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Research report

Training response inhibition to food is associated with weight loss and reduced energy intake

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ABSTRACT

The majority of adults in the UK and US are overweight or obese due to multiple factors including excess energy intake. Training people to inhibit simple motor responses (key presses) to high-energy density food pictures reduces intake in laboratory studies. We examined whether online response inhibition training reduced real-world food consumption and weight in a community sample of adults who were predominantly overweight or obese (N = 83). Participants were allocated in a randomised, double-blind design to receive four 10-min sessions of either active or control go/no-go training in which either high-energy density snack foods (active) or non-food stimuli (control) were associated with no-go signals. Participants' weight, energy intake (calculated from 24-h food diaries), daily snacking frequency and subjective food evaluations were measured for one week pre- and post-intervention. Participants also provided self-reported weight and monthly snacking frequency at pre-intervention screening, and one month and six months after completing the study. Participants in the active relative to control condition showed significant weight loss, reductions in daily energy intake and a reduction in rated liking of high-energy density (no-go) foods from the pre-to post-intervention week. There were no changes in self-reported daily snacking frequency. At longer-term follow-up, the active group showed significant reductions in self-reported weight at six months, whilst both groups reported significantly less snacking at one- and six-months. Excellent rates of adherence (97%) and positive feedback about the training suggest that this intervention is acceptable and has the potential to improve public health by reducing energy intake and overweight.

1. Introduction

The prevalence of overweight and obesity has shown an increase over the past 30 years and the majority of adults in the US and UK are now overweight or obese (65–70%; Flegal, 2005; Wang & Beydoun, 2007). Overeating in a food-rich environment is a key contributor to rising obesity levels (Hill, Wyatt, Reed, & Peters, 2003) begging the question, how can we support people to reduce their over-consumption of food? Weight management interventions need to include behaviour change strategies that improve eating behaviour and reduce energy intake (Cavill & Ells, 2010).

Several models of self-control, notably dual process models, indicate that one important determinant of behaviour toward palatable, high-energy density foods is the unintentional elicitation of motor impulses towards these foods (Hofmann, Friese, & Wiers, 2008; Metcalfe & Mischel, 1999; Strack & Deutsch, 2004). These fast-acting, associatively-mediated impulses are thought to be regulated by a slow, controlled, reflective system that enables explicit goals and personal standards to influence behaviour, e.g. via top-down cognitive control. The strength of the impulses towards food and whether or not they give rise to consumption, depends on the interaction between the impulsive

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and reflective system, which are reflected in individual differences in food reward-sensitivity and self-control, respectively (Hofmann, Friese, & Roefs, 2009; Lawrence, Hinton, Parkinson, & Lawrence, 2012). Individuals who show a strong reward-related response to foods combined with low levels of self-control are particularly susceptible to overeating and overweight, whereas those with effective self-control appear to be protected (Lawrence et al., 2012; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010). This supports substantial evidence linking behavioural measures of poor self-control, namely motor response inhibition measured using stop-signal and go/no-go tasks (Verbruggen & Logan, 2008a), to overeating and overweight (Batterink, Yokum, & Stice, 2010; Guerrieri et al., 2007; Houben, Nederkoorn, & Jansen, 2014; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006a, 2012; 2006b). Thus regulation or reduction of food-related impulses seems to be required to control eating behaviour in our plentiful food environment and is a promising target for weight management interventions aimed at the habitual or impulsive system (Marteau, Hollands, & Fletcher, 2012; Van't Riet, Sijtsema, Dagevos, & Bruijn, 2011).

Laboratory studies suggest that the inhibition of responses to specific stimuli can be trained using consistent stimulus-stop or no-go associations, resulting in automatic response inhibition (Verbruggen & Logan, 2008b). More specifically, response inhibition is said to be 'automatic' when it is triggered by the retrieval of stimulus-stop associations from memory (Logan, 1988; Verbruggen & Logan, 2008b). Training response inhibition to specific snack food stimuli reduces the subsequent intake, choice and self-served portion size of those foods (Houben, 2011; Houben & Jansen, 2011, 2015; Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015; Van Koningsbruggen, Veling, Stroebe, & Aarts, 2014; Veling, Aarts, & Papies, 2011; Veling, Aarts, & Stroebe, 2013a; 2013b). These training effects are particularly pronounced in restrained eaters (Houben & Jansen, 2011; Lawrence et al., 2015; Veling et al., 2011), who are prone to overeating when disinhibited and frequently attempt to diet with or without success (Lowe, 1993). Response inhibition training effects on food choices are also stronger in those with a high appetite and in those who frequently consume the palatable, high-energy density 'no-go' training foods (Veling et al., 2013a; 2013b), suggesting stronger training effects in those most vulnerable to overeating and overweight.

In terms of the potential mechanisms underlying the effects of food response inhibition training on reduced food intake and choice, findings suggest that stimuli associated with response inhibition show reductions in motor excitability and reward value (Verbruggen, McLaren, & Chambers, 2014). For example, the automatic motor impulses activated by stimuli, and in particular palatable food cues, are reduced following response-inhibition training (Chiu, Aron, & Verbruggen, 2012; Chiu, Cools, & Aron, 2014; Houben & Jansen, 2015; Veling et al., 2011; Verbruggen & Logan, 2008a), and this may be associated with reduced food consumption (Houben & Jansen, 2015; Veling et al., 2011; *cf* Houben, Havermans, Nederkoorn, & Jansen, 2012). In terms of reward value, affective cues associated with no-go responses show a reduction in rated valence (Doallo et al., 2012; Veling, Holland, & van Knippenberg, 2008; Veling et al., 2013a) and more negative implicit affective reactions (Houben et al., 2011; 2012; Veling & Aarts, 2009). If food-associated response inhibition training effectively boosts automatic motor inhibition and reduces the reward value associated with food cues, it could help at-risk individuals control their food intake. This study therefore examined the effects of repeated sessions of food-associated no-go training, delivered via the internet, on a range of 'real world' measures of eating behaviour.

1.1. The present study

Previous studies have employed both stop-signal and go/no-go tasks to train associations between foods and motor inhibition. Stop-signal tasks impose a delay between the stimulus and a stop signal and so require the cancellation of an initiated response, whereas the no-go signal is presented at the same time as the stimulus so a response should not be initiated (Schachar et al., 2007). Recent findings from our lab suggest that food no-go training ('action restraint') may be more effective than stop-training in reducing food intake (Adams, Verbruggen, Lawrence, & Chambers, 2014, discussed in Lawrence et al., 2015) so here we used a food go/no-go task based on our lab studies, in which high-energy density foods (greater than 4 kcal/g) were consistently associated with no-go signals and healthy, lower-energy density foods were consistently associated with go-signals.

Lab studies to date have compared food response inhibition training to control conditions requiring either consistent or inconsistent 'go' responses to foods, which may have inadvertently increased approach towards, and intake of food in control participants (Lawrence et al., 2015; Schonberg et al., 2014). To avoid this potential confound, the present study employed a control condition in which participants were trained to inhibit responses to non-food pictures and were never exposed to pictures of high-energy density foods. As the active group were repeatedly exposed to images of high-energy density food (paired with no-go responses) during training, mere exposure effects would predict *increased* food intake in the active relative to control group (Fedoroff, Polivy, & Herman, 1997); any reduction is therefore likely due to the food-associated inhibition training, which may include related processes such as food cue exposure with response prevention.

Participants completed four sessions of food-related (versus control) no-go training in one week and effects on weight loss, energy intake and daily snacking frequency were measured. We also examined training effects on two variables used in previous laboratory studies - subjective ratings of food images (Veling et al., 2013a) and food intake in a taste test presented immediately following an additional training session (Lawrence et al., 2015). Finally, we measured the longer-term effects of training by contacting participants one month and six months after their final session and asking them to provide their current weight and snacking frequency. We predicted that the active group would show a greater reduction than the control group in weight, snacking frequency, energy intake and snack food intake in the taste test. We also expected a larger reduction (devaluation) in subjective ratings of the high-energy density (no-go) foods in the active relative to control group.

Since the current research was conducted a similar study has been published that associated stop signals with many palatable foods and drinks in a dieting sample to facilitate weight loss (Veling, Koningsbruggen, Aarts, & Stroebe, 2014). Four weekly training sessions delivered via the internet resulted in weight loss in the active group relative to a control group that, like here, was trained to inhibit to non-food images. The Veling et al. (2014) sample included predominantly young, healthy females, and the effects of no-go training on weight loss were greater in higher BMI participants. Veling et al. (2014) suggested that further work was required to determine whether the food no-go intervention is associated with weight-loss over the longer term, whether it is effective in more overweight participants, and what the possible mechanisms of training effects are before this promising intervention can be recommended as a weight-loss tool. All of these factors were addressed in the current study, which recruited predominantly middle-aged overweight or obese adults, followed them up over a longer period of time and examined some putative