential effectiveness by self-control. Addressing this gap should be a priority for researchers working to identify health behaviour interventions that are equally effective across whole populations. Relatedly, the possibility that individual differences in self-control caused by material deprivation might help to account for socioeconomic differences in intervention outcomes (i.e., intervention generated inequalities; McGill et al., 2015) requires further exploration.

Regarding policy implications, current evidence does not indicate that self-control has a reliable moderating effect on interventions to change health-harming consumption behaviours. It is, therefore, not appropriate at this stage to state that self-control should be a key consideration when designing and implementing such interventions. That said, given the sizeable evidence of cross-sectional links between self-control and consumption behaviours, and the relatively common, albeit unreliable, moderation findings shown here, self-control should also not be ruled out as a potential moderator of intervention effectiveness and may be usefully considered when designing health behaviour interventions. More research of stronger quality is required before making firm claims in either direction.

### **Conclusion**

A heterogeneous evidence base, mostly low in quality, suggests an inconsistent effect of low self-control on interventions to change consumption of alcohol, tobacco, and unhealthy food. Further research is needed to assess whether interventions to change physical and economic environments, which should be less likely to require self-control to be effective, are more, or at least similarly, effective in those with low as well as high self-control.

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KS conceived the study; prepared the protocol; conducted searches, screening, extraction, and quality assessment; conducted the analysis; and drafted the manuscript. ZZ helped prepare the protocol; conducted searches, screening, extraction, and quality assessment; and provided critical revisions of the manuscript. MF provided critical comments on the protocol and provided critical revisions of the manuscript. TMM helped prepare the protocol; provided critical comments throughout the review process; and provided critical revisions of the manuscript.

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