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Research report

# Stopping to food can reduce intake. Effects of stimulus-specificity and individual differences in dietary restraint ☆

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ABSTRACT

Overeating in our food-rich environment is a key contributor to obesity. Computerised response-inhibition training could improve self-control in individuals who overeat. Evidence suggests that training people to inhibit motor responses to specific food pictures can reduce the subsequent choice and consumption of those foods. Here we undertook three experiments using the stop-signal task to examine the effects of food and non-food related stop-training on immediate snack food consumption. The experiments examined whether training effects were stimulus-specific, whether they were influenced by the comparator (control) group, and whether they were moderated by individual differences in dietary restraint. Experiment 1 revealed lower intake of one food following stop- vs. double- (two key-presses) response training to food pictures. Experiment 2 offered two foods, one of which was not associated with stopping, to enable within- and between-subjects comparisons of intake. A second control condition required participants to ignore signals and respond with one key-press to all pictures. There was no overall effect of training on intake in Experiment 2, but there was a marginally significant moderation by dietary restraint: Restrained eaters ate significantly less signal-food following stop- relative to double-response training. Experiment 3 revealed that stop- vs. double-response training to non-food pictures had no effect on food intake. Taken together with previous findings, these results suggest some stimulus-specific effects of stop-training on food intake that may be moderated by individual differences in dietary restraint.



## Introduction

We are in the midst of an obesity epidemic. Rates of obesity (BMI ≥ 30 kg/m$^2$) in adults have increased three- to four-fold in the last 30 years, rising from 6% (UK) and 15% (US) in 1980 to 26% and 35% respectively today, with most adults (60–70%) now overweight or obese (Department of Health, 2012; Flegal, 2005; Flegal, Carroll, Kit, & Ogden, 2012). Over-eating in the context of an increasingly food-rich environment is a key contributor to rising obesity levels (Hill, Wyatt, Reed, & Peters, 2003), with large individual differences in susceptibility to our shared 'obesogenic' environment (Carnell, Kim, & Pryor, 2012; Grucza et al., 2010).

We and others have recently shown that individual differences in response to food pictures in reward/motivation-related brain regions are positively associated with food intake (Lawrence, Hinton, Parkinson, & Lawrence, 2012) and can predict weight gain in healthy and obese individuals (Demos, Heatherton, & Kelley, 2012; Murdaugh, Cox, Cook, & Weller, 2012). Importantly, however, individual differences in self-control can moderate the impact of heightened food cue-reactivity on weight over the longer-term: Individuals who show a strong reward-related response to foods combined with low levels of self-control are particularly susceptible to gaining weight, whereas those with effective self-control appear to be protected (Lawrence et al., 2012; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010). These findings are consistent with evidence linking impulsivity to obesity in adults and children (e.g. Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006a; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006b). In particular, poor motor response inhibition, measured using stop-signal and go/no-go tasks (Verbruggen & Logan, 2008a), is associated with increased BMI (Nederkoorn et al., 2006a, 2006b) and increased food intake in the lab (Guerrieri et al., 2007). Furthermore, the inhibition of

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responses to appetising food pictures may be particularly compromised in overweight individuals (Batterink, Yokum, & Stice, 2010; Houben, Nederkoorn, & Jansen, 2014; Nederkoorn, Coelho, Guerrieri, Houben, & Jansen, 2012).

These findings have prompted studies examining whether inhibitory control can be strengthened through training in order to influence people's eating behaviour. Several studies have now demonstrated that one session of inhibiting simple motor responses to pictures of snack foods, in the context of go/no-go or stop-signal tasks, can reduce subsequent consumption or choice of those foods (Houben, 2011; Houben & Jansen, 2011; Van Koningsbruggen, Veling, Stroebe, & Aarts, 2014; Veling, Aarts, & Papies, 2011; Veling, Aarts, & Stroebe, 2013a, 2013b). Similar effects have been demonstrated for alcohol consumption following one session of inhibiting responses to pictures of alcohol (Bowley et al., 2013; Houben, Havermans, Nederkoorn, & Jansen, 2012a; Houben & Jansen, 2011; Houben, Nederkoorn, Wiers, & Jansen, 2011; Jones & Field, 2013). Although the precise methods and results of these studies differ (e.g. some show only immediate effects whilst others demonstrate longer-lasting reduction of intake), they suggest that response-inhibition training has the potential to help reduce excessive or impulsive eating and drinking behaviour.

Several questions about these training effects remain, including their mechanism of action, cue-specificity, duration, influence of participants' awareness of the training, and the moderation of effects by individual differences. For example, in the three published studies on food intake, the effects of response-inhibition training were moderated by individual differences in inhibitory control ability (Houben, 2011) or dietary restraint (Houben & Jansen, 2011; Veling et al., 2011), with stronger training effects observed in more impulsive or restrained individuals. Impulsivity and dietary restraint are themselves risk factors for overeating and overweight (Johnson, Pratt, & Wardle, 2012; Nederkoorn et al., 2006b), suggesting that response-inhibition training to food pictures may specifically help to reduce overeating in vulnerable individuals, which supports its therapeutic potential.

In terms of underlying mechanisms, it is important to clarify whether response-inhibition training effects are mediated through a general strengthening or priming of inhibitory control, consistent with evidence for 'inhibitory spillover' between psychological or behavioural domains (Berkman, Burklund, & Lieberman, 2009; Tuk, Trampe, & Warlop, 2011), or whether the effects are specific to motivationally-salient stimuli. For example, if equivalent reductions in food intake could be achieved through general response-inhibition training using non-food stimuli, this would be advantageous as it would avoid exposing at-risk individuals to high-incentive food cues, which alone can increase food consumption (Fedoroff, Polivy, & Herman, 1997; Lawrence et al., 2012). Preliminary findings suggest, however, that such general response-inhibition training is ineffective in reducing the immediate consumption of food (Guerrieri, Nederkoorn, & Jansen, 2012) or alcohol (Jones & Field, 2013), indicating that training effects may be stimulus-specific.

Stimulus-specific effects of response-inhibition training have also been demonstrated by comparing the relative intake of foods associated with going or stopping in a repeated-measures design (Houben, 2011). Recent investigations into the mechanism underlying response-inhibition training also support stimulus-specific effects: Affective cues associated with no-go responses show a reduction in rated valence (Doallo et al., 2012; Veling et al., 2013a; Veling, Holland, & Van Knippenberg, 2008) and more negative implicit affective reactions (Houben, Nederkoorn, & Jansen, 2012b; Veling & Aarts, 2009). In addition, the automatic motor impulses activated by cues are modified through response-inhibition training (Verbruggen & Logan, 2008a), although it is unclear whether this specific mechanism also influences food consumption (Houben et al., 2012a; Veling et al., 2011). Thus, further research is needed to clarify the stimulus-specificity and mechanisms underlying the effects of response-inhibition training in order to optimise this behavioural intervention prior to testing it in clinical or real-world contexts.

Here we report three experiments, which progressively build upon one another, to examine the effects of the stimulus-specificity of response-inhibition training on immediate snack food consumption, along with the influence of the comparator (control) condition and individual differences in dietary restraint. Dietary restraint can be defined as the tendency to deliberately restrict food intake with the aim of losing weight or preventing weight gain; however, this is often unsuccessful and restrained eaters typically eat and weigh more than unrestrained eaters (see Johnson et al., 2012 for a recent review). Whilst different measures of restraint have been used in prior studies, findings agree that restrained eaters show stronger effects of food response-inhibition training in reducing food intake (Houben & Jansen, 2011; Veling et al., 2011) so in all three experiments we examined whether individual differences in restraint moderated the effects of training on food intake. We also used a funnelled debriefing interview to gauge participants' awareness of the stop-associations in the training tasks.

In Experiment 1, we adopted a simple between-subjects design to examine the effect of stop- vs. double-response training to food stimuli on subsequent crisp consumption. In the stop condition, participants performed a variant of the stop-signal reaction time task (Logan, 1994; Verbruggen & Logan, 2008b). In this task, participants have to withhold their response to a go stimulus when an extra signal is presented. The double-response control condition required participants to carry out the normal response followed by an additional response when an extra signal was presented (see methods), which has been used a control condition for stop-signal training in our previous studies (Verbruggen, Adams, & Chambers, 2012). The double-response task controls for the additional attentional and action updating components associated with the stop-signal training task, but in a way that does not require outright response inhibition (Dodds, Morein-Zamir, & Robbins, 2011; Verbruggen, Aron, Stevens, & Chambers, 2010). Standard control conditions do not do this; they either contain all 'go' trials (with no signals being presented at all) or they require random response inhibition (i.e. all stimuli are randomly associated with stop and go signals). In Experiment 2, we included a third control condition. In this condition, participants were instructed to ignore additional signals, and execute a single response on each trial. In a taste test, participants were given two foods to eat (crisps and chocolate), only one of which was associated with stop-, double-response, or ignore signals, to enable both between- and within-subjects comparisons of intake. In Experiment 3, we examined the effects of stop- vs. double-response training to non-food stimuli on subsequent consumption of the same two foods as in Experiment 2.

## Experiment 1 – stop- vs. double-response training effects on consumption of one food

The first study used a modified stop-signal task (SST) to train participants to inhibit or make double-responses to images of foods, in particular to one subsequently presented food (crisps). We predicted that consistent stimulus-stop associations would affect participants' consumption when they were presented with crisps in an ad-libitum snacking phase.

### *Methods and materials*

#### *Participants*

Sixty-five participants (39 women) were recruited from the student and staff population at Cardiff University, using online