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10 Inhibitory self-control moderates the effect of changed implicit food evaluations on snack

11 food consumption

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Abstract

The current study used a modified implicit association test (IAT) to change implicit evaluations of unhealthy snack food and tested its effects on subsequent consumption. Furthermore, we investigated whether these effects were moderated by inhibitory self-control. A sample of 148 women (17-25 years) motivated to manage weight through healthy eating completed an IAT intervention, and pre- and post-intervention IATs assessing implicit evaluations of unhealthy food. The intervention IAT trained participants to pair unhealthy food stimuli with either positive or negative stimuli. A task disguised as a taste-test was used to assess consumption of unhealthy snack foods. Inhibitory self-control was measured using a self-report scale. As predicted, the implicit evaluation of unhealthy food became more negative from pre- to post-training among participants in the food negative pairing condition; however, there was no corresponding change in the food positive pairing condition. The effect of the training on snack consumption was moderated by inhibitory self-control with only participants low in inhibitory self-control having lower snack intake following the food negative training. This finding is consistent with dual-process models of behaviour which predict that self-control capacity renders impulses less influential on behaviour. Furthermore, it suggests that an intervention that retrains implicit food evaluations could be effective at reducing unhealthy eating, particularly among those with low inhibitory self-control.

Keywords: implicit evaluations; food intake; implicit association test; inhibitory control; implicit evaluation change.

1   Despite the negative health consequences resulting from overconsumption of food high in

2   fat, sugar, and salt, many individuals find it difficult to regulate their eating behaviour in line

3   with long-term health or weight-management goals (Cohen & Farley, 2008; Fishbach,

4   Friedman, & Kruglanski, 2003; World Health Organization, 2011). Due to their rewarding

5   sensory properties, unhealthy foods are generally associated with positive affect, and this

6   implicit positivity toward food stimuli drives approach behaviour toward them (Chen &

7   Bargh, 1999; Cohen & Farley, 2008; Dovidio, Kawakami, Johnson, Johnson, & Howard,

8   1997; Duckworth, Bargh, Garcia, & Chaiken, 2002; Ferguson & Bargh, 2008). However, the

9   relationship between a more positive implicit evaluation of unhealthy food (i.e., association

10   of food with positive affect) and subsequent consumption depends on individual differences

11   in control resources. A stronger relationship exists between implicit evaluations and

12   subsequent behaviour among individuals with lower capacity for impulse inhibition

13   (Hofmann, Friese, & Roefs, 2009).

14   **Dual process models of behaviour**

15   Dual process models posit that behaviour is determined by two interacting systems. On

16   the one hand, the impulsive system drives behaviour through an automatic appraisal of a

17   stimulus in terms of its affective and motivational properties (Strack & Deutsch, 2004). For

18   example, a more positive implicit evaluation of food has been shown to predict choice of

19   unhealthy over healthy food and higher intake of unhealthy snack food (Conner, Perugini,

20   O'Gorman, Ayres, & Prestwich, 2007; Friese, Hofmann, & Wanke, 2008; Hofmann,

21   Gschwendner, Friese, Wiers, & Schmitt, 2008). On the other hand, the reflective system

22   guides behaviour through long-term goals and personal standards (e.g., Deutsch & Strack,

23   2006; Strack & Deutsch, 2004). When a conflict between these two systems arises, higher

24   order inhibitory processes need to be employed to ensure behaviour is consistent with

25   personal standards rather than being guided by unhealthy impulses (e.g., inhibition of

1   automatic impulses to eat unhealthy food such that behaviour is consistent with a goal of

2   weight management) (Deutsch & Strack, 2006; Strack & Deutsch, 2004). Success at

3   achieving control over impulses is dependent on available cognitive resources which vary

4   between individuals and across situations (Deutsch & Strack, 2006; Strack & Deutsch, 2004).

5   **Inhibitory control**

6   Weaker inhibitory control, or the inability to inhibit unwanted impulsive reactions, has

7   been associated with obesity and intake of unhealthy food in a laboratory setting (Guerrieri,

8   Nederkoorn, & Jansen, 2007; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006).

9   However, it has been argued that inhibitory control itself does not determine behaviour, but

10   rather that low inhibitory control may allow impulses (e.g., automatic evaluations of stimuli)

11   to have a more potent influence on behaviour (Hofmann et al., 2009). This is evidenced in

12   findings demonstrating that inhibitory control moderates the relationship between implicit

13   evaluations of appetitive stimuli (e.g., food, alcohol), and subsequent consumption. For

14   example, Hofmann et al. (2009) showed that for individuals with lower inhibitory control,

15   positive implicit attitudes towards candy were more strongly related to subsequent candy

16   intake than for individuals with higher inhibitory control. Similarly, Nederkoorn, Houben,

17   Hofmann, Roefs, and Jansen (2010) found that only among participants with lower inhibitory

18   control did an implicit preference for snack food predict higher weight gain over one year.

19   Likewise, in the alcohol domain, more positive alcohol evaluations predicted higher levels of

20   alcohol use and alcohol problems, but again, only among those with low inhibitory control

21   (Houben & Wiers, 2009). However, these studies were correlational in nature.

22   Other studies that have experimentally manipulated response inhibition capacity have

23   shown support for its causal role in moderating the effect of implicit evaluations on

24   behaviour. For example, randomising participants to a high cognitive load or resource

25   depletion condition subsequently limited their capacity for inhibitory control over impulses

relative to participants randomised to a low cognitive load or resource depletion condition

(Friese et al., 2008; Hofmann, Rauch, & Gawronski, 2007). These manipulations of state

inhibitory control capacity were shown to moderate the relationship between implicit snack

attitudes and subsequent choice of unhealthy over healthy snacks and snack consumption in a

lab-based task, such that individuals with low capacity for inhibitory control showed a

stronger relationship between their impulses and behaviour than those with higher inhibitory

control capacity (Friese et al., 2008; Hofmann et al., 2007).

Manipulating impulses: implicit food evaluations

While previous studies have manipulated inhibitory control to explore its causal role in

moderating the relationship between impulses and behaviour, impulses have not themselves

been manipulated. As noted by Houben and Wiers (2009), research needs to determine the

causality of the relationship between implicit evaluations and behaviour at the same time as

investigating the moderating role of inhibitory control. In line with findings of previous

studies (e.g., Friese et al., 2008; Hofmann et al., 2009; Hofmann et al., 2007; Nederkoorn et

al., 2010), experimentally manipulating implicit evaluations of food is likely to show a

change in implicit evaluations for all individuals, but a corresponding change in consumption

is likely to occur only for those low in inhibitory control. By contrast, despite a change in

implicit evaluations, a corresponding change in eating behaviour is not likely to be observed

among individuals with high inhibitory control, evidencing a dissociation between impulses

and behaviour.

A number of previous studies have attempted to modify implicit evaluations. One way of

achieving this is to use evaluative conditioning, which repeatedly pairs a conditioned

stimulus (CS; e.g., unhealthy food), with unconditioned stimuli (US) which evoke either

positive or negative affective reactions (e.g., general positive or negative images or words)

(De Houwer, Thomas, & Baeyens, 2001). For example, participants presented with unhealthy

1 food stimuli paired with aversive images of negative health consequences of consumption

2 subsequently evaluated those foods more negatively (Hollands, Prestwich, & Marteau, 2011;

3 Lebens et al., 2011). This paradigm has also been applied in the alcohol domain, where

4 presenting participants with alcohol-related stimuli paired with negative concepts resulted in

5 a more negative implicit evaluation of alcohol (Houben, Havermans, & Wiers, 2010; Houben,

6 Schoenmakers, & Wiers, 2010).

7   Another approach to changing implicit evaluations is through a modified version of an

8 implicit association test (IAT). This task requires participants to respond to one type of CS

9 and negative US with one response key and to a comparison category CS and positive US

10 with a separate response key (Ebert, Steffens, von Stulpnagel, & Jelenec, 2009). This training

11 procedure works on the same principle as evaluative conditioning in that it provides

12 contingent pairings of CS and US. However, in contrast to evaluative conditioning, which

13 requires participants to simply watch a stream of pictures presented on a computer screen, the

14 modified IAT requires participants to actively categorise the stimuli. A study using a

15 modified IAT conducted in the consumer choice domain found that individuals trained to pair

16 one brand of candy with negative stimuli and another brand with positive stimuli,

17 consequently evaluated the negatively-paired brand more negatively than the comparison

18 brand (Ebert et al., 2009). IAT re-training has also been reported to successfully modify

19 implicit evaluations of the self, and of mathematics (Ebert et al., 2009; Forbes & Schmader,

20 2010)

21   Implicit evaluation modification using evaluative conditioning or a modified IAT has

22 achieved variable success in affecting subsequent behaviour toward CS. While some studies

23 have shown effects of implicit evaluation training on subsequent behaviour, including alcohol

24 consumption (Houben, Havermans, et al., 2010; Houben, Schoenmakers, et al., 2010),

25 healthy snack choices (Hollands et al., 2011; Walsh & Kiviniemi, 2013), and motivation

1   toward solving math problems (Forbes & Schmader, 2010), a number of studies have not

2   (Ebert et al., 2009; Lebens et al., 2011). These inconsistent findings regarding the training of

3   implicit evaluations on subsequent consumptive behaviour may be attributable to individual

4   differences in inhibitory control. Given that previous research has shown that impulses affect

5   behaviour to a greater extent among individuals with low inhibitory control, the effect of

6   implicit evaluation interventions on snack intake may be greater in these individuals (e.g.,

7   Friese et al., 2008; Hofmann et al., 2009; Hofmann et al., 2007; Houben & Wiers, 2009;

8   Nederkoorn et al., 2010).

9   **The current study**

10   The current study aimed to investigate the moderating role of inhibitory self-control in the

11   effect of changed food evaluations on subsequent food intake. In line with previous findings,

12   we predicted that implicit food evaluations would become more negative among participants

13   who were trained to pair food with negative stimuli, while implicit food evaluations would

14   become more positive among participants trained to pair food with positive stimuli. However,

15   because individuals with low inhibitory control are less successful at regulating impulses so

16   that their behaviour is in line with goals or personal standards, we expected that the

17   intervention would only affect subsequent consumption of unhealthy snacks for participants

18   with low inhibitory self-control. The current study used a modified IAT to change implicit

19   evaluations of unhealthy food. This ensured that participants were paying attention to the

20   critical CS-US pairings by requiring them to actively categorise stimuli rather than simply

21   viewing them being presented on the computer screen, as occurs in evaluative conditioning.

22   **Method**

23   **Participants**

24   One hundred and forty-eight women between the ages of 17 and 25 years ($M = 19.49$,

25   $SD = 1.82$) were recruited from Flinders University. The study advertisement targeted

1   individuals motivated to manage weight through healthy eating. This recruitment strategy

2   was used as dual process models posit that motivation to control impulses (reflected in a goal

3   of healthy eating for weight management) is important in the regulation of behaviour by the

4   reflective system (Fazio & Towles-Schwen, 1999). Only women were recruited, as they have

5   higher levels of food liking and craving than men (Cepeda-Benito, Fernandez, & Moreno,

6   2003; Zellner, Garriga-Trillo, Rohm, Centeno, & Parker, 1999). One hundred and seven first-

7   year psychology student volunteers participated for course credit, and the remaining paid

8   volunteers received a $15 honorarium. The mean body mass index (BMI) of the sample was

9   22.55 ($SD = 3.76$).

10   **Design**

11   The study used a 2 (training condition: positive, negative) x 2 (time: pre-training

12   assessment, post-training assessment) mixed factorial design. Participants were randomised

13   to either the food positive or the food negative training IAT. Participants (but not the

14   experimenter) were blinded to the training conditions. Implicit food evaluations and snack

15   intake were dependent variables. Inhibitory self-control was tested as a moderator.

16   **Materials**

17   **Implicit food evaluation.** The modified implicit association test (IAT) consisted of

18   three phases: (1) a pre-training assessment of implicit evaluations of unhealthy food, (2) a

19   modified IAT training phase, and (3) a post-training assessment of implicit evaluations of

20   unhealthy food (e.g., Kemps, Tiggemann, Martin, & Elliot, 2013). Implicit evaluation of

21   unhealthy snack foods was measured and modified with a recoding-free IAT (IAT-RF,

22   Rothermund, Teige-Mocigemba, Gast, & Wentura, 2009). In the IAT-RF, the response keys

23   assigned to the target category change between trials rather than between blocks, as in the

24   traditional IAT. This prevents participants from recoding into a two-category sorting task

25   whereby the target category is grouped with one evaluative category on the basis of salience

1   or familiarity. Instead, participants must respond to the target stimulus based on its semantic

2   category membership. This makes the IAT-RF a more valid assessment of implicit

3   associations with the target concept (Houben, Rothermund, & Wiers, 2009; Rothermund et

4   al., 2009).

5   Participants sorted word stimuli belonging to three categories: two evaluative

6   categories (positive and negative, labelled "I like" and "I dislike", respectively), and the

7   target category ("food"). The evaluative category labels ("I like"/"I dislike") better reflect

8   personal evaluations and decrease the influence of normative social evaluations of target

9   stimuli compared with the traditional "positive/negative" or "pleasant/unpleasant" labels

10   (Olson & Fazio, 2004). They have also been used in previous research (e.g., Craeynest,

11   Crombez, Haerens, & De Bourdeaudhuij, 2007; Houben & Wiers, 2007; Nederkoorn et al.,

12   2010). The positive evaluative stimuli were: holiday, pleasure, rainbow, gift, peace and

13   friend; the negative evaluative stimuli were: accident, sickness, abuse, dead, fear, and pain.

14   The food stimuli were chocolate, cake, ice-cream, chips, pizza, and hamburger, similar to

15   those used in previous studies (e.g., Richetin, Perugini, Prestwich, & O'Gorman, 2007; Roefs,

16   Herman, MacLeod, Smulders, & Jansen, 2005; Roefs & Jansen, 2002; Roefs et al., 2006).

17   The stimuli between evaluative categories were matched on number of syllables, frequency,

18   and arousal (Bradley & Lang, 1999), and were selected from previous IAT studies (e.g.,

19   Karpinski & Steinman, 2006; Olson & Fazio, 2004; Roefs et al., 2005). All words were

20   presented in lower case letters.

21   The evaluative category labels appeared fixed at the top left and right hand corners of

22   the computer screen, and the food category label switched between the top left and right hand

23   corners of the screen randomly throughout the task, so that it appeared on the same side as the

24   positive label on 50% of food trials, and on the same side as the negative label on the

25   remaining 50% of food trials. Word stimuli were presented individually in the centre of the

screen. Participants were asked to respond by pressing a key designated to the position of the

word's category on the screen (left or right). The task is easier when the concept 'food' and

the attribute with which it is paired at the top of the screen are more strongly associated.

Therefore, trials which required a response to food words with the same key as trials with

positive words were expected to elicit a quicker response than those requiring a response with

the same key as negative words, indicating a more positive implicit food evaluation.

   Pre-training implicit food evaluation. The pre-training implicit association test (IAT)

consisted of three blocks. The first was a practice block consisting of 24 trials, which

required participants to categorise positive and negative word stimuli into their respective

categories. Each positive and negative stimulus was presented twice. In the second practice

block (36 trials), participants were required to categorise stimuli into both evaluative

categories (i.e., positive and negative), and the target category (i.e., food). The response key

assigned to evaluative categories (left and right) remained constant throughout the task, and

was counterbalanced between participants. The response assignment of the target category

however, switched randomly between trials, sharing a response key with the positive category

on half of the trials (congruent trials), and sharing a response key with the negative category

on the remaining half of the trials (incongruent trials). Each positive, negative, and food

stimulus was presented twice. The third block was identical to the second, with the number of

trials increased to 144, such that each positive, negative, and food stimulus was presented

eight times. Three buffer trials were presented at the beginning of the test block and again

after a short break halfway through the test phase. The buffer trials presented one positive,

one negative, and one food word ("evil", "sunlight", and "hotdog", respectively). These gave

participants a chance to re-focus their attention on the task after reading the instructions.

   Each block was preceded by a standardised set of instructions presented on the screen,

which included a list of the words belonging to each category and the appropriate key

1 responses for the evaluative categories. Participants were instructed to respond to each

2 stimulus word as quickly and accurately as possible. On each trial, the category labels

3 appeared at the top of the screen on the side of the appropriate response key. They were

4 displayed 1500ms before presentation of the stimulus. Participants responded to the stimulus

5 by pressing the appropriate response key (i.e., left 'z', or right '/'). The target stimulus

6 remained on the screen until the participant responded. The inter-trial interval was 400ms.

7 Accuracy and response times were recorded. The order of presentation of stimulus words was

8 randomised within each block.

9   *Modified IAT training*. The training task resembled the third block of the pre-training

10 IAT, except that participants randomised to the food positive condition paired food words

11 mainly with positive words, while participants randomised to the food negative condition

12 paired food words mainly with negative words. Participants in the food positive condition

13 completed three blocks of 72 trials each (216 total), where 90% of the trials were congruent

14 (food + positive), and 10% were incongruent (food + negative). Those in the food negative

15 condition completed the same task, except the contingencies were switched: 90% of trials

16 were incongruent (food + negative), and 10% were congruent (food + positive). Mirroring

17 previous research (Kemps et al., 2013; Wiers, Rinck, Kordts, Houben, & Strack, 2010), a

18 90:10 response distribution was used to prevent a response bias from developing, and to

19 reduce the obviousness of the contingency while still effectively training associations

20 between food and positive or negative concepts.

21   *Post-training implicit food evaluation*. The post-training measure of implicit food

22 evaluation was identical to the third block of the pre-training IAT.

23   **Snack intake.** Intake of unhealthy snack food was assessed with a taste test (Coelho

24 et al., 2009). Participants were presented with four full bowls of pre-weighed popular energy-

25 dense snack foods: 80g of M&Ms (Mars, 2050 kilojoules [kJ]/100g), 30g of original salted

1   chips (Smiths, 2190kJ/100g), 30g of Cheese Twisties (Smiths, 2080kJ/100g), and 80g of mini

2   choc-chip cookies (White Wings, 1959kJ/100g). The placement position of the four bowls

3   from left to right was counterbalanced across participants using a Latin square procedure with

4   four orders. One paper-pencil format rating sheet containing six questions about the foods'

5   sensory attributes (e.g., "How sweet is this product?"), answered on 100mm visual analog

6   scales (ranging from "*not at all*" to "*extremely*") accompanied each bowl of food. The taste-

7   test was presented to participants using a standardized verbal script, to avoid potential biases:

8   "The next task is a taste-test. Please rate the sensory properties of each of the four snack

9   products by placing a small vertical line on the scales provided. Please taste as much of the

10   products as you need to make your ratings as accurate as possible. You will have 10 minutes

11   to complete the task, which should be ample time. Once you have completed your ratings,

12   feel free to go back and sample more of the products (any leftover will be thrown away), but

13   please do not change your initial ratings. I will be in the next room setting up for the next

14   participant." The pre- and post-taste test weight of each bowl was measured using sensitive

15   and reliable weight scales, to measure intake without participants' knowledge. Food intake in

16   grams was multiplied by the number of kilojoules (kJ) per gram in each food, and summed to

17   give total intake in kJ.

18   **Hunger**. A single item was used to assess subjective hunger: "Please indicate the

19   place on the scale which best reflects your current level of hunger". Responses were made on

20   a 7-point Likert scale ranging from 1 (*not hungry at all*), to 7 (*extremely hungry*).

21   **Inhibitory self-control.** Inhibitory self-control was measured using the 6-item

22   inhibitory self-control scale (De Ridder, de Boer, Lugtig, Bakker, & van Hooft, 2011). The

23   scale assesses the domain-general ability to inhibit unwanted behavioural impulses that are

24   detrimental to long-term interests but bring immediate pleasure (e.g., "I am good at resisting

25   temptation"). Participants respond by rating the extent to which each statement represents

them on 5-point likert scales ranging from 1 (*not at all like me*) to 5 (*very much like me*), with

higher scores indicating higher levels of inhibitory self-control. De Ridder et al. (2011)

demonstrated the predictive validity of the inhibitory self-control scale, showing that low

inhibitory self-control predicted behaviours that are driven by unhealthy impulses (e.g.,

smoking cigarettes, drinking alcohol). Internal consistency of the scale was adequate,

Cronbach's $\alpha = $ .68, although slightly lower than that observed in previous research,

Cronbach's α in two different samples = .76, .78 (De Ridder et al., 2011).

Awareness of taste-test purpose. Awareness of the purpose of the taste test measure

of intake was assessed with a single open-ended probe question. Participants were asked

"What do you think was the purpose of the taste-test?" and were categorised as being aware

of the taste-test's purpose if their response referred to the assessment of food intake, self-

control of eating, or resisting temptation.

Procedure

Participants completed the experiment individually in the Applied Cognitive

Psychology Laboratory. Each session ran for approximately 45 minutes. Participants were

told that the experiment would investigate the relationship between language processing and

taste perception. To equalise hunger levels, participants were asked to eat something 2 hours

before their scheduled session, and to refrain from eating again until the experiment.

Participants first completed the hunger scale, followed by the pre-training IAT, the training

task, post-training IAT, and taste test. Subsequently, participants were asked to complete the

measures of inhibitory self-control and taste-test awareness, and to disclose background

information, including age, height and weight.

Data analysis

Calculating IAT scores. IAT scores from block 3 of the pre-training assessment and

the post-training assessment were calculated using the D600 algorithm (Greenwald, Nosek, &

1   Banaji, 2003), following the procedure specified for the analysis of single-category IATs by

2   Karpinski and Steinman (2006). Namely, participants with an error rate greater than 20%

3   were excluded from analysis ($n = 22$). However, the inclusion of these participants in

4   analyses did not change the pattern of results. Trials with response times of less than 350ms

5   or more than 10000ms were also discarded. Incorrect responses on the remaining trials were

6   replaced with the mean of the response times from that block plus an error penalty of 400ms.

7   Mean response times to food stimuli on congruent trials (where the food category shared a

8   response key with positive category) were subtracted from the mean response times on

9   incongruent trials (where the food category shared a response key with negative category).

10   The difference between congruent and incongruent trials was divided by the standard

11   deviation of all correct response times in the food trials to adjust for the effect of response

12   variability on scores (Greenwald, Nosek, & Banaji, 2003; Karpinski & Steinman, 2006).

13   Higher IAT scores indicate a more positive implicit evaluation of unhealthy snack food.

14   **Statistical analyses.** Independent samples *t*-tests were conducted to compare the

15   training conditions on baseline variables of age, BMI, hunger, pre-training implicit food

16   evaluations, and inhibitory self-control; and to compare intake between participants who were

17   aware and those who were not aware of the purpose of the taste test. The percentage of

18   participants indicating awareness of the taste test purpose was compared between conditions

19   using a chi square analysis. A one-sample *t*-test was conducted to assess whether pre-training

20   IAT scores were significantly different from zero.

21   As hunger and BMI have been found to play a role in implicit food evaluations,

22   inhibitory control, and eating behaviour (Hofmann et al., 2009; Nederkoorn, Guerrieri,

23   Havermans, Roefs, & Jansen, 2009; Seibt, Häfner, & Deutsch, 2007), we controlled for these

24   variables in statistical analyses.

1   A mixed model ANOVA compared changes in pre- to post-training implicit

2   associations between training conditions, and a univariate ANOVA compared intake between

3   the training conditions. Multiple regression analyses were conducted to assess the main

4   effects of inhibitory control, pre- and post-training food evaluation, and change in implicit

5   food evaluation from pre- to post-training on snack intake.

6   The SPSS macro PROCESS was used to test whether inhibitory control moderated the

7   effect of training condition on both post-training implicit evaluations controlling for pre-

8   training implicit food evaluations, and snack food consumption.

9   **Results**

10   **Preliminary analyses**

11   Descriptive statistics for baseline variables are shown in Table 1. Comparison of these

12   variables between participants assigned to the food positive training condition and the food

13   negative training condition revealed no significant differences. Participants evaluated

14   unhealthy food positively at pre-training, and a one-sample t-test revealed that the pre-

15   training implicit evaluation score was significantly different from zero, $t(125) = 7.80$, $p <$

16   .001, $d = 1.40$, 95% CI (0.07, 0.12).

17   Intake of snack food was significantly higher among participants who indicated

18   awareness of the purpose of the taste test ($n = 20$, $m = 1459.38$, $sd = 1216.18$) than those who

19   were not aware, ($n = 128$, $m = 835.13$, $sd = 608.67$), $t(20.51) = -2.25$, $p = .04$, $d = .65$, 95%

20   CI (-1201.59, -46.91). Therefore, in line with Coelho, Jansen, Roefs, and Nederkoorn (2009),

21   participants who indicated awareness of the purpose of the taste-test were excluded from

22   analyses of intake as they did not complete the taste-test measure of intake as intended.

23   Four outliers were detected in food consumption data. Deleting or changing these did

24   not exert a significant effect on the results: namely, any significant results did not change to

25   non-significant, and vice versa. Therefore, these participants were retained for analysis.

1   **Main effects**

2   **Effect of IAT training on change in implicit food evaluation.** A 2 (training

3   condition: food + positive, food + negative) x 2 (time: pre-training, post-training) mixed

4   model ANOVA was conducted to assess the effect of the training on implicit food evaluation.

5   As predicted, there was a significant interaction between training condition and time, $F(1,$

6    $124) = 5.00$, $p = .03$, partial $\eta^2 = .04$. Paired samples t-tests revealed that participants trained

7   to associate food with negative words showed a significant decrease in IAT scores (Figure 1),

8   indicating a more negative implicit food evaluation at post-training than at pre-training, $t(61)$

9    $= 3.88$, $p < .001$, $d = .46$, 95% CI (0.04, 0.11). However, participants trained to associate food

10   with positive words did not show a significant change in implicit food evaluation following

11   the training, $t(63) = 0.19$, $p = .85$, 95% CI (-0.04, 0.05).

12   **Effect of IAT training, inhibitory control, and implicit food evaluations on snack**

13   **food consumption.** A univariate ANOVA revealed that the training conditions did not differ

14   significantly on snack consumption (Table 1), $F(1, 120) = 1.22$, $p = .27$. Results of four

15   separate regression analyses showed that neither inhibitory control, $\beta = -0.04$, $t(3, 119) = -$

16   0.43, $p = .67$, 95% CI (-33.24, 21.38); pre-training implicit food evaluation, $\beta = 0.12$,

17   $t(3,103) = 1.24$, $p = .22$, 95% CI (-305.80, 1329.58); post training implicit food evaluation, β

18   $= 0.14$, $t(3,103) = 1.45$, $p = .15$, 95% CI (-155.22, 997.39), or change in implicit food

19   evaluation from pre- to post-training, $\beta = -0.06$, $t(3,103) = -.058$, $p = .57$, 95% CI (-768.30,

20   421.57), significantly predicted snack consumption.

21   **Moderation of training effects by inhibitory self-control.**

22   **Moderation of IAT training effect on change in implicit food evaluation.** The

23   SPSS macro, PROCESS (Hayes, 2012), was used to test whether inhibitory self-control

24   moderated the effect of training on post-training implicit food evaluations while controlling

25   for pre-training levels. The predictors (training condition and inhibitory self-control) were

1   first regressed on the outcome variable (post-training implicit food evaluation), and then the

2   interaction term (product of the predictors) was added to the model. The interaction term

3   (product of training condition and inhibitory self-control) did not significantly predict

4   implicit food evaluation at post-training, $B = -0.002$, $t(120) = -0.30$, $p = .76$, 95% CI (-0.02,

5   0.01), indicating that the effect of training condition on implicit food evaluation did not vary

6   according to participants' inhibitory self-control levels.

7   **Moderation of IAT training effect on snack intake.** A similar analysis was

8   conducted to assess whether inhibitory self-control moderated the effect of training on

9   consumption of unhealthy snacks. The interaction term (product of training condition and

10   inhibitory self-control) was a marginally significant predictor of intake, $B = -52.95$, $t(117) = -$

11   1.94, $p = .05$, 95% CI (-106.92, 1.02). To explore this interaction, simple slopes were

12   estimated at plus ("high") and minus ("low") one SD from the sample mean for inhibitory

13   self-control. As shown in Figure 2, training condition predicted snack food intake among

14   participants with low inhibitory self-control, such that those in the food negative condition

15   consumed less snack food than those in the food positive condition, $B = 320.24$, $t(117) =$

16   2.08, $p = .04$, 95% CI (15.58, 624.91). However, training condition did not predict snack food

17   intake among participants with high inhibitory self-control, indicating that snack intake

18   among those with high inhibitory self-control was not affected by the training they

19   completed, $B = -105.35$, $t(117) = -0.68$, $p = .50$, 95% CI (-410.78, 200.08).

20   **Additional analysis of awareness of taste-test purpose.**

21   Because there was a significant difference in snack intake between participants who

22   were aware of the purpose of the taste test and those who were not, we re-ran the previous

23   analysis including awareness as an additional predictor. The two-way interaction term

24   representing the product of training condition and awareness was a significant predictor of

25   snack intake, $B = -725.65$, $t(132) = -2.08$, $p = .04$, 95% CI (-1415.35, -35.95), indicating that

1   awareness of the purpose of the taste test moderated training effects on snack intake. As

2   shown in Figure 3, simple slopes analysis revealed that among participants who indicated

3   awareness of the taste test purpose, training condition fell just short of significance in

4   predicting snack food intake, with participants in the negative training condition eating more

5   than those in the positive training condition, $B = -608.06$, $t(132) = -1.86$, $p = .06$, 95% CI (-

6   1253.21, 37.10). However, training condition clearly did not predict snack food intake among

7   participants who did not indicate awareness of the taste test purpose, $B = 117.59$, $t(132) =$

8   0.95, $p = .34$, 95% CI (-127.78, 362.97). In addition, the two-way interaction term

9   representing the product of training condition and inhibitory control was not statistically

10   significant, $B = -49.25$, $t(132) = -1.65$, $p = .10$, 95% CI (-108.25, 9.76), indicating that with

11   all participants included in the analysis, inhibitory control did not moderate training effects

12   on intake. Furthermore, the three way interaction term (product of training condition,

13   inhibitory self-control, and awareness) was not a significant predictor of intake, $B = -45.02$,

14   $t(132) = -0.44$, $p = .66$, 95% CI (-245.32, 155.28), suggesting that the moderation of training

15   on intake by inhibitory self-control did not significantly differ between participants aware and

16   those not aware of the taste-test purpose.

17   **Discussion**

18   The current study used a modified IAT to change implicit evaluations of unhealthy

19   food and tested its effects on subsequent intake of unhealthy snack foods. The intervention

20   successfully modified implicit food evaluations; however a corresponding effect on snack

21   food intake was only found among participants with low inhibitory self-control.

22   **Effect of training on implicit food evaluations**

23   As expected, participants assigned to the food negative training condition showed a

24   significant change in their implicit food evaluations from pre- to post-training in the negative

25   direction. These results are consistent with previous studies showing that repeated pairing of

1   appetitive stimuli with negatively valenced stimuli changes implicit evaluations of those

2   stimuli to become more negative (e.g., Ebert et al., 2009; Houben, Havermans, et al., 2010;

3   Houben, Schoenmakers, et al., 2010; Lebens et al., 2011).

4   Participants in the food positive training condition in contrast, showed no change in

5   their implicit food evaluations. Some studies have shown a change toward a more positive

6   implicit evaluation of a food category following the pairing of food CS with positive US

7   (e.g., Lebens et al., 2011); however, in contrast to the current study, these studies trained

8   participants to develop positive attitudes toward healthy foods. The absence of an effect of

9   food positive training on implicit food evaluations here may have been due to a ceiling effect:

10 participants in our sample already evaluated unhealthy food very positively at pre-training.

11 The training may therefore only be effective at reversing an existing implicit positive food

12 evaluation, rather than making it stronger. A similar finding occurred in the alcohol domain

13 (but showing a floor effect), where participants were trained to associate alcohol with

14 negative concepts. Participants already showed a negative implicit evaluation of alcohol at

15 pre-training, and subsequently showed no significant change in implicit alcohol evaluations

16 from pre- to post-training (Houben, Havermans, et al., 2010).

17 **Moderation of training effects by inhibitory self-control**

18   As predicted, implicit evaluation training affected snack intake only for participants low

19 in inhibitory self-control. Specifically, training participants with low inhibitory self-control to

20 pair food with negative stimuli led them to consume less unhealthy snack food. It is likely

21 that their lower inhibitory control ability rendered the change in implicit food attitudes more

22 influential on subsequent eating behaviour (Hofmann et al., 2009; Hofmann et al., 2007). The

23 lack of training effects for participants with high inhibitory self-control could be attributable

24 to their enhanced capacity to inhibit unwanted impulses toward unhealthy food and act in a

25 manner consistent with their personal standards for healthy eating (Hofmann et al., 2009;

1   Hofmann et al., 2007). The current findings support previous research which has

2   demonstrated the moderating role of state inhibitory control, both measured (Hofmann et al.,

3   2009) and experimentally manipulated (Friese et al., 2008; Hofmann et al., 2007), in the

4   relationship between individuals' pre-existing implicit food evaluations and subsequent

5   eating behaviour. The current study extends this correlational work, in demonstrating for the

6   first time the moderating role of trait inhibitory self-control in the effect of experimentally-

7   manipulated implicit food evaluations on subsequent food consumption. Thus, the results

8   suggest that interventions targeting implicit food evaluations may only be effective at

9   changing subsequent food consumption for individuals low in inhibitory self-control.

10   By contrast, inhibitory self-control did not moderate the effect of training condition

11   on post-training implicit food evaluation after controlling for pre-training levels. This

12   indicates that the training protocol was effective at changing implicit evaluations of food for

13   all participants regardless of their level of inhibitory self-control. While individuals with

14   higher inhibitory self-control would be expected to be able to inhibit unwanted impulses and

15   act in a manner consistent with personal goals (e.g., limit unhealthy snack intake despite

16   positive evaluations of food, supported by the current results) (Deutsch & Strack, 2006;

17   Strack & Deutsch, 2004), there is no reason to expect that their impulses themselves would

18   be more resistant to change than for individuals with lower inhibitory self-control, which is

19   consistent with the finding that inhibitory self-control moderated the effect of training on

20   snack food consumption, but not implicit food evaluations.

21   **Theoretical implications**

22   Theoretically, the finding that inhibitory self-control moderates the relationship

23   between experimentally manipulated implicit food evaluations and subsequent food intake

24   supports dual process models of behaviour which posit that inhibitory control of impulses (an

25   operation of the reflective system) moderates the effect of impulses on behaviour (Deutsch &

1   Strack, 2006; Strack & Deutsch, 2004). Furthermore, although the effect of impulse change

2   (i.e., modification of implicit evaluations of unhealthy food) on subsequent consumptive

3   behaviour depends on inhibitory self-control, modification of impulses themselves does not.

4   This demonstrates that operations of the impulsive system are no more resistant to change

5   among individuals with high inhibitory self-control than those with low inhibitory self-

6   control, but rather that those with high inhibitory self-control evidence a dissociation between

7   these impulses and subsequent behaviour. This would hold true even in the direction that

8   would promote an increase in unhealthy behaviour, that is, a more positive implicit food

9   evaluation, as demonstrated by the finding that participants with high inhibitory self-control

10   ate less food in the food positive than the food negative training condition. In contrast, snack

11   consumption among participants with low inhibitory self-control was consistent with the

12   expected effects of the training conditions: those in the food positive condition ate more than

13   those in the food negative condition. A similar dissociation between impulses and eating

14   behaviour has been observed among individuals high in eating disorder symptomatology. In

15   particular, Ellis, Kiviniemi, and Cook-Cottone (2014) recently showed that only for

16   individuals with low levels of eating disorder symptomatology did implicit affective

17   associations with fruit predict their choice of fruit over snacks. This is consistent with both

18   dual process models, and with the current findings, as eating disorder symptomatology is in

19   part characterised by high levels of self-control over eating (Ellis et al., 2014).

20   Impulse control is a multifaceted construct. The current study focused on just one

21   aspect of impulse control, namely, trait inhibitory self-control. By contrast, Hofmann et al.

22   (2009) tested three subcomponents of impulse control: inhibitory control, executive attention,

23   and affect regulation, and demonstrated that each of these constructs independently

24   moderated the relationship between implicit candy attitudes and subsequent intake. Future

25   research could consider testing the moderating role of the various impulse control

1   subcomponents in an experimental design which manipulates implicit food evaluations as

2   was done in the current study, and thus contribute to a more comprehensive understanding of

3   the different aspects of impulse control.

4   **Practical implications**

5   The observation that inhibitory self-control moderates the effect of experimentally

6   manipulated implicit food evaluations on snack intake suggests that interventions that aim to

7   modify implicit attitudes toward food to reduce unhealthy eating behaviour may be most

8   suitable for individuals with low levels of inhibitory self-control. By contrast, interventions

9   that aim to increase the cognitive accessibility of the goal of weight management as a means

10 of reducing unhealthy eating may be better suited to individuals high in self-control. In

11 support, a correlational study by Haynes, Kemps, Moffitt, and Mohr (2014) showed that

12 cognitive accessibility of the goal of weight management predicted snack intake among

13 individuals with high levels of trait self-control, but not those with low self-control. Previous

14 interventions aimed at changing implicit food evaluations as well as those aimed at increasing

15 cognitive goal accessibility have produced inconsistent results (e.g., Ebert et al., 2009;

16 Harderwijk, 2010; Kroese, Adriaanse, Evers, & De Ridder, 2011; Walsh & Kiviniemi, 2013).

17 This may have been because individual differences in self-control were not taken into

18 account. The current findings demonstrate the value of screening individuals for inhibitory

19 self-control so as to tailor interventions to optimise their impact. For example, individuals

20 with low inhibitory self-control are likely to benefit from modification of implicit food

21 evaluations, while individuals with high self-control would most likely benefit from increased

22 cognitive goal accessibility. The inhibitory self-control scale may provide a useful brief

23 screening tool to select individuals for the particular intervention that is likely to be the most

24 effective at reducing unhealthy eating. Future research investigating this possibility would be

25 valuable.

1   **Limitations**

2   Like all studies, the current study is subject to a number of limitations. First, our

3   sample consisted of undergraduate students of mostly normal weight. Given the importance

4   of the development of interventions to manage (over)eating among overweight individuals,

5   future research should endeavour to generalise the current findings to this more representative

6   sample. Furthermore, we did not measure participants' motivation or explicit attitudes toward

7   healthy eating. Instead, participants identified themselves as being motivated to manage

8   weight through healthy eating. Therefore, we cannot be certain that the consumption of

9   participants with high inhibitory self-control is driven to a greater extent by those personal

10   standards than implicit food evaluations, or whether implicit food evaluations are just less

11   influential on their consumption relative to participants with low inhibitory self-control.

12   Future research along the lines of Hofmann et al. (2007), who assessed the impact of both

13   implicit candy attitudes and personal dietary standards on intake among participants in whom

14   inhibitory control resources had been experimentally depleted, could further elucidate the

15   decision-making processes of those with high versus low inhibitory self-control. Moreover,

16   as analyses in the current study were conducted on a subset of the total sample, a larger

17   sample size may have proven beneficial to provide greater power to detect effects.

18   Second, because the inhibitory self-control scale was administered after the taste-test,

19   it is possible that participants' food intake may have affected their responses on the self-

20   control scale. However, this scale is a trait measure, and thus should not be reactive to

21   experimental manipulation. In fact, inhibitory self-control scores did not differ between

22   training conditions, nor were they associated with food intake. By contrast, administering the

23   inhibitory self-control scale after the taste-test could have primed the concept of

24   'impulsivity', which has been found to impact subsequent caloric intake (Guerrieri,

25   Nederkoorn, Schrooten, Martijn, & Jansen, 2009). Nevertheless, counterbalancing the order

1   of all study elements could enable future research to more firmly establish the moderation of

2   the effect of implicit food evaluations on food intake by inhibitory self-control.

3   Third, we did not assess participants' awareness of the experimental training task

4   contingencies, which could have moderated the effect of training on snack consumption.

5   While some research has indeed found training effects only among participants who are

6   aware of the experimental task contingencies (Field & Duka, 2002), other studies have shown

7   that contingency awareness in cognitive bias modification and evaluative conditioning has no

8   impact on training effects (Baeyens, Eelen, & Bergh, 1990; Field et al., 2007; Field &

9   Eastwood, 2005). We did, however, assess participants' awareness of the purpose of the taste

10   test. This awareness did moderate the effect of training on intake, such that participants who

11   were aware of the taste-test purpose ate surprisingly more when trained to pair food with

12   negative concepts than when trained to pair food with positive. By contrast, participants who

13   were not aware of the purpose of the taste test showed a pattern of intake consistent with the

14   expected training effects: that is, they ate more when trained to pair food with positive

15   concepts than when trained to pair food with negative; however, this difference was not

16   statistically significant. The unexpected results of participants aware of the purpose of the

17   taste test may be due to reactance bias, in that they may have adjusted their intake in

18   reactance to their suspicions about the experimental manipulation or the taste test. However,

19   this possibility remains speculative as the current study did not include an assessment of

20   participants' awareness of the training task contingencies. Awareness of the purpose of the

21   taste test did not significantly moderate the combined effect of training condition and

22   inhibitory control on intake. Nevertheless, inhibitory self-control no longer significantly

23   moderated the effect of training condition on intake when participants who were aware of the

24   purpose of the taste test were included in the analysis. Taken together, the results of these

analyses highlight the importance of considering participants' awareness of the intentionally

hidden purpose of a task measuring intake.

Finally, in the absence of a no-training control group, it is not clear whether the

observed difference in snack intake between the two conditions is due to an increase in intake

among participants in the food positive condition, or a decrease in intake among those in the

food negative condition, or both. The inclusion of a control condition could enable more

definitive conclusions about the direction of the training effects on implicit food evaluations

and food intake.

Conclusion

In conclusion, the current study was the first to demonstrate that inhibitory self-

control moderates the relationship between experimentally manipulated implicit food

evaluations and subsequent consumption of unhealthy snacks. Theoretically, the results

support dual process models of behaviour which posit that the reflective system, represented

by inhibitory self-control, renders impulses less influential on behaviour. Specifically, the

current study demonstrated that experimentally manipulating impulses (implicit food

evaluations) impacted snack consumption among individuals low in inhibitory self-control,

but not those with high inhibitory self-control, suggesting that the behaviour of the latter

group of individuals is not driven by impulses. In addition, the current study has identified an

important individual differences variable that could identify individual suitability for an

intervention to reduce unhealthy eating, therefore maximising its impact for the many

individuals struggling to regulate eating in line with personal weight-management or health-

related goals (Cohen & Farley, 2008; Fishbach et al., 2003).

1   Acknowledgments

2   We are grateful to Paul Douglas for developing the software for the implicit

3   association tests.

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3