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Testing Go/No-Go training effects on implicit evaluations of unhealthy and healthy snack foods

Sandra Wittleder[a], Tilman Reinelt[b,c], Luiça Milanowski[d], Clare Viglione[e], Melanie Jay[a] and Gabriele Oettingen[f]

[a]NYU Grossman School of Medicine, New York, NY, USA; [b]Family Larsson-Rosenquist Foundation Center for Neurodevelopment, Growth, and Nutrition of the Newborn, Department of Neonatology, University of Zurich, Zurich, Switzerland; [c]Department of Neonatology, University Hospital Zurich, Zurich, Switzerland; [d]Department of Psychology, University of Hamburg, Hamburg, Germany; [e]UC San Diego Herbert Wertheim School of Public Health and Longevity Science, San Diego University, San Diego, CA, USA; [f]Department of Psychology, New York University, New York, NY, USA

ABSTRACT

Objective: Despite intending to eat healthy foods, people often yield to temptation. In environments rife with unhealthy food options, a positive implicit evaluation of unhealthy foods may inadvertently influence unhealthy choices. This study investigates if and under which conditions implicit evaluations of unhealthy and healthy foods can be influenced by a computer-based Go/No-Go (GNG) training.

Design: Undergraduate student participants ($N = 161$ participants; 117 females, 44 males; M_{age} = 19 years, $SD = 2$ years) completed a GNG training with two healthy (grape and nut) and two unhealthy (potato chip and cookie) stimuli. Participants were either instructed to inhibit their responses to the potato chip (No-Go Chips/Go Grape) or to a grape (No-Go Grape/Go Chips).

Main Outcome Measure: Implicit evaluations of chips and grapes were assessed using the Extrinsic Affective Simon Task.

Results: This GNG training impacted implicit evaluations of chips, but not grapes. GNG training effects were stronger for participants with lower sensitivity for behavioural inhibition measured with the Behavioural Inhibition System scale.

Conclusion: GNG training might help people change implicit food evaluations. More research is needed to understand how individual and training characteristics affect outcomes with the goal of tailoring and optimising the GNG training to produce the strongest effect.

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Go/No-Go training; implicit evaluations; unhealthy food; behavioural inhibition system (BIS); extrinsic affective Simon task (EAST)

Obesity rates have tripled over the past three decades in America and worldwide (Hales et al., 2020) Partly to blame are ubiquitous unhealthy and highly palatable foods (Cummins & Macintyre, 2006). The ease with which unhealthy foods can be obtained poses a constant challenge for individuals attempting to resist these foods to manage their weight. Behavioural interventions to support adults with obesity have focussed

CONTACT Sandra Wittleder sandra.wittleder@nyulangone.org Department of Medicine, NYU Grossman School of Medicine, 423 East 23rd Street, Room 15028CN, New York, NY 10010, USA.
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on providing education, teaching self-regulation skills, and building motivation and intention to change (LeBlanc et al., 2018; Whatnall et al., 2018). However, contrary to the belief that self-control and intention to make healthy eating choices are sufficient, dual-process theories posit that dietary behaviour is driven by controlled and automatic processes (Gawronski & Creighton, 2013; Kahneman, 2003; Strack & Deutsch, 2004). Cravings and reward-related eating can arise because unhealthy food can quickly and automatically capture attention and activate reward circuitry (Wang et al., 2004). Such positive implicit food biases are stronger among people with obesity, and indeed predict eating behaviour and weight gain (Nijs et al., 2010; Price et al., 2016; Yokum et al., 2011). Despite having the intention to avoid unhealthy foods, having a positive implicit association with unhealthy foods may still impact our choices, in particular when self-control is low or the environment is rife with temptation (Raghunathan et al., 2006). To help people make healthy food choices, research has more recently focussed on finding ways to reduce implicit biases towards unhealthy choices.

Researchers have explored using computer-based response inhibition training to target implicit food biases (Stice et al., 2016). Growing evidence suggests that such training can reduce unhealthy dietary behaviour and weight (Allom et al., 2016; Forcano et al., 2018; Jones et al., 2018; Lawrence, O'Sullivan, et al., 2015; Lawrence, Verbruggen, et al., 2015; Yang et al., 2019). An example is the computer-based Go/No-Go (GNG) training, in which people train to inhibit responses to images of foods (Houben & Jansen, 2011). Such training is based on the distractor devaluation effect, the phenomenon that ignoring or withholding a behavioural response to a stimulus can subsequently lead to a negative evaluation of this stimulus (Fenske & Raymond, 2006; Gollwitzer et al., 2014; Martiny-Huenger et al., 2014; Raymond et al., 2003; Veling et al., 2007). Findings, however, regarding the mechanisms and influencing factors underlying GNG training's effectiveness are not well understood (Veling et al., 2017).

Support for the proposed conceptual model that GNG training leads to devaluation stems from studies that have used explicit rather than implicit evaluation measures (Chen et al., 2016; Jones et al., 2016; Lawrence, Verbruggen, et al., 2015; Veling et al., 2008, 2013a, 2013b, 2017). Evaluations assessed explicitly allow time for deeper reflections and tend to be indicative of a person's conscious intentions or goals. In contrast, evaluations assessed implicitly, via quick responses, measure a person's automatic associations and tend to be indicative of impulsive behaviours or unconscious intentions or goals. Explicit and implicit measures of evaluations coincide often, but not always (Gawronski, 2019). To illustrate this, people often have healthy eating intentions, but not always make healthy choices. In this case, implicit measures of evaluation can predict unique variance in behaviour (Lindgren et al., 2015). To our knowledge, it is unknown whether GNG training affects implicit food evaluations.

Another limitation is that researchers may have overlooked potential moderators of devaluation effects. For instance, GNG training effects on dietary behaviour and weight are stronger among participants who reported high dietary restraint, who restrict or try to restrict food intake for weight control (Bazzaz et al., 2017; Houben & Jansen, 2011; Lawrence, Verbruggen, et al., 2015; Veling et al., 2011, 2014). Further, response inhibition training reduces food intake for those participants who had more difficulty with inhibiting unwanted behaviours (Houben, 2011). Another study has found stronger effects of GNG training on weight-loss for men, which might have been due to higher motivation regarding computerised game-like elements (Forman et al., 2021). In addition, the type of food used in the training and other training characteristics also matter. For instance, GNG training reduces food intake more for foods that are more regularly consumed and that are more desirable (Veling et al., 2013a, 2013b). Researchers, however, have yet to investigate if these individual and contextual factors also moderate devaluation effects assessed via implicit measures. There is some evidence that GNG training might not only decrease consumption of foods that people inhibit their responses to but also increase consumption of foods that people react to (Adams et al., 2017; Chen et al., 2019). Such an effect could be counterproductive if unhealthy foods are used or helpful, if healthy foods are used as stimuli. In fact, two studies have found GNG training increases attention to and selection of healthy foods (Chen et al., 2019; Kakoschke et al., 2014; Porter et al., 2018). Given that implicit food biases have been linked to weight gain and disordered eating eating (Paslakis et al., 2021; Yokum et al., 2011), understanding if and under which conditions a GNG training impacts implicit food evaluations of unhealthy and healthy foods is an important area of investigation. Therefore, the objective of this study is to investigate the effect of GNG training on implicit food evaluations of healthy and unhealthy food stimuli and explore potential moderators: restraint/disordered eating, behaviour regulation/control, food consumption habits, and gender. To study this, we created a GNG training task with pictures of unhealthy snack foods (a potato chip and cookie) and pictures of healthy snack foods (a grape and almond). Participants were randomly assigned to a No-Go Chips/Go Grape Group or a No-Go Grape/Go Chips Group. For the first group, participants inhibited their response to the image of a potato chip, while they reacted to the grape along with the two other snack food. For the second group, participants inhibited their response to the image of a grape while they reacted to the potato chip along with the two other snack foods. We predict that repeated inhibition to snack food pictures would lead to a more negative implicit evaluation of these foods (i.e. chips or grape, depending on experimental group assignment). We also explore if repeated reactions to snack food pictures would lead to a more positive implicit evaluation of these foods (i.e. chips or grape, depending on experimental group assignment).

2. Materials and method

2.1. Procedure and cover story

Study procedures were approved by the Institutional Review Board at New York University. Participants gave their informed consent before data collection began. The study was conducted in a computer lab using Inquisit 3.0 by Millisecond Software, an experimentation tool for measurements of response times with millisecond precision. Participants were allowed to ask the experimenter questions at any point.

The order of study operations was as follows. First, participants completed surveys and then they were randomly assigned to either the No-Go Chips/Go Grape Group or the No-Go Grape/Go Chips Group. Participants were presented with the following text:

> The next task assesses cognitive abilities. It will test executive functioning and inhibitory control. We are interested in how your preferences interact with executive functioning and inhibitory control. We are interested in how fast and accurately people perceive different

types of snacks. To measure the perceptual speed, you will participate in two tasks during which you will have to classify different types of snacks as fast and accurately as possible.

Subsequently, implicit evaluations of chips and grapes were assessed with the extrinsic affective Simon task (EAST) (De Houwer & Houwer, 2003). At the end of the experiment, participants were debriefed about the purpose of the study. The study lasted approximately 45 minutes and all participants received course credit for their time.

2.2. Participants

Based on a meta-analysis of procedures to change implicit measures, we expected a small to medium-to-small effect size (d = .24) (Forscher et al., 2019). To detect a repeated-measures, within-between interaction across the two experimental groups, power analysis indicated a minimum sample size of 160 participants, with $\alpha = 0.05$, $1 - \beta = 0.90$, and a correlation of r = .36 among repeated measures of implicit evaluation scores (Andrews et al., 2010). Anticipating that some participants may need to be excluded from data analysis due to missing data or failure to adhere to the protocol, we over-recruited until 172 undergraduate students had participated. We excluded participants with more than 20% RT outliers or error rates over 20% during the EAST (De Houwer & Houwer, 2003) ($n = 11$) to ensure a reliable assessment of the dependent variable (implicit evaluation). Thus we analysed the data of 161 (93.6%) of 172 participants.

2.3. Manipulation via a Go/No-Go task

We investigated a GNG training because GNG paradigms have shown stronger effects than other paradigms such as the Stop-signal training or an approach avoidance training for diet and weight outcomes (Allom et al., 2016). Pictures of either a potato chip, cookie, grape or almond were presented in black and white in front of a white background. In the No-Go Chips/Go Grape Group, participants were instructed to press the spacebar as fast as possible for every image except the potato chip. In this setup, the potato chip was the no-go stimulus and the three other images (grape, cookie, and almond) were the go stimuli. In the No-Go Grape/Go Chips Group, the grape was the no-go stimulus and the three other images (potato chip, cookie, and almond) were the 'go' stimuli, see Figure 1. As such the two experimental groups were identical regarding the number of stimulus presentations, sets of stimuli, and proportions of no-go trials. Image order was random, so that approximately 25% were no-go trials and 75% were key press or dominant trials (go tasks).

Each trial started with a fixation cross in the middle on a white background, which lasted for either 600, 900 or 1200 milliseconds (ms). Subsequently, the stimulus appeared and disappeared after the participant pressed the spacebar or 1200 ms had passed. Stimulus-onset time was varied in this way to prevent participants from anticipating when the next stimulus appeared, therefore ensuring they reacted to the stimulus and were not habituating to the time. A 500 ms break was set between the trials. After the instructions were given, 20 practice trials were completed in which a correct answer prompted a green check mark and a wrong, or no answer, prompted

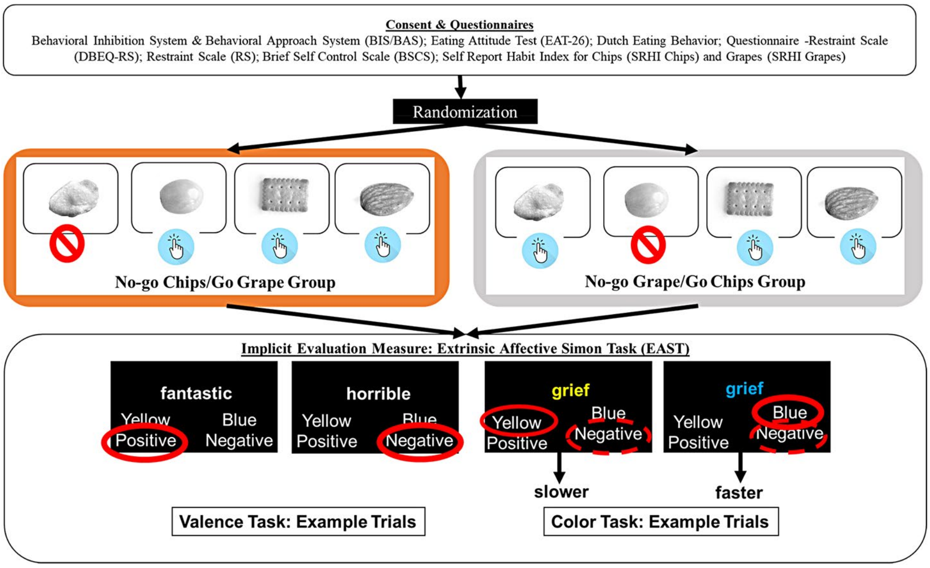

Figure 1. Schematic study design overview.

a red 'X'. After the practice, as well as after each block, participants were reminded of the rules. In total, five blocks, each with 80 trials, were completed. Stimuli and latencies of the fixation cross were chosen at random. In the test blocks, only the red 'X' appeared after wrong answers.

2.4. Measures

2.4.1. Dependent measure: extrinsic affective Simon task

To assess implicit evaluations of chips and grapes, we used the Extrinsic Affective Simon Task (EAST) (De Houwer & Houwer, 2003). We chose the EAST because it is suitable to assess implicit evaluations of a single target concept (e.g. chips and grape) compared to other measures like the Implicit Association Test, which assess implicit evaluations of categories (e.g. healthy and unhealthy) (De Houwer & Houwer, 2003; Greenwald et al., 1998). In our EAST, words were presented either in white or in colour (blue or yellow) on a black background. If the word was white, participants indicated whether the word had a positive or negative valence. White word stimuli were *fantastic*, *excellent,* and *beautiful* (positive) and *horrible*, *dreadful,* and *gruesome* (negative). If the word was coloured, participants had to ignore the word's valence and categorise it by its colour (blue or yellow). Coloured word stimuli were *joy* and *health* (positive), *pain* and *grief* (negative), and *chips* and *grape*. Although participants switched between these two tasks, the response keys were the same. Blue-coloured and negative words shared the 'A' key, and yellow-coloured and positive words shared the 'L' key.

The EAST started with 10 practice trials for the valence-categorisation task (only white words), 10 practice trials for the colour-categorisation task (only coloured words), and 15 practice trials that combined the two tasks of colour- and valence-categorisation (white and coloured words). After these 35 practice trials, participants completed 10 blocks, each consisting of 48 trials selected at random with each stimulus being presented at least one time. On average, out of 480 main trial consisted of 66.67% colour-categorisation trials (~11.1% positive words in blue, positive words in yellow, negative words in blue, negative words in yellow, ~5.6% chips in blue, chips in yellow, grapes in blue, grapes in yellow) and 33.33% valence-categorisation trials (~16.6% positive words in white and negative words in white). During the trials, category labels were presented on the bottom left and right of the screen to avoid participants' confusion, and to help them remember which key to press for each category. Each trial began with a white fixation cross in the centre of the screen. After 500 ms the stimulus appeared, and remained until the participant reacted by pressing either the response key ('A' or 'L' key). Error feedback was given by presenting the word error for 1000 ms in the centre of the screen. Between blocks, participants took self-timed breaks.

By repeatedly categorising words, the EAST stimulates a connection such that participants associated the 'L'-key with positive valence and yellow colour and they associated the 'A'-key with negative valence and blue colour. Typically, participants categorise positive words faster if they are presented in yellow compared to when they are presented in blue colour. Correspondingly, negative words are typically categorised faster in blue compared to yellow color. Following this logic, if participants associated chips as positive, they would be quicker to respond to the word *chips* presented in yellow (shared the same key as positive valence) compared to the word *chips* presented in blue (shared the same key as negative valence). Hence, as an indicator of the implicit evaluation of chips, for example, EAST Chips scores were calculated by subtracting the average reaction time on trials where the word *chips* was presented in yellow (associated with the positive valence key) from the average reaction time on trials where the word *chips* was presented in blue (associated with the negative valence key). Higher EAST Chips scores indicated a more positive implicit evaluation of chips. We used only switch trials (i.e. all color trials that were preceded by at least one valence trial; range: 38%-51% of trials per participant) because those trials should show larger compatibility effects and should therefore be most appropriate for measuring the implicit evaluations (Kiesel et al., 2010; Meiran, 2005; Voss & Klauer, 2007). Using the same approach, we computed EAST scores for color-categorisation trials that used the word *grape* (EAST Grape score), as well as for color-categorisation trials that used the positive words *joy* and *health* (EAST Positive score), and for color-categorisation trials that used the negative words *grief* and *pain* (EAST Negative score). The positive and negative scores served as validation to demonstrate that the EAST was able to measure implicit evaluations of negative and positive coloured words. Furthermore, we chose to compare our implicitly assessed EAST evaluation scores to positive and negative untrained items because this comparison allows meaningful interpretation of direction and strengths of evaluations of otherwise not intuitive to interpret EAST scores.

2.4.2. Moderator: behaviour regulation/control indicators

2.4.2.1. Behavioural Inhibition System/Behavioural Approach System (BIS/BAS) Scales. The BIS/BAS scales assess a person's sensitivity for behavioural inhibition and activation (Carver & White, 1994). BIS is thought to reflect an avoidance of aversive stimuli and is especially active in situations of goal conflict (e.g. when there are both signals of to approach and avoid). In contrast, BAS is associated with a higher sensitivity to rewards and appetitive stimuli. The BIS/BAS scales comprise a BIS scale of seven items and a BAS scale of 13 items that measure drive, reward responsiveness, and fun seeking. We computed a mean score for BIS and BAS with higher scores indicating participants are more sensitive to reward (BAS possible range: 0 to 4) and punishment (BIS possible range: 0 to 4), based on previous research (Kelley et al., 2019). Internal consistencies were high (BIS: α = .78; BAS: α = .82) and similar to previous studies varying from α = .66 to α = .76 (Carver & White, 1994).

2.4.2.2. Brief Self-Control Scale (BSCS). The BSCS assesses a person's perceived ability to control their thoughts, emotions, impulses, performance, and habits in favour of a pursued goal (Tangney et al., 2004). The BSCS consists of 13 items that are combined to a sum score with higher numbers indicating higher self-control ability (possible range: 13 to 65). Internal consistency was high (α = .80) and similar to previous studies (α = .89) (Tangney et al., 2004).

2.4.3. Moderator: restraint/disordered eating indicators

2.4.3.1. Restraint Scale (RS). The RS assesses the extent of a person's chronic motivation to control their weight by dieting (e.g. 'Do you give too much time and thought to food?'), and is related to consequences of mostly unsuccessful dieting and weight fluctuation (Herman, 1978). We computed a sum score with higher numbers indicating increased intention to restrict food intake (possible range: 0 to 35). Internal consistency was high (α = .81) and similar to previous studies (α = .78) (Laessle et al., 1989).

2.4.3.2. Dutch Eating Behaviour Questionnaire – Restraint Scale (DEBQ-R). The DEBQ-R assesses a person's intention and behaviour to restrain food intake and is related to more successful dieting behaviours (e.g. 'Do you deliberately eat foods that are slimming?') (van Strien et al., 1986). The DEBQ-R consists of ten items that are combined to a mean score with higher numbers indicating increased dietary restraint (possible range: 1 to 5). Internal consistency was high (α = .92) and similar to previous studies varying from α = .92 to α = .95 (van Strien et al., 1986).

2.4.3.3. Eating Attitude Test (EAT-26). The EAT-26 assesses a person's symptoms and concerns characteristic of eating disorders (DM et al., 1982; Garner & Garfinkel, 1980). The EAT-26 consists of 26 items that assess dieting (e.g. terrified of being overweight), food preoccupation and binge eating (e.g. being preoccupied with food), and oral control (e.g. displaying self-control around food). We computed a sum score with higher numbers indicating increased disordered eating tendencies (possible range: 0 to 78). Internal consistency was high (α = .87) and similar to previous studies (α = .83) (DM et al., 1982).

2.4.4. Moderator: food consumption habits

2.4.4.1. Self-Report Habit Index (SRHI). The SRHI assesses a person's habitual behaviours (Verplanken & Orbell, 2003). We adapted the index to assess habitual consumption of chips and grapes. The SRHI consists of 12 items that assess psychological constructs of a habit: a history of repetition, automaticity (lack of control and awareness, efficiency), and expressing identity. We computed a mean score with higher numbers indicating stronger habits (possible range: 1 to 7). Internal consistency was high (SRHI Chips: α = .90; SRHI Grapes: α = .94) and similar to previous studies varying from α = .89 to .95 (Verplanken & Orbell, 2003).

2.5. Statistical analysis

All analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0. A two-sided p-value < 0.05 was considered statistically significant. Study variables were summarised using descriptive statistics, with mean and standard deviation for continuous variables or frequencies and percentages for categorical variables. To assess baseline differences between group assignments (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips) we used independent t-tests for continuous variables and chi-square tests for categorical variables.

A mixed model ANOVA compared differences in implicit evaluations between groups. Greenhouse-Geisser correction was used when the assumption of sphericity was violated. To break down the interaction effects, we conducted two separate repeated measures (RM) ANOVAs with implicit evaluation word type (chips vs. grape vs. positive vs. negative) as within-subject factors for the No-Go Chips/Go Grape vs. No-Go Grape/Go Chips group, respectively.

To explore moderation effects of the GNG training task on implicit evaluations of the no-go food word, we specified separate between-person ANOVAs (one for each candidate moderator) with the factor Group (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips), the candidate moderator (e.g. BIS score) as continuous variables, and their interaction as predictors. We report effect size estimates to indicate if these variables warrant further investigation in future studies. Interaction terms with $p < .050$ were probed and plotted using Model 1 of the PROCESS macro for SPSS (version 3.04) provided by Hayes (2013).

Additional exploratory analyses examined associations between error rates on no-go trials and implicit evaluation by experimental group assignment in order to explore whether the effects of the GNG training depended on overall task performance (i.e. how well a person inhibited responses to no-go stimuli). These analyses were performed using Model 1 of the PROCESS macro for SPSS (version 3.04) provided (Hayes, 2013). The research data supporting this publication are openly available from https://doi.org/10.17605/OSF.IO/8GY6B

3. Results

3.1. Participant characteristics

All 161 participants (117 females, 44 males; M_{age} = 19 years, SD = 2 years) were undergraduate students. The average BMI was 22.53 kg/m^2 (SD = 3.63 kg/m^2), which falls within the normal range of 18.5 to 24.9 kg/m^2. The majority, almost two-third of participants, self-identified as female gender. Randomisation checks showed that the groups were well matched for baseline characteristics. The gender ratio was similar for both groups and there were no significant differences in age, BMI, or any of the survey measures: Behavioural Inhibition/Approach System (BIS/BAS Scales), self-control (BSCS), restraint or disordered eating indicators (DEBQ-R, RS, EAT-26), or habit strength for chips and grapes consumption (SRHI scales), all *ps* > .152, all *d*s < .23; see Table 1.

3.2. GNG training performance/data pre-processing

Overall errors rates ranged from 0-21% for go trials and from 0-15% for no-go trials. Mean error rates did not differ by experimental group for go trials and no-go trials, *ps* > .343. For calculating the mean go reaction time (goRT), we used only correct responses and excluded reaction times < 150 ms or > 3SDs from the individual z-standardised mean to reduce the influence of overly fast or slow responses. An average of 1.1% of trials per participant was excluded (range: 0–29%). We found that the average goRT was faster in the No-Go Grape/Go Chips Group versus the No-Go Chips/Go Grape Group, $t(159) = 2.79$, $p = .006$, see Table 1.

3.3. East performance/data pre-processing

Overall errors rates did not differ by group, $p = .825$. For reaction time analyses, we used only correct responses and excluded the first three trials of each block, which were considered practice trials. Although researchers concur *that* outliers should be excluded, they dispute the criteria on *how* outliers should be excluded (Berger &

Table 1. Characteristics of participants in the two experimental groups with significance tests.

	Total (*n* = 161)	No-Go chips/Go grape group (*n* = 77)	No-Go grape/Go chips group (*n* = 84)				
Gender	*N* (%)	*N* (%)	*N* (%)	*χ2*	*df*	*p*	OR
Female	117 (72.7%)	53(68.83%)	64(76.19%)	1.10	1	0.295	1.45
Male	44 (27.3%)	24(31.17%)	20(23.81%)				
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*t*	*df*	*p*	Cohen's *d*
Age[1]	19.46 (1.52)	19.45 (1.66)	19.48 (1.38)	−0.12	158	0.905	0.02
BMI[7]	22.52 (3.63)	22.67 (3.85)	22.39 (3.43)	0.48	152	0.635	0.08
BIS[2]	2.97 (0.64)	2.94 (0.69)	3.00 (0.58)	−0.63	157	0.531	0.10
BAS[5]	2.99 (0.51)	2.97 (0.50)	3.02 (.52)	−0.59	154	0.557	0.09
BSCS[3]	37.91 (8.61)	38.91 (9.27)	36.95 (7.86)	1.44	156	0.153	0.22
RS[6]	14.15 (6.38)	14.53 (6.91)	13.86 (5.86)	0.57	145.46	0.568	0.09
DBEQ-R[3]	2.69 (0.95)	2.70 (1.09)	2.69 (0.80)	0.04	139.21	0.969	0.01
EAT-26[4]	11.25 (10.15)	11.64 (10.39)	10.90 (9.98)	0.45	155	0.651	0.07
SRHI chips[4]	2.86 (1.26)	2.91 (1.34)	2.80 (1.17)	0.55	155	0.586	0.09
SRHI grapes[8]	3.22 (1.56)	3.18 (1.61)	3.24 (1.52)	−0.23	151	0.816	0.04
EAST errors (%)	6.87 (3.83)	6.80 (3.99)	6.94(3.71)	−0.22	159	0.825	0.04
EAST reaction time (ms)	589.09 (97.45)	579.90 (94.00)	597.51 (100.32)	−1.15	159	0.253	0.18
GNG: Go errors (%)	1.24 (2.61)	1.19 (2.68)	1.29 (2.57)	−0.23	159	0.820	0.04
GNG: No-go errors (%)	4.46 (2.59)	4.66 (2.67)	4.27 (2.52)	0.95	159	0.343	0.15
GNG reaction time (ms)	405.83 (30.12)	412.61 (27.81)	399.61 (30.98)	2.79	159	0.006	0.23

Note. BMI = Body Mass Index; BIS = Behavioural Inhibition System; BAS = Behavioural Approach System; BSCS = Brief Self Control Scale; RS = Restraint Scale; DBEQ-R = Dutch Eating Behaviour Questionnaire - Restraint Scale; EAT-26 = Eating Attitude Test; SRHI = Self-Report Habit Index; EAST = Extrinsic Affective Simon Task; GNG = Go/No-Go; Superscripts indicate number of missing values.

Kiefer, 2021). We excluded overly fast or slow responses because they likely indicate inattention to the task. Reaction times < 150 ms were excluded according to the assumption that it is not possible for humans to encode and respond to stimulus items that quickly (Whelan, 2008). Additionally, we also excluded reaction times > 3SDs from the individual z-standardised mean. A simulation study comparing reaction time outlier exclusion methods, recommended using SDs-based approaches because they showed small (absolute) biases, few Type-I errors, and excluded only small proportions of RTs overall (Berger & Kiefer, 2021). An average of 1.7% of trials per participant was excluded (range: 0-4%). The average reaction time on the EAST did not differ between groups, p = .253, see Table 1.

Because our decisions regarding the exclusions and selection of relevant trials may have introduced bias, we repeated our analysis without the lower limit cut-off of 150 ms and an upper limit cut-off of reaction times > 2 SDs from the individual z-standardised mean. These different cut-off criteria did not alter the pattern of results (see supplemental material).

To demonstrate that the EAST was able to measure implicit evaluations of negative and positive coloured words, we used a mixed effects ANOVA with the within-person factor Word Valence (Positive vs. Negative) and the between-person factor Group (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips). Results confirmed the main effect of Word Valence, $F(1, 159) = 77.01$, $p < .001$, and, as expected, neither a significant effect of Group, p = .991, nor a significant interaction effect between Word Valence X Group, p = .848. The EAST Positive Score was significantly higher (M = 48.51 ms, SD = 9.97 ms), indicating greater positivity, compared to the EAST Negative Score (M = −35.38 ms, SD = 9.76 ms).

3.4. GNG training effects on implicit evaluations of healthy and unhealthy snack food

To examine the effect of the GNG manipulation on implicit evaluations of no-go and go word stimuli (i.e. chips and grape), we conducted mixed effects ANOVAs with the between-person factor Group (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips) and the within-person factor Word Type (Positive vs. Negative vs. Grape vs. Chips). We found a significant interaction, Greenhouse-Geisser corrected $F(2.48, 394.99) = 2.89$, p = .045, η^2_p = .035 (see Figure 2). Between-person t-tests indicated that group assignment had a significant effect on the EAST Chips score, $t(142.04) = -2.39$, p = .018, but not on the EAST Grape score, p = .541, or the positive word EAST score, p = .919, or the negative words EAST score, p = .933.

Within the No-Go Chips/Go Grape, follow-up within-subjects contrasts indicated that the EAST Chips score was significantly lower (more negative), M = −24.92, SD = 129.36, than the EAST Grape score, M = 18.24, SD = 160.23, $F(1,76) = 5.72$, p = .019, and the EAST Positive score, M = 49.53, SD = 145.34, $F(1,76) = 25.55$, p <.001. The EAST Chips score did not differ significantly from the EAST Negative score, M = −36.19, SD = 130.67, $F(1,76) = .85$, p = .359.

Within the No-Go Grape/Go Chips group, follow-up within-subjects contrasts indicated that the EAST Chips score, M = 38.72, SD = 203.77, was not different from

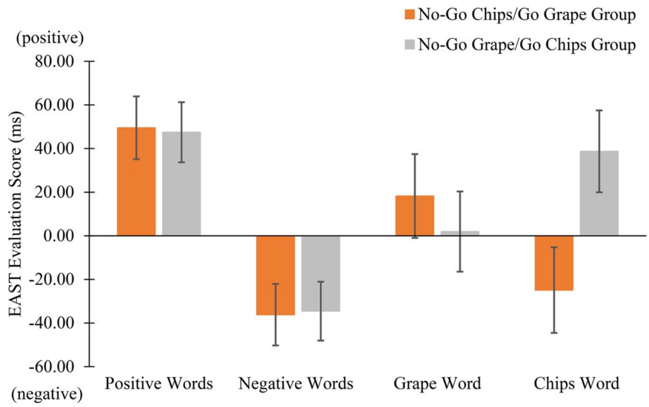

Figure 2. Group assignment by word type interaction effect on mean implicit evaluation scores of positive words, negative words, grape word, and chips word.*Note*. Bars represent standard errors.

the EAST Grape score, $M = 1.95$, $SD = 176.08$, $F(1,83) = 1.45$, $p = .232$, or the EAST Positive Score, $M = 47.50$, $SD = 105.95$, $F(1,83) = 0.11$, $p = .742$, but it was significantly higher than the EAST Negative Score, $M = -34.56$, $SD = 117.08$, $F(1,83) = 7.56$, $p = .007$.

3.5. Exploratory moderation analysis

3.5.1. Moderation effects on implicit evaluation of chips

We conducted a series of between-person ANOVAs with the factor Group (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips), candidate moderators as continuous variables, and their interaction as predictors, and implicit evaluations of chips as dependent variable. With regard to behavioural inhibition (BIS), a significant main effect of group assignment on the implicit evaluation of chips, $F(1, 155) = 6.93$, $p = .009$, partial $\eta^2 = .04$, was further qualified by BIS, $F(1, 155) = 4.93$, $p = .028$, partial $\eta^2 = .03$. There was no additional main effect of BIS, $F(1, 155) = 0.31$, $p = .579$, partial $\eta^2 = .002$. The implicit evaluation of chips was more negative in the No-Go Chips/ Go Grape than in the No-Go Grape/Go Chips and this effect was particularly strong for participants with lower values of BIS (16th percentile), $t = -3.14$, $p = .002$, while absent in participants with higher values of BIS (84th percentile), $t = 0.24$, $p = .808$, see Figure 3. For all other candidate moderators (see Table 2), interaction terms were not significant, *ps* > .065.

3.5.2. Moderation effects on implicit evaluation of grapes

We conducted a series of between-person ANOVAs with the factor Group (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips), candidate moderators as continuous variables, and their interaction as predictors, and implicit evaluations of grapes as dependent variable. None of the candidate moderators reached significance, see Table 2 for statistics and effect size estimates.

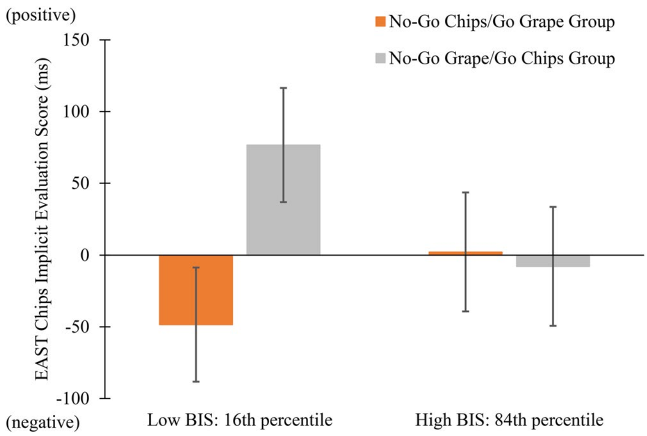

Figure 3. Group X Behavioural Inhibitions Scale (BIS) interaction on the implicit evaluation of chips.*Note*. BIS = Behavioural Inhibition System Scale. Bars represent standard errors. Low BIS = 16[th] percentile = 2.29, High BIS = 84[th] percentile = 3.71.

Table 2. Group X candidate moderator interactions on the mean implicit evaluation scores of chips and grapes.

	EAST chips score			EAST grape score		
Predictor (interactions)	*F*	*p*	η_p^2	*F*	*p*	η_p^2
Group X BIS	**4.93**	**.028**	**.03**	.04	.840	.00
Group X BAS	.02	.876	.00	2.90	.091	.02
Group X BSCS	2.28	.133	.02	.20	.655	.00
Group X RS	1.28	.260	.01	.01	.913	.00
Group X DEBQ-R	.51	.475	.00	.09	.761	.00
Group X EAT-26	.30	.589	.00	.05	.826	.00
Group X SRHI	.96	.330	.01	1.36	.246	.01
Group X Gender	3.45	.065	.02	.44	.510	.00

Note. BIS = Behavioural Inhibition System; BAS = Behavioural Approach System; BSCS = Brief Self Control Scale; RS = Restraint Scale; DBEQ-R = Dutch Eating Behaviour Questionnaire - Restraint Scale; EAT-26 = Eating Attitude Test; SRHI = Self-Report Habit Index. Significance values p < .050 are in bold

3.5.3. Moderation by GNG training performance

We further investigated whether the implicit evaluations of chips, respectively grape, depended on the performance in the GNG training. We therefore conducted two between-person ANOVAs with the factor Group (No-Go Chips/Go Grape vs. No-Go Grape/Go Chips), inhibition error rate, and their interaction as predictors, and implicit evaluations of chips, respectively grape, as dependent variable.

Regarding the evaluation of chips, results indicated no main effect of group, $F(1, 157) = 0.10$, $p = .758$, $\eta^2 < .01$, but a main effect of inhibition error rate, $F(1, 157) = 5.38$, $p = .022$, $\eta^2 < .03$. Participants who committed more inhibition errors evaluated chips more positively. However, this association was independent of group assignment as the interaction of group and inhibition error rate was non-significant, $F(1, 157) = 3.37$, $p = .068$, $\eta^2 < .02$.

Regarding the evaluation of grapes, results indicated no main effect of group, $F(1, 157) = 1.58$, $p = .211$, $\eta^2 < .01$, but a main effect of inhibition error rate, $F(1, 157) = 6.25$, $p = .013$, $\eta^2 < .04$. Participants who committed more inhibition errors evaluated grapes more negatively. However, this association was independent of group assignment as the interaction of group and inhibition error rate was non-significant, $F(1, 157) = 3.69$, $p = .057$, $\eta^2 < .02$.

4. Discussion

This novel study demonstrated that a GNG training changed implicit evaluations of unhealthy snack food (chips), but not healthy snack food (grape). Participants instructed to inhibit their responses to chips and react to grapes (No-Go Chips/Go Grape), implicitly evaluated chips more negatively than participants instructed to inhibit their responses to grapes and react to chips (No-Go Grape/Go Chips). However, implicit evaluations of grapes did not differ by training group.

4.1. GNG performance and implicit evaluation effects

Participants' average response times on go-trials were faster in the No-Go Grape/Go Chips Group than in the No-Go Chips/Go Grape Group. As stimuli in the two GNG training groups were identical, these differences suggest that participants responded faster on chips trials than on grape trials. This could be due to a greater desirability of chips as compared to grapes as unhealthy foods are typically perceived as tastier than healthy food (Raghunathan et al., 2006). Moreover, slower response times could reflect greater task difficulty such that inhibiting responses to the more desirable chips is more difficult than inhibiting responses to the less desirable grape, leading to higher response times.

Participants who committed more inhibition errors (i.e. responded to the no-go stimulus) evaluated chips more positively and grapes more negatively. Although, the interaction term between group assignment and inhibition error rates was not significant ($p = .068$ and $p = .057$), for participants who committed more inhibition errors (i.e. 84th percentile = 6.88% inhibition errors), we observed a stronger effect of group assignment on the implicit evaluation of chips. Interestingly, the same pattern was observed regarding the implicit evaluation of grapes. For participants who committed more inhibition errors (i.e. 84th percentile = 6.88% inhibition errors), we observed a stronger effect of group on the implicit evaluation of grapes. It has been demonstrated that the strength of the devaluation effect might depend on the amount of inhibition needed (Frischen et al., 2012). Thus, devaluation of the no-go stimulus should be greater in participants who find the GNG task more difficult. Thus, future studies should power their sample to be able to detect such interaction effects. If task difficulty actually influences devaluation this would offer a target to individualise GNG training to optimise devaluation effects (e.g. by manipulation of reaction time deadline or different distractor go stimuli) (Benikos et al., 2013; Ramos-Loyo et al., 2017).

4.2. Integrating study findings with the behaviour stimulus interaction (BSI) theory and the devaluation-by-inhibition hypothesis

Our finding that a GNG task impacted implicit evaluations provides support for the Behaviour Stimulus Interaction (BSI) theory, which states that the distractor devaluation effect stems from the response conflict between an approach tendency towards a stimulus and response inhibition. During GNG training, conflict results from the predominant approach reaction towards a high-value stimulus while also actively withholding a response. BSI assumes that because conflict is an inherently aversive signal, the experience of negative affect gets linked to the conflicting stimulus (Dreisbach & Fischer, 2012, 2015). As such, grapes may have generated less 'response conflict' because they may be perceived as less desirable (than chips).

On the other hand, the devaluation-by-inhibition hypothesis assumes that devaluation of no-go stimuli occurs because no-go stimuli interfere with the focal task of responding, and devaluation eases task execution (Fenske & Raymond, 2006; Gollwitzer et al., 2014). This hypothesis would predict that both chips and grapes would be devaluated equally since both GNG training tasks included the same number of stimulus presentations, sets of stimuli, and proportions of no-go trials. Hence, in both experimental groups no-go stimuli should interfere similarly with the task. Although our finding that the GNG task did not impact the implicit evaluations of grapes challenges a strict devaluation-by-inhibition hypothesis, our results might imply that the difficulty to inhibit responses may also depend on type of stimuli, which then may impacts the strengths of devaluation.

4.3. Individual moderators of the GNG training effect on implicit evaluation

Our findings suggest that GNG training effects on the implicit evaluation of chips were more pronounced among study participants, who reported lower sensitivity for behavioural inhibition (i.e. who have a lower tendency to avoid negative stimuli or conflict). One explanation may be that people who are less sensitive to avoidance may have more difficulty inhibiting their responses and stronger devaluation might aid them in performing the GNG task. We did not observe that GNG training effects differed by restraint or disordered eating indicators among our student sample, which is in contrast to previous studies that have demonstrated stronger GNG training effects on diet and weight among participants who report higher dietary restraint (Houben & Jansen, 2011; Lawrence, Verbruggen, et al., 2015; Veling et al., 2011). We also did not find the GNG training effects on implicit evaluations differed depending on how habitually foods were consumed, which is in line with another study that has found training effects on explicit devaluations for both appetitive and less appetitive food (Chen et al., 2018). Together our exploratory analysis provide preliminary evidence that some individual factors (e.g. behavioural inhibition) may already affect the evaluation of food stimuli automatically and other factors (e.g. restraint eating) may operate later at the behavioural stage or via different mechanisms.

4.4. Strengths and limitations

To the best of our knowledge, we present the first study that systematically investigates (1) response inhibition effects on implicit food evaluations, (2) response training of healthy and unhealthy snack food, and (3) important moderators within a single experimental setting. A significant study strength is that we show GNG effects on implicit food evaluations, which were measured via quick responses and tend to be indicative of impulsive responses. This finding is in line with other work suggesting that GNG training particularly affected food choices when they are made within a short time limit (1500 milliseconds), and not when unlimited time was provided to respond (Chen et al., 2021).

Effects of GNG training on implicit evaluations have been shown only in the context of alcohol consumption (Bowley et al., 2013; Houben et al., 2011, 2012). Lack of findings in the context of unhealthy foods might be because the definition of unhealthy food, in contrast to alcoholic beverages, may be less clear as dietary recommendation have been changing over time and people's level of nutrition literacy may differ (Carbone & Zoellner, 2012). GNG training effects, which seem to be specific to the stimuli used, might not generalise easily to a heterogeneous category such as unhealthy foods (Lawrence, Verbruggen, et al., 2015). Thus, instead of focussing on unhealthy foods as a category, in this study, we manipulated and measured specific healthy and unhealthy food items (i.e. grapes versus chips). As such, instead of using the Implicit Association Test, which is suitable to assess implicit evaluations of concepts (e.g. healthy and unhealthy) as it uses a block-switch structure, we chose the EAST, which is suitable to assess implicit evaluations of a single stimuli (e.g. chips and grape) as it uses a trial-switch structure (De Houwer & Houwer, 2003).

Another difference to previous research involving GNG is the absence of external cues, a visual (border color) or auditory (tone), to indicate whether people should respond or not respond to a food stimulus (Veling et al., 2017). Instead of using an external cue, participants in our study were instructed to execute or inhibit their response to chips or grapes (depending on group assignment). In this way, the identity of the stimulus functions as the cue, which assures that participants are aware stimulus-response contingencies. Some studies suggest that GNG training might be more effective if people are aware of the intended effect of the manipulation (Chen et al., 2021; Noel & Petzel, 2020). Thus, instructing participants to inhibit their responses to specific unhealthy food items may boost GNG effectiveness.

While most research has focussed on the devaluation of unhealthy foods, recently, researchers have begun to explore whether there may also be a valuation of foods that people react to (go stimuli), which could hold promise as a tool to encourage consumption of healthy foods (Kakoschke et al., 2014; Porter et al., 2018). Our results, however, indicate that, on an implicit level, the grape as healthy snack foods were not more positively evaluated when used as go stimuli. In contrast, chips, when used as go-stimuli, were more positively evaluated on an implicit level. This may be important as researchers and intervention developers begin curating GNG training paradigms for use in clinical practice. It might be prudent to avoid unhealthy foods as a 'go' stimuli to prevent unintended consequences of encouraging consumption of unhealthy foods.

A limitation of this study is that moderation analyses were not adequately powered to detect interaction effects. Our findings, thus, require replication in a larger study. Another limitation is a lack of a pre-post comparison of implicit evaluations. We decided against assessing implicit evaluations pre and post the GNG training given that both tasks are computerised reaction time paradigms, which are typically exhausting for participants. To reduce participant burden and avoid attention depletion effects that would have impacted our ability to reliably assess our dependent variable (implicit evaluations), we avoided a baseline assessment. Instead, we decided to add positive and negative words as control stimuli to provide reference responses to aid interpretation of the implicit evaluation scores.

In addition, rather than including a category of healthy or unhealthy foods, our GNG training used four stimuli of which only one was to be ignored. This limits the study's external validity as real-world interventions typically do not aim to reduce the intake of a single food but rather a variety of unhealthy foods. However, results of this and previous research implicate that GNG training effects may not transfer well to an unhealthy food category in general (Lawrence, Verbruggen, et al., 2015). Thus, to be most effective, GNG may need to be personalised to include specific foods a person wants to avoid.

Further, because we recruited a student population, it is not clear if findings may be generalisable to other populations. For example, based on findings that people with a BMI in the obese range tend to have stronger implicit attention biases towards unhealthy foods and stronger responses to inhibition training on their diet and weight, we would expect to also see stronger GNG training effects on implicit food evaluations.

5. Conclusion

In this novel study of GNG training we found that GNG training impacted implicit evaluation of unhealthy foods and the effects were stronger for those who reported lower sensitivity for behavioural inhibition. Our findings suggest that GNG training effects may depend on individual and task characteristics. To optimise training effects, we believe it is imperative to carefully assess and investigate such factors in future studies.

A better understanding of the underlying mechanism of GNG training would enable us to optimise interventions to more effectively change people's unhealthy diets. Further, understanding who benefits most from these kinds of training paradigms would allow healthcare providers and behavioural interventionists to make personalised recommendations to ultimately increase treatment efficacy. Future work should investigate other moderating factors that could further personalise treatment, along with testing GNG effectiveness in real-world and clinical settings with more diverse populations with obesity.

Authors' contributions

SW, TR, and GO developed the study hypotheses and study design. SW and TR designed data collection tools and developed intervention materials and protocols. SW and TR devised the statistical analysis plan. SW implemented the study. SW and TR performed the data analysis and interpretation. SW, TR, CV, and LM drafted the manuscript, and MJ and GO provided critical revisions. All authors approved the final version of the paper for submission.

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Availability of data and materials

The data that support the findings of this study are openly available at https://doi.org/10.17605/OSF.IO/8GY6B

Ethics approval

All study procedures were approved by the Institutional Review Boards at NYU (IRB-FY2018-1201). All methods were performed in accordance with the principles stated in the Declaration of Helsinki. Written informed consent was obtained by all participants prior to any data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

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ORCID

Sandra Wittleder http://orcid.org/0000-0003-2108-404X
Tilman Reinelt http://orcid.org/0000-0003-0951-5927
Clare Viglione http://orcid.org/0000-0003-0958-8229
Melanie Jay http://orcid.org/0000-0001-7343-3120
Gabriele Oettingen http://orcid.org/0000-0002-6139-1493

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