Maastricht University

Computerized neurocognitive training for improving dietary health and facilitating weight loss

Citation for published version (APA):

Forman, E. M., Manasse, S. M., Dallal, D. H., Crochiere, R. J., Loyka, C. M., Butryn, M. L., Juarascio, A. S., & Houben, K. (2019). Computerized neurocognitive training for improving dietary health and facilitating weight loss. *Journal of Behavioral Medicine*, *42*(6), 1029-1040. https://doi.org/10.1007/s10865-019-00024-5

Document status and date:
Published: 01/12/2019

DOI:
10.1007/s10865-019-00024-5

Document Version:
Publisher's PDF, also known as Version of record

Document license:
Taverne

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy
If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.

Download date: 12 Mar. 2022

J Behav Med (2019) 42:1029–1040
https://doi.org/10.1007/s10865-019-00024-5

Computerized neurocognitive training for improving dietary health and facilitating weight loss

Evan M. Forman[1] · Stephanie M. Manasse[1] · Diane H. Dallal[1] · Rebecca. J. Crochiere[1] · Caitlin M. Loyka[1] · Meghan L. Butryn[1] · Adrienne S. Juarascio[1] · Katrijn Houben[2]

Received: December 24, 2018 / Accepted: March 2, 2019 / Published online: March 19, 2019
© Springer Science+Business Media, LLC, part of Springer Nature 2019

Abstract Nearly 70% of Americans are overweight, in large part because of overconsumption of high-calorie foods such as sweets. Reducing sweets is difficult because powerful drives toward reward overwhelm inhibitory control (i.e., the ability to withhold a prepotent response) capacities. Computerized inhibitory control trainings (ICTs) have shown positive outcomes, but impact on real-world health behavior has been variable, potentially because of limitations inherent in existing paradigms, e.g., low in frequency, intrinsic enjoyment, personalization, and ability to adapt to increasing ability. The present study aimed to assess the feasibility, acceptability, and efficacy of a gamified and non-gamified, daily, personalized, and adaptive ICT designed to facilitate weight loss by targeting consumption of sweets. Participants ($N = 106$) were randomized to one of four conditions in a 2 (gamified vs. non-gamified) by 2 (ICT vs. sham) factorial design. Participants were prescribed a no-added-sugar diet and completed 42 daily, at-home trainings, followed by two weekly booster trainings. Results indicated that the ICTs were feasible and acceptable. Surprisingly, compliance to the 44 trainings was excellent (88.8%) and equivalent across both gamified and non-gamified conditions. As hypothesized, the impact of ICT on weight loss was moderated by implicit preference for sweet foods [$F(1,95) = 6.17$, $p = .02$] such that only those with higher-than-average implicit preference benefited (8-week weight losses for ICT were 3.1% vs. 2.2% for sham). A marginally significant effect was observed for gamification to *reduce* the impact of ICT. Implications of findings for continued development of ICTs to impact health behavior are discussed.

Keywords Inhibitory control training · Health behavior · Diet · Obesity · Weight loss · Gamification

✉ Evan M. Forman
emf27@drexel.edu

[1] Drexel University, Philadelphia, USA

[2] Maastricht University, Maastricht, The Netherlands

Introduction

An estimated 70% of Americans are overweight, and a key contributing factor is poor dietary intake (National Center for Health Statistics, 2013–2014). Sugar consumption is especially problematic due to its high energy density, palatability and ubiquity (World Health Organization, 2015). As a result, more than half of American adults consume added sugars in excess of major dietary guidelines (Bowman et al., 2017; US Department of Health & Human Services, 2017). Of note, sugar consumption is also associated with other health concerns such as systemic inflammation, heart disease, metabolic disturbances and cancer (De Koning et al., 2012; Peeters et al., 2017; Schulze et al., 2004). Major dietary guidelines recommend limiting intake of foods high in added sugars, and link reduced consumption of sugary foods to weight loss and numerous associated health benefits (Hu, 2013).

While many adults attempt to lose weight and reduce sweets consumption, biologically-based taste preferences for sugar make doing so exceptionally difficult (Drewnowski, 1997; Drewnowski et al., 2004; Drewnowski & Greenwood, 1983). The gaps between intention and behavior can be explained by the dual-process model of self-control. This model posits that the consumption of hedonic foods like sweets is governed by a balance between powerful, prepotent impulses toward reward-driven behavior and a reflective system that employs cogni-

tive control to rein in these impulses and to align behavior with long-term goals (Metcalfe & Mischel, 1999; Strack & Deutsch, 2004). In order for the reflective system to control behavior, it must suppress reward-driven behavior via a basic cognitive capacity called “inhibitory control” (i.e., a cognitive ability governed by the prefrontal cortex that enables witholding an automatic or prepotent response; Logan et al., 1997). Those who have stronger preferences (especially on an implicit level) for hedonic foods are theorized to have an increased need for inhibitory control to achieve goal-consistent dietary behavior (Hofmann et al., 2008).

Consistent with the dual-process model, poor inhibitory control has been shown to predict unhealthy eating (e.g., Friese et al., 2008), unsuccessful dieting (e.g., Jansen et al., 2009), obesity (e.g., Nederkoorn et al., 2006), and weight gain (e.g., Nederkoorn et al., 2010). Despite the fact that inhibitory control plays a critical role in restraining reward-driven, goal-inconsistent (or unhealthy) consumptive behaviors, conventional interventions are incapable of specifically enhancing inhibitory control capacity and thus may fail to equip individuals with skills needed to curb powerful, reward-driven impulses.

Although conventional interventions do not target inhibitory control, evidence suggests that inhibitory control can be trained (e.g., Houben & Jansen, 2011). Specifically, computerized inhibitory control trainings (ICTs) have been developed that involve repeatedly inhibiting automatic responses to targeted stimuli (e.g., food) presented on a computer screen using key presses (Allom et al., 2016; Jones et al., 2016; Spierer et al., 2013). Importantly, ICTs not only strengthen inhibitory control capacity, but also produce behavioral transfer, i.e., the trained inhibitory response to computer-based stimuli (e.g., palatable food) translates into real-life inhibition of the corresponding behavior (e.g., inhibiting food intake; Dahlin et al., 2008; Houben, 2011). For example, ICTs have been effective in reducing consumption of targeted food/beverages such as chocolate (Houben & Jansen, 2015), snack foods (Houben, 2011), and beer (Houben et al., 2012), and have achieved short-term weight loss (Lawrence et al., 2015; Preuss et al., 2017; Veling et al., 2014). One interesting debate in the literature concerns whether the effects of ICT are indeed transmitted through improvements in inhibitory control. While some mediation results support this supposition (Jones et al., 2016), others have argued and shown that ICTs in fact strengthen implicit associations between stimuli and a “no-go” response via bottom-up processing (vs. top-down inhibitory control; Best et al., 2016; Veling et al., 2017).

Despite mounting evidence for the effectiveness of ICT, the extant literature also contains limitations. These limitations include (1) inhibitory control improvements are often measured in the laboratory, thereby lacking ecological validity (Turton et al., 2016); (2) outcomes are assessed just hours or days after the completion of training, precluding conclusions about longer-term effects (Jones et al., 2016, 2017); (3) several studies have failed to achieve the behavioral transfer of inhibitory control, which may be due to methodological limitations of ICT (e.g., use of an unorthodox inhibition training paradigm) (Giel et al., 2017; Guerrieri et al., 2012); (4) most evaluations of ICT use single-session trainings, whereas evidence shows repeated trainings are needed to enact change (Blackburne et al., 2016; Kühn et al., 2017); (5) most ICTs fail to personalize stimuli, which likely better equips individuals to translate inhibition abilities to the real world (Schonberg et al., 2014; Veling et al., 2011); and (6) many ICT trainings are not adaptive to performance, i.e., consistently challenging inhibition accuracy to produce persistent gains (Benikos et al., 2013; Vinogradov et al., 2012). Moreover, specifically in terms of weight loss, some outcomes are in question because they have been self-reported by unblinded participants (Lawrence et al., 2015) and confounded by a therapeutic intervention (Preuss et al., 2017).

Newly-designed ICT paradigms for changing real-world health behavior should perhaps be modified to take into account the points just reviewed. For instance, ICTs should personalize stimuli to match individual’s behavioral patterns. In addition, the difficulty of ICTs should vary as participants’ capacity increases, so that inhibition continues to strengthen. Also, ICTs should be repeated frequently and for an extended period of time, and thus take place in the home where such repetition is feasible. In addition, strategies should be developed to enhance interest and engagement in ICT. One such strategy that is receiving increasing attention is gamification, i.e., feedback (e.g., sounds, graphics), rewards for performance (points, badges, levels, special powers), and a unified story (with consistent actions, sounds, graphics, etc.; Boendermaker et al., 2013). Gamification has been successfully applied to a number of cognitive training paradigms (Anguera et al., 2013; e.g., inhibition, attention, switching; Boendermaker et al., 2013; Johnstone et al., 2017; Prins et al., 2011; Van Schie & Boendermaker, 2014). Of special relevance, children in an inpatient obesity treatment program lost weight when assigned to a 6-week, 25-session gamified inhibitory-control-plus-working-memory-training (Verbeken et al., 2013). However, efficacy was not definitely established as the control (usual care) left several confounds in place (e.g., exposure to goal salience-increasing stimuli). Some limited evidence exists that gamification increases enjoyment and adherence (Boendermaker et al., 2013; Lumsden et al., 2016). Yet, several studies have found that training games are not rated as particularly enjoyable by participants once they have been played for a

short time (Johnstone et al., 2017; Van Schie & Boendermaker, 2014; Verbeken et al., 2013) and may not outperform non-gamified versions (Poppelaars et al., 2018).

As such, the present study aimed to assess the feasibility, acceptability and efficacy of a gamified and non-gamified, daily, personalized, and adaptive ICT that facilitated weight loss by targeting consumption of sweets. We hypothesized that ICT would produce greater weight losses than a sham training and that gamification of the training would enhance compliance and therefore potency. We also aimed to examine change in inhibitory control as a mechanism of action in facilitating weight loss as a result of the training and hypothesized that improvements in inhibitory control would explain the effect of ICT on weight change. Thus, we further sought to test the hypothesis (drawn from the dual-process model) that individuals with higher implicit preference for sweet foods would derive the greatest benefit from the training. To achieve these aims, we randomized overweight and obese individuals to undergo an 8-week training in one of four conditions using a 2 (gamified vs. non-gamified) by 2 (active vs. sham training) factorial design.

Methods

Design

This study utilized a 2 (gamified vs. non-gamified; gamification factor) by 2 (ICT vs. sham training; training factor) factorial design. Participants were randomized to one of four conditions that allowed for evaluating the main and interacting effects of each factor: ICT game, ICT non-game, sham game and sham non-game.

Participants

Participants (N = 106) were adults between the ages of 18 and 65 and a BMI between 25 and 50 kg/m^2 from the Philadelphia area, recruited using postings on social media and the web, mass transit, newspaper and radio advertisements, and postcards. Inclusion criteria included baseline consumption of three or more servings of high-sugar foods daily. Additionally, participants needed to have an internet-enabled computer in their homes. Exclusion criteria included medical or psychiatric conditions that could interfere with the ability to comply with diet recommendations, pregnancy (or planning to become pregnant in the next 12 months) or current breastfeeding, a history of bariatric surgery, weight loss of five percent or more within the last 6 months, and beginning or changing a dosage of a weight-affecting medication within the last 3 months.

Procedure

All participants completed a preliminary phone screen with an assessor and attended a baseline assessment to confirm eligibility. During the baseline assessment, participants provided their informed consent, and completed a series of tasks and surveys. The assessment and training schedules are depicted in Fig. 1.

Prior to randomization, all participants attended a 2-h workshop in which they were provided with a dietary prescription (to eat only foods without added sugar or with very low amounts of added sugar, such as certain low-sugar breakfast cereals) as well as guidance in making dietary modifications (e.g., reading food labels, shopping and cooking substitutions). Explanatory text, figures, and tables that allowed participants to easily identify targeted foods with added sugar were distributed. Each workshop included five to ten participants and an interventionist with training in lifestyle modification. Participants were then assigned, over 8 weeks, to complete 42 daily and 2 weekly 10-min trainings delivered on their home computers via the Unity 3D game engine (Unity3D Game Engine, 2016). In-lab research assessments were conducted at three time points: baseline (week 0), post-treatment (week 6) and post-booster (week 8).

Training conditions

Gamification

Gamification included a premise of moving as fast as possible through a grocery store and putting the correct food in a grocery cart (while refraining from choosing the incorrect foods; see Fig. 2). The game also included surrounding graphics (3D animated grocery store, aisles, scoreboards), sound (background music and action sounds), and rewards/reinforcements (points, badges, levels). Points were awarded for correct items placed in carts. Story and design elements of the gamified training were absent from non-gamified training, such that participants were shown stimuli on a blank black screen.

Inhibitory control training (ICT)

While both a Go/No Go and a Start Stop Task have been used as ICTs, we selected a Go/No Go (GNG) paradigm (Allom et al., 2016; Jones et al., 2016; Veling et al., 2017) in the current trial given evidence that GNG paradigms are more successful than the Stop Signal Task in engaging response inhibition and producing changes in real-world behavior (Allom et al., 2016; Jones et al., 2016; Veling et al., 2017). In the GNG, participants must respond to a

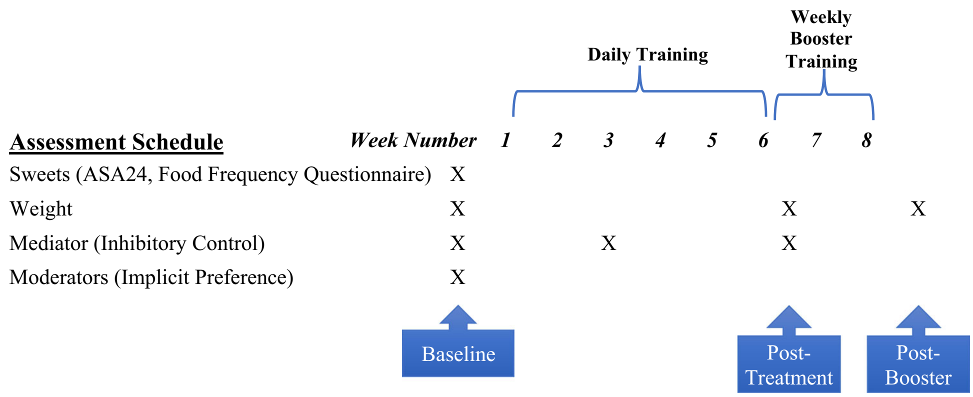

Fig. 1 Assessment and training schedules

Fig. 2 Screenshot from gamified inhibitory control training

frequently-presented stimulus and inhibit their responses to an infrequently-presented non-target (Allom et al., 2016; Jones et al., 2016; Spierer et al., 2013). The frequent responding to a presented target establishes a "prepotent" or automatic, response towards a stimuli, and withholding one's response represents successful response inhibition. In food-based ICTs, food and non-food stimuli are typically accompanied simultaneously by a Go or No Go signal (e.g., a letter or color outline) that signifies to the participant whether he/she should "go" (i.e., press a key) or No Go (i.e., withhold a response) (Allom et al., 2016; Jones et al., 2016; Spierer et al., 2013). In each trial of ICT, participants were presented with one of three types of stimuli: a high-sugar food (always paired with No Go; 25% of trials), a healthy food such as a fruit or vegetable (always paired with a Go signal; 25% of trials), or a neutral item that can be found at a grocery store such as foil or toothpaste (50% paired with a Go and 50% paired with No Go signal). We used a green checkmark as the Go signal, and a roach as the No Go signal, with the hopes that pairing an aversive signal with the high sugar foods would strengthen the effect of the training by reducing implicit preference for such foods (Hofmann et al., 2008, 2009; Porter et al., 2018). Participants were instructed that, for Go items, they should press "q" when the item was on the left side of the screen and "p" when on the right side of the screen, as quickly as possible.

Given evidence that trainings need to be sufficiently difficult to produce a robust effect on inhibitory control (Benikos et al., 2013; Vinogradov et al., 2012) the difficulty of the training was modified to participants' abilities. Specifically, participants were initially allowed 1000 ms to press a key for Go trials, but this amount of time (latency) decreased (i.e., became more difficult) or increased (i.e., became less difficult) by 50 ms depending on whether the participant scored above an accuracy threshold at the end of each block (Benikos et al., 2013; Vinogradov et al., 2012). This threshold was itself dynamic such that it started at 80% correct, increased by 3% (up to a maximum of 98%) if the threshold was exceeded, and decreased by 3% (down to a minimum of 80%) if the threshold was not exceed. By decreasing the latency to respond to stimuli, the Go response becomes increasingly automatic (better approximating an automatic behavioral approach response to sweet foods), making inhibition of the response more challenging. Conversely, latency increased (became less difficult) when the participant scored below a lower-bound accuracy threshold at the end of each block. This threshold started at 75%, and increased (up to 93%) or decreased (down to 75%) by 3% depending on whether the threshold was exceeded or not. In the training task, there were 8 blocks of 50 trials (for a total of 400 trials). Task difficulty (i.e., allowed latency to respond) was adjusted based on participant performance at the end of every block of 50 trials. In other words, participants were required to reach increasing levels of accuracy in order to move to the next level of difficulty of the task. Latency to respond (and threshold levels) carried over from training session to training session. A task ceiling (i.e., easiest level) was set at a latency of 1200 ms and the floor (i.e., most difficult) at a latency of 600 ms.

After each trial, during a 1000 ms inter-stimulus interval, participants received feedback, i.e., correct (checkmark) or incorrect ("X" symbol) that also served as a

fixation point. Accuracy of responses is typically used as the outcome variable for the GNG, however, due to the adaptive nature of the task, it is likely that individuals who performed better made equivalent or greater number of mistakes than those who did not improve, as reaching a more difficult level may lead to committing more errors. As such, for this ICT, time allotted to respond to stimuli (i.e., response latency) was utilized as the measure of inhibitory control, with lower response latency representing greater inhibitory control ability. The sham conditions were designed to control of attention, stimuli exposure and expectations and experimenter demand. Thus, they were identical to ICT conditions except that no stop signals were presented. i.e., participants were instructed to sort stimuli (regardless of type) based on where they appeared on the screen (left or right), as quickly as possible.

Tailoring of sweet foods

All conditions, including sham conditions, included sweet food stimuli personalized to individual preferences for sweet consumption. We created a "library" of 116 sweet food stimuli. For each participant, an individualized library of 35 food stimuli was created based on the sweets that the participants ate the most frequently. Of these 35 sweet food stimuli, 15 stimuli were chosen based on direct matches (e.g., Snickers chocolate bar, Pepsi, Kellogg's Frosted Flakes) and 20 stimuli were chosen based on category matches (e.g., candy bars, breakfast cereals and bars, baked goods and other desserts, sweet drinks). The rationale for category matching was to reduce the likelihood that participants would substitute one sweet (e.g., Kit Kat) for another similar one (e.g., Snickers).

Assessments

Satisfaction and acceptability

Participants used a Likert scale of 1 (completely disagree) to 5 (completely agree) to rate how easy, fun, and boring the computerized training was to use, as well as whether they would continue using it at the completion of the study, if allowed.

Baseline sweets consumption

For the purposes of eligibility and tailoring training stimuli, we measured baseline sweets consumption using two measures. The *Food Frequency Questionnaire* (FFQ) is a self-report measure in which participants select the average frequency of consumption of various foods in a specified time period (Feskanich et al., 1993; Hu et al., 1999). The FFQ was modified for the current project to include only high sugar foods. Another measure of sweets consumption was the *ASA24*, a free software tool that enables self-administered, but interactive, 24-h dietary recalls via a web browser on a home computer (Subar et al., 2012). Measurements were not repeated after baseline because of poor participant acceptability (ASA24) and staff error (FFQ).

Weight

Weight was measured utilizing a standardized Seca® scale at baseline, post-treatment, and post-booster.

Implicit preference for sweets

The *Implicit Association Test* (IAT) requires participants to respond quickly to images on a computer screen so that an immediate and uncensored association between two constructs is assessed. In the instructions, participants were presented with two affective categories ("good" and "bad") and two target food categories (healthy and sweet). Participants sorted images into "good" or "bad" categories using respective keys ("e" or "i") as quickly and accurately as possible. For half of the test blocks, participants classified stimuli from one target (e.g., cookies) and other positive stimuli with "good" with one response key, and the other target (e.g., healthy) and negative stimuli with "bad" with the other response key. In the other half of blocks, participants completed the reverse combination of targets and attributes (e.g. sweets with "bad" and healthy food with "good"). Blocks were counterbalanced. "Good" pictures were meant to elicit a positive response (e.g., puppies), and "bad" negative response (e.g., spiders). In each of the four test blocks, stimuli were presented in for 2000 ms, preceded by an interstimulus white box for 500 ms. A differential (d score) was calculated representing the difference in speed between sorting sweets together with "good" and sorting sweets together with "bad." We calculated the mean latencies in responses for the "compatible" blocks (in which participants classified food and "good" together) and the incompatible block (in which participants classified food with "bad"). As per Greenwald (Greenwald et al., 2003), we then divided the difference between test block latency means by the standard deviation of the latencies. The larger the d score, the stronger the implicit preference for sweets (i.e., the stronger the association was between sweets stimuli and "good" compared to sweets with "bad"). Negative d scores represent weaker associations between sweet stimuli and "good." IAT measures have good construct validity (Nosek et al., 2005) and internal consistency (.80) (Banse et al., 2001; Egloff & Schmukle, 2002).

Table 1 Baseline characteristics by condition

	ICT game (n = 27); M (SD)	ICT non-game (n = 29); M (SD)	Sham game (n = 27); M (SD)	Sham non-game (n = 23); M (SD)	Test statistic
Age	47.48 (6.73)	47.86 (8.76)	46.11 (9.27)	47.56 (9.03)	$F(3,102) = .23$, $p = .88$
% Male	11.1%	6.9%	7.4%	8.6%	χ^2 (3) = .38, $p = .95$
BMI	32.76 (4.86)	34.16 (6.28)	33.71 (5.30)	33.50 (5.58)	$F(3,102) = .31$, $p = .82$
%Non-white	25.9%	28.6%	22.2%	13.0%	χ^2 (3) = 1.92, $p = .59$

Table 2 Acceptability and satisfaction ratings by gamification

Satisfaction/acceptability item[a]	Overall (n = 106); M (SD)	Non-game (n = 52); M (SD)	Game (n = 54); M (SD)	Test statistic
Easy to use	3.98 (.96)	4.02 (.96)	3.94 (.97)	$t(97) = .68$, $p = .68$
Had fun when using	3.07 (1.08)	3.15 (.97)	3.00 (1.18)	$t(97) = .67$, $p = 51$
Would continue using	3.43 (1.18)	3.54 (1.10)	3.33 (1.26)	$t(97) = .88$, $p = .38$
Boring	2.75 (1.17)	2.67 (1.08)	2.82 (1.26)	$t(97) = .66$, $p = .51$

[a]All items were rated from 1 (completely disagree) to 5 (completely agree)

Statistical analysis

Analyses were conducted in SPSS version 25. Data were inspected visually for outliers. The expectation maximization algorithm was used to impute missing weight data to account for the impact of missingness on other variables. All analyses were conducted using imputed values (i.e., based on an intent-to-treat approach; Little & Yau, 1996) and with available data. Results were equivalent, and thus the full intention-to-treat dataset results are reported.

Outcomes included percent of initial body weight lost at post-treatment (week 6) and post-booster (Week 8). Compliance was computed by dividing the number of trainings completed by the total number of assigned trainings across the 6-week daily training period and was also computed by week. To examine differences in overall compliance by condition, a univariate analysis of variance (ANOVA) was conducted. To examine differences in compliance over time by Gamification (i.e., game or non-game), a repeated measures ANOVA was conducted with week as the within-subjects factor and Gamification factor as the between-subjects factor. To examine the effect of factor (training [i.e., ICT or sham] and gamification) on percent weight change at post-treatment and post-booster, a 2 × 2 ANOVA, with main effects and interactions of Training and Gamification, was conducted. In other words, although there were four treatment conditions, conditions were collapsed by factor to increase statistical power to isolate the impacts of training and gamification. Implicit preference towards sugary foods was examined in a separate (grand-mean centered) model via the addition of a main effect for implicit preference, 2-way interaction terms (e.g., implicit preference × training and moderator × gamification) and a 3-way interaction term (i.e., implicit preference × training × gamification). To examine the association between changes in inhibitory control and weight change (not available for sham conditions), residualized change in inhibitory control from baseline to mid-treatment (week 3) was correlated with percent weight change at post-treatment and post-booster separately.

Results

Baseline characteristics

The sample was 91.5% female, and was 77.1% White, 16.2% Black, 4.8% Hispanic, 1.0% Asian and 1.0% Multiracial. Age was 47.25 ± 8.4 years (mean ± SD) and starting BMI was 33.54 ± 5.4 kg/m^2. As seen in Table 1, baseline characteristics did not differ by treatment condition.

Acceptability and compliance

See Table 2 for self-reported ratings of acceptability (overall and by gamification); we detected no statistically significant differences in acceptability and satisfaction ratings by gamification. Participants assigned to a sham condition also rated satisfaction and acceptability equivalently high (e.g., "Would continue using" M_{Sham} = 3.33 (SD = 1.33), M_{ICT} = 3.53 (SD = 1.03), $t(88.51) = .82$,

p = .42) suggesting that the sham condition was perceived as credible by participants.

Overall compliance across the daily training period and training conditions was 88.8% (SD = 17.05) with no significant differences by Gamification, $F(3,102) = .12$, $p = .95$, $\eta_p^2 = .00$. A repeated measures ANOVA with week (1–6) as the within-subjects factor demonstrated that compliance with the trainings decreased significantly over time across conditions [$F(3.19, 328.71) = 9.63$, $p < .01$, $\eta_p^2 = .17$]. Compliance by week is depicted in Fig. 3. In order to examine whether gamification impacted compliance over time, we examined gamification as a moderator (i.e., we conducted a factorial ANOVA in which week was the within-subjects factor and gamification was the between-subjects factor). Unexpectedly, Gamification had no moderating effect on the relation between week and compliance [$F(3.19, 328.71) = .25$, $p = .87$, $\eta_p^2 = .00$], indicating that compliance decreased similarly in the game and non-game conditions.

Attrition

Overall attrition was 12.3%, and did not differ by treatment condition [ICT game = 14.8%, ICT non-game = 13.8%, sham game = 7.4%, sham non-game = 13.0%, Wald $X^2(3) = .83$, $p = .84$].

Effect on percent weight loss

A 2 × 2 factorial ANOVA revealed no significant main effects of training ($F(1,102) = .00$, $p = .98$, $\eta_p^2 = .00$) or gamification [$F(1,102) = 2.63$, $p = .11$, $\eta_p^2 = .03$] and no significant training × gamification interaction [$F(1,102) = .03$, $p = .87$, $\eta_p^2 = .00$] on percent weight loss at post-treatment. At post-booster, there was no main effect of training [$F(1,102) = .10$, $p = .75$, $\eta_p^2 = .00$], however, the effect of gamification was marginally statistically significant [$F(1,102) = 2.84$, $p = .095$, $\eta_p^2 = .03$] such that gamification was associated with *less* weight loss. The training × gamification interaction at post-booster was not statistically significant [$F(1,102) = .20$, $p = .67$, $\eta_p^2 = .00$; see Fig. 4].

Moderation effects

See Table 3 for 2-way and 3-way interactions of training and gamification on implicit preference for sweets. As hypothesized, IAT moderated the effect of training, both at post-treatment (marginally significant) and post-booster. Specifically, those with higher implicit preference for sugary foods showed a demonstrable benefit from randomization to ICT versus sham; e.g., among those who demonstrated above-average implicit preference for sweets, the 8-week weight losses were 3.1% for ICT versus 2.2% for sham (see Fig. 5). As a way of examining the clinical significance of the training × IAT interaction, we utilized a logistic regression to examine the main and interacting effects of Training and IAT in predicting the likelihood of reaching 3% weight loss, a benchmark chosen based on the minimum value of weight loss thought to have meaning, the short (8-week) period, the low intensity of the intervention, and findings of mean losses ranging from 1 to 3% in similar-intensity interventions (Hartmann-Boyce et al., 2015; Tsai & Wadden, 2009). The training × IAT interaction was statistically significant, such that the combination of high IAT and ICT was most likely to result in 3% weight loss, Wald $X^2(1) = 6.76$, $p < .01$, OR 1.78. [36.0% of sham reached 3% vs. 48.3% ICT].

Mechanism

Inhibitory control significantly improved from pre- to post-treatment [$t(84) = 20.04$, $p < .01$] for those in ICT conditions (weekly inhibitory control data was not available for those in sham conditions). Notably, 71% of participants reached the "ceiling" (i.e., maximum difficulty) of the training task by week 3 of the training. Residualized

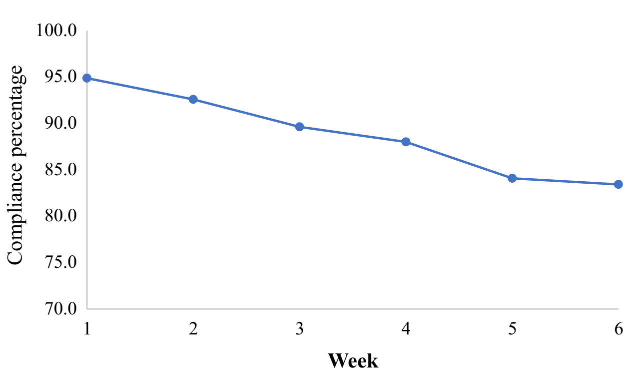

Fig. 3 Compliance by week

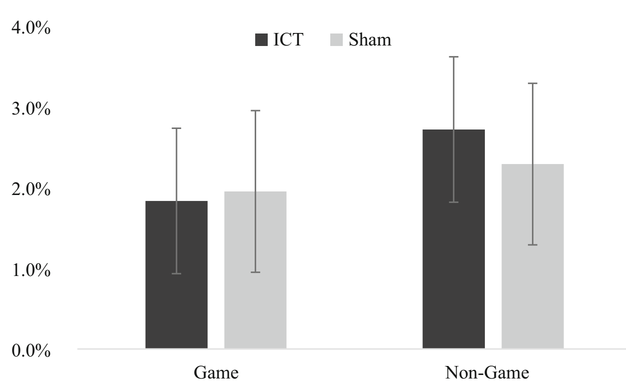

Fig. 4 Training × gamification interaction on percent weight loss at post-booster (week 8). Note: Error bars represent standard error

Table 3 Moderation effects of implicit preference

Effect	*df*	*F*	*p*	η_p^2
Post-treatment (week 6)				
IAT (main effect)	1,95	.15	.70	.00
IAT × training	1,95	3.39	.07	.03
IAT × gamification	1,95	.00	.98	.00
IAT × training × gamification	1,95	1.79	.18	.02
Post-booster (week 8)				
IAT (main effect)	1,95	.04	.85	.00
IAT × training	1,95	6.17	.02	.06
IAT × gamification	1,95	.06	.80	.00
IAT × training × gamification	1,95	2.30	.13	.02

IAT implicit attitudes test

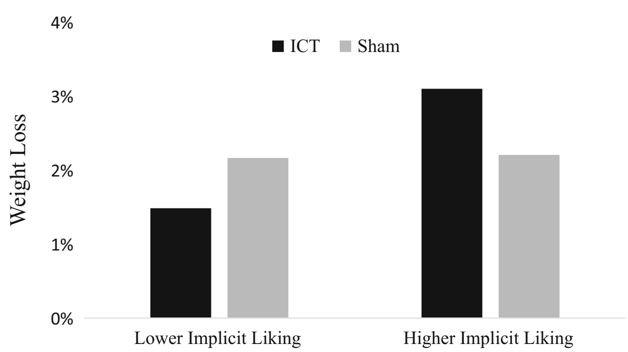

Fig. 5 Implicit preference × training interaction on weight loss at post-booster (week 8). Note: Implicit liking was included as a continuous moderator in analyses, but is dichotomized (using a median split) here for graphing purposes

change scores in inhibitory control from week 1 to week 3 were significantly associated with prospective percent weight loss at post-treatment ($r = .22$, $p = .03$) such that greater improvements were associated with greater percent weight loss. However, this association was not statistically significant for percent weight loss at post-booster ($r = .17$, $p = .10$). Implicit preference did not change significantly from pre- to post-treatment [$t(89) = -.14$, $p = .89$].

Discussion

This study examined the feasibility, acceptability and effectiveness of a gamified and non-gamified 6-week daily ICT (plus two weekly boosters) targeting sweets consumption in order to facilitate weight loss among a group of individuals with overweight or obese BMIs. This home computer-based ICT proved feasible to deploy, despite the complexity of developing four versions (an active ICT and a sham version, crossed with a gamified and non-gamified version) and of personalizing the ICT stimuli to the sweets most commonly eaten by each participant (in order to maximize potency). In addition, participants indicated they found the daily training satisfactory, that it became part of their daily routine and that they wished to continue the trainings if they were available. Consistent with these self-reports, participants showed excellent compliance across the 42 daily and two once-weekly trainings. In terms of effectiveness, only a subgroup of participants—those with higher implicit preference for sweets—benefited from randomization to ICT versus the sham control. Yet for those who were above the average on this moderator, the effects of ICT were notable. In fact, the rate of weight loss for this subgroup (across 8 weeks) is roughly equivalent to in-person behavioral weight loss treatment (Diabetes Prevention Program Research Group, 2004). In terms of clinical significance, nearly half of the ICT participants reached our weight loss threshold (3%) versus only one-third of sham. This moderator effect is aligned with several previous studies that have also detected that ICT has greatest impact for those at higher levels implicit preference for the target being trained (Houben & Jansen, 2011; Veling et al., 2011). Consistent with the dual process model, training inhibition may be most warranted for subsets of individuals with the strongest implicit preference or drive towards the target.

It was hypothesized that adding gamification elements to the ICT training would improve acceptability and compliance, and therefore efficacy. Not only was this hypothesis unsupported, it appeared that gamification slightly *reduced* the impact of ICT. One possible explanation for this unexpected finding is that gaming elements (visual surround, music, sound effects) distracted from attention to the core stimuli, reduced the strength of prepotent reward response and thus reduced the fidelity the inhibitory response. Moreover, the underlying premise—i.e., that compliance and satisfaction would be poor for the non-gamified versions—appeared to be false. That is, even

participants receiving the non-gamified version of the training displayed excellent compliance and indicated they liked engaging in the training. Thus, our results, echoing others' (Poppelaars et al., 2018; Van Schie & Boendermaker, 2014; Verbeken et al., 2013), suggest it not worth expending the considerable effort and resources entailed in developing gamified versions of ICT. On the other hand, some gamifications of cognitive trainings have appeared to be successful (Boendermaker et al., 2013; Prins et al., 2011). Importantly, although overall compliance remained very good even by the end of treatment, some minimal drop-off was observed. Given the relatively short-term nature of this study, with only two once-weekly booster sessions, it is unknown what compliance and effectiveness would have looked like over a long stretch of time for this population. Perhaps gamification (or some other form of engagement device) would be necessary to prevent poor compliance for later, long-term deployments given those are most likely necessary to sustain weight loss.

One unexpected result was that even participants receiving the sham training lost a fair amount of weight. The psychoeducational workshop was a very low intensity intervention (i.e., 2 h), and previous findings demonstrate that low intensity interventions do not produce weight loss in similar time spans. However, it is conceivable that the relative simplicity of a no-added sugar dietary prescription facilitated short-term caloric reduction even with minimal intervention time. An alternate possibility is that there was an unintended positive effect of the sham training. For example, engaging in a daily training and seeing images of healthy and unhealthy foods may have served as a relatively powerful boost of goal salience which has been shown to have independent efficacy in modifying dietary behavior (Freund & Hennecke, 2012). In any case, perhaps the ICT effects among those with higher implicit preference for sweet foods are even more impressive against the baseline of a potent control.

In terms of mechanism of effects, we detected indirect evidence of the training acting through improvements in inhibitory control. Specifically, those receiving ICT showed improvements in inhibitory control and these improvements were associated with weight loss at the end of the daily trainings. Not all ICTs have demonstrated impact on inhibitory control; perhaps our paradigm did so because trainings were repeated frequently, we adapted difficulty to ability gains and personalized stimuli to participant consumption patterns. However, our mechanistic evidence is limited in several respects, including that the training task was used as the measure of inhibitory control performance and that we did not have a way to compare improvement in the sham group. Notably, despite prior findings that ICT impacts implicit preference (Best et al., 2016; Veling et al., 2017), and our attempts to maximize this effect with an evaluative conditioning version of a stop signal (a roach), we detected no effect at all of the training on implicit preference for sweets. Taken together, our findings support (in a qualified fashion) that change in inhibitory control, and not implicit preference, is the active ingredient of ICT.

This study contained a number of limitations that should guide interpretation of study findings. Perhaps most importantly, the study period was short-term, i.e., 8 weeks. Thus, the design precluded understanding whether people would have continued to comply with booster trainings into the long-term and whether weight losses would have persisted. Second, this intervention focused specifically on reducing consumption of one type of food, i.e., foods with added sugar, and not on more broadly lowering calorie intake which is the standard approach to weight loss. We cannot assume that simply adding stimuli to ICT would produce equivalent effects because including more types of food stimuli necessarily reduces exposure to any one food, which potentially degrades potency. Another limitation is that we did not have usable measures of dietary intake. As such, we could not explicitly demonstrate that ICT produced reductions in sweet food consumption which, in turn, drove weight loss. As mentioned, our attempts to understand mechanism of the training were also limited by the use of a within-training index of improvement and the lack of a comparison. Finally, we observed that many participants reached ceiling on the difficulty of the adaptive ICT, raising the possibility that we set this ceiling too low and that a higher ceiling would have produced stronger effects.

Balancing these weaknesses are several notable strengths. For example, this is the first study to examine the impact of a highly personalized and/or gamified ICT on weight loss using repeated, at-home trainings. Importantly, this study used an in-lab, objective measure of weight as its main outcome variable. The use of a sham training was a strength in that it controlled for effects of experimenter demand, placebo, and stimuli exposure. In addition, the factorial design let us efficiently and simultaneously examine the effect of ICT and gamification. We also included innovations such as a system to personalize the trainings by automatically selecting stimuli that were identified as most frequently consumed by each participant on the basis of 4 days of food tracking, adaptations of difficulty as participants increased their inhibitory control ability, and a gaming environment complete with background story, visual surround, sound effects, background sound, scoring, and badges.

Future research should investigate whether compliance and weight can be maintained into the long-term, and what schedule of booster sessions maintains both compliance and weight loss. To the extent that compliance falls off, alternative gamification and other engagement strategies

should be investigated that do not harm potency of ICT. For example, perhaps some elements of gamification (e.g., visual surround, sounds) are distracting whereas others (e.g., points that reflect and incentivize improvement) do not reduce potency and in fact increase engagement. Future work should also investigate the extent to which smartphones improve dissemination (because they are owned by a rapidly-increasing majority; Deloitte, 2016), compliance (because they are so often at arm's reach; Pew Research Center, 2017), and potency (because touching/not touching stimuli directly on the screen might be a closer analog to consumption and inhibition in real-life eating). Yet, this work must also determine the extent to which smartphones compromise efficacy (because of environmental distraction and/or reduced screen size; Lawrence et al., 2015). Finally, researchers might explore whether broadening ICT's dietary target to include other high-calorie foods improves weight losses.

Taken as a whole, study findings offer qualified support for the use of a computerized cognitive training to facilitate weight loss, in that daily short trainings for 6 weeks plus two subsequent weekly trainings were well tolerated and produced a clinically significant boost in weight in those individuals with higher-than-average implicit preference for sweets. However, a great deal of work remains to better understand how to create future trainings that are powerful and engaging enough to exert effects into the long-term.

Acknowledgements The authors would like to thank Cara Dochat, Valerie Everett, and Jerry Martin for their help coordinating the study, and Michael Wagner, Travis Chandler, Josh Korn, Ricardo Concha, and Rachel Buttry for their help creating and maintaining the project's graphics and code.

Funding This study was funded by the National Cancer Institute (R21CA191859; PI: E Forman).

Compliance with ethical standards

Conflict of interest Evan Forman declares that he has no conflict of interest. Stephanie Manasse declares that she has no conflict of interest. Diane Dallal declares that she has no conflict of interest. Rebecca Crochiere declares that she has no conflict of interest. Caitlin Loyka declares that she has no conflict of interest. Meghan Butryn declares that she has no conflict of interest. Adrienne Juarascio declares that she has no conflict of interest. Katrijn Houben declares that she has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

References

Allom, V., Mullan, B., & Hagger, M. (2016). Does inhibitory control training improve health behaviour? A meta-analysis. *Health Psychology Review, 10,* 168–186.

Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., et al. (2013). Video game training enhances cognitive control in older adults. *Nature, 501,* 97.

Banse, R., Seise, J., & Zerbes, N. (2001). Implicit attitudes towards homosexuality: Reliability, validity, and controllability of the IAT. *Zeitschrift für experimentelle Psychologie*, *48*, 145–160.

Benikos, N., Johnstone, S. J., & Roodenrys, S. J. (2013). Short-term training in the Go/Nogo task: Behavioural and neural changes depend on task demands. *International Journal of Psychophysiology, 87,* 301–312.

Best, M., Lawrence, N. S., Logan, G. D., McLaren, I. P., & Verbruggen, F. (2016). Should I stop or should I go? The role of associations and expectancies. *Journal of Experimental Psychology: Human Perception and Performance, 42,* 115.

Blackburne, T., Rodriguez, A., & Johnstone, S. J. (2016). A serious game to increase healthy food consumption in overweight or obese adults: Randomized controlled trial. *JMIR Serious Games, 4*, e10.

Boendermaker, W., Prins, P., & Wiers, R. (2013). *Documentation of the CityBuilder game. Theoretical background and parameters*. Amsterdam: University of Amsterdam.

Bowman, S. A., Clemens, J. C., Martin, C. L., Anand, J., Steinfeldt, L. C., & Moshfegh, A. J. (2017). *Added sugars intake of Americans: What we eat in America, NHANES 2013–2014*. Maryland: Worldwide Web Site: Food Surveys Research Group.

Dahlin, E., Nyberg, L., Bäckman, L., & Neely, A. S. (2008). Plasticity of executive functioning in young and older adults: Immediate training gains, transfer, and long-term maintenance. *Psychology and Aging, 23*, 720.

De Koning, L., Malik, V. S., Kellogg, M. D., Rimm, E. B., Willett, W. C., & Hu, F. B. (2012). Sweetened beverage consumption, incident coronary heart disease and biomarkers of risk in men. *Circulation, 111*, 067017.

Deloitte. (2016). *2016 global mobile consumer survey: US Edition*. Retrieved December 10, 2018 from https://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/us-global-mobile-consumer-survey-2016-executive-summary.pdf.

Diabetes Prevention Program Research Group. (2004). Achieving weight and activity goals among diabetes prevention program lifestyle participants. *Obesity Research, 12*, 1426–1434.

Drewnowski, A. (1997). Taste preferences and food intake. *Annual Review of Nutrition, 17*, 237–253.

Drewnowski, A., Darmon, N., & Briend, A. (2004). Replacing fats and sweets with vegetables and fruits—A question of cost. *American Journal of Public Health, 94,* 1555–1559.

Drewnowski, A., & Greenwood, M. (1983). Cream and sugar: Human preferences for high-fat foods. *Physiology & Behavior, 30,* 629–633.

Egloff, B., & Schmukle, S. C. (2002). Predictive validity of an implicit association test for assessing anxiety. *Journal of personality and social psychology*, *83*, 1441.

Feskanich, D., Rimm, E. B., Giovannucci, E. L., Colditz, G. A., Stampfer, M. J., Litin, L. B., et al. (1993). Reproducibility and validity of food intake measurements from a semiquantitative

food frequency questionnaire. *Journal of the American Dietetic Association, 93,* 790–796.

Freund, A. M., & Hennecke, M. (2012). Changing eating behaviour vs. losing weight: The role of goal focus for weight loss in overweight women. *Psychology & Health, 27,* 25–42.

Friese, M., Hofmann, W., & Wänke, M. (2008). When impulses take over: Moderated predictive validity of explicit and implicit attitude measures in predicting food choice and consumption behaviour. *British Journal of Social Psychology, 47,* 397–419.

Giel, K. E., Speer, E., Schag, K., Leehr, E. J., & Zipfel, S. (2017). Effects of a food-specific inhibition training in individuals with binge eating disorder—Findings from a randomized controlled proof-of-concept study. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity, 22,* 345–351.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the implicit association test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology, 85*, 197.

Guerrieri, R., Nederkoorn, C., & Jansen, A. (2012). Disinhibition is easier learned than inhibition. The effects of (dis)inhibition training on food intake. *Appetite, 59*(1), 96–99.

Hartmann-Boyce, J., Jebb, S. A., Fletcher, B. R., & Aveyard, P. (2015). Self-help for weight loss in overweight and obese adults: Systematic review and meta-analysis. *American Journal of Public Health, 105,* e43–e57.

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and self-control from a dual-systems perspective. *Perspectives on Psychological Science, 4,* 162–176.

Hofmann, W., Friese, M., & Wiers, R. W. (2008). Impulsive versus reflective influences on health behavior: A theoretical framework and empirical review. *Health Psychology Review, 2,* 111–137.

Houben, K. (2011). Overcoming the urge to splurge: Influencing eating behavior by manipulating inhibitory control. *Journal of Behavior Therapy and Experimental Psychiatry, 42,* 384–388.

Houben, K., Havermans, R. C., Nederkoorn, C., & Jansen, A. (2012). Beer à No-Go: Learning to stop responding to alcohol cues reduces alcohol intake via reduced affective associations rather than increased response inhibition. *Addiction, 107,* 1280–1287.

Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite, 56,* 345–349.

Houben, K., & Jansen, A. (2015). Chocolate equals stop. Chocolate-specific inhibition training reduces chocolate intake and go associations with chocolate. *Appetite, 87,* 318–323.

Hu, F. B. (2013). Resolved: There is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obesity Reviews, 14,* 606–619.

Hu, F. B., Rimm, E., Smith-Warner, S. A., Feskanich, D., Stampfer, M. J., Ascherio, A., et al. (1999). Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *The American Journal of Clinical Nutrition, 69,* 243–249.

Jansen, A., Nederkoorn, C., van Baak, L., Keirse, C., Guerrieri, R., & Havermans, R. (2009). High-restrained eaters only overeat when they are also impulsive. *Behaviour Research and Therapy, 47,* 105–110.

Johnstone, S. J., Roodenrys, S. J., Johnson, K., Bonfield, R., & Bennett, S. J. (2017). Game-based combined cognitive and neurofeedback training using focus pocus reduces symptom severity in children with diagnosed AD/HD and subclinical AD/HD. *International Journal of Psychophysiology, 116,* 32–44.

Jones, A., Di Lemma, L. C., Robinson, E., Christiansen, P., Nolan, S., Tudur-Smith, C., et al. (2016). Inhibitory control training for appetitive behaviour change: A meta-analytic investigation of mechanisms of action and moderators of effectiveness. *Appetite, 97,* 16–28.

Jones, A., Hardman, C. A., Lawrence, N., & Field, M. (2017). Cognitive training as a potential treatment for overweight and obesity: A critical review of the evidence. *Appetite, 124,* 50–67.

Kühn, S., Lorenz, R. C., Weichenberger, M., Becker, M., Haesner, M., O'Sullivan, J., et al. (2017). Taking control! Structural and behavioural plasticity in response to game-based inhibition training in older adults. *NeuroImage, 156,* 199–206.

Lawrence, N. S., O'Sullivan, J., Parslow, D., Javaid, M., Adams, R. C., Chambers, C. D., et al. (2015). Training response inhibition to food is associated with weight loss and reduced energy intake. *Appetite, 95,* 17–28.

Little, R., & Yau, L. (1996). Intent-to-treat analysis for longitudinal studies with drop-outs. *Biometrics, 52,* 1324–1333.

Logan, G. D., Schachar, R. J., & Tannock, R. (1997). Impulsivity and inhibitory control. *Psychological Science, 8,* 60–64.

Lumsden, J., Edwards, E. A., Lawrence, N. S., Coyle, D., & Munafò, M. R. (2016). Gamification of cognitive assessment and cognitive training: A systematic review of applications and efficacy. *JMIR Serious Games, 4*, e11.

Metcalfe, J., & Mischel, W. (1999). A hot/cool-system analysis of delay of gratification: Dynamics of willpower. *Psychological Review, 106,* 3.

National Center for Health Statistics. (2013–2014). *National health and nutrition examination survey data*. Retrieved December 10, 2018 from https://www.cdc.gov/nchs/fastats/obesity-overweight.html.

Nederkoorn, C., Houben, K., Hofmann, W., Roefs, A., & Jansen, A. (2010). Control yourself or just eat what you like? Weight gain over a year is predicted by an interactive effect of response inhibition and implicit preference for snack foods. *Health Psychology, 29,* 389.

Nederkoorn, C., Smulders, F. T., Havermans, R. C., Roefs, A., & Jansen, A. (2006). Impulsivity in obese women. *Appetite, 47,* 253–256.

Nosek, B. A., Greenwald, A. G., & Banaji, M. R. (2005). Understanding and using the Implicit Association Test: II. Method variables and construct validity. *Personality and Social Psychology Bulletin*, *31*, 166–180.

Peeters, K., Van Leemputte, F., Fischer, B., Bonini, B. M., Quezada, H., Tsytlonok, M., et al. (2017). Fructose-1, 6-bisphosphate couples glycolytic flux to activation of Ras. *Nature Communications, 8,* 922.

Pew Research Center. (2017). *Record shares of Americans now own smartphones, have home broadband*. Retrieved December 10, 2018 from http://www.pewresearch.org/fact-tank/2017/01/12/evolution-of-technology/.

Poppelaars, A., Scholten, H., Granic, I., Veling, H., Johnson-Glenberg, M. C., & Luijten, M. (2018). When winning is losing: A randomized controlled trial testing a video game to train food-specific inhibitory control. *Appetite, 129,* 143–154.

Porter, L., Bailey-Jones, C., Priudokaite, G., Allen, S., Wood, K., Stiles, K., et al. (2018). From cookies to carrots; The effect of inhibitory control training on children's snack selections. *Appetite, 124,* 111–123.

Preuss, H., Pinnow, M., Schnicker, K., & Legenbauer, T. (2017). Improving inhibitory control abilities (ImpulsE)—A promising approach to treat impulsive eating? *European Eating Disorders Review, 25,* 533–543.

Prins, P. J., Dovis, S., Ponsioen, A., Ten Brink, E., & Van der Oord, S. (2011). Does computerized working memory training with game elements enhance motivation and training efficacy in children with ADHD? *Cyberpsychology, Behavior, and Social Networking, 14,* 115–122.

Schonberg, T., Bakkour, A., Hover, A. M., Mumford, J. A., Nagar, L., Perez, J., et al. (2014). Changing value through cued approach:

An automatic mechanism of behavior change. *Nature Neuroscience, 17,* 625–630.
Schulze, M. B., Manson, J. E., Ludwig, D. S., Colditz, G. A., Stampfer, M. J., Willett, W. C., et al. (2004). Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *JAMA, 292,* 927–934.
Spierer, L., Chavan, C., & Manuel, A. L. (2013). Training-induced behavioral and brain plasticity in inhibitory control. *Frontiers in Human Neuroscience, 7,* 427.
Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8,* 220–247.
Subar, A. F., Kirkpatrick, S. I., Mittl, B., Zimmerman, T. P., Thompson, F. E., Bingley, C., . . . Potischman, N. (2012). The automated self-administered 24-hour dietary recall (ASA24): A resource for researchers, clinicians, and educators from the national cancer institute. *Journal of the Academy of Nutrition and Dietetics*, *112*, 1134–1137. https://doi.org/10.1016/j.jand.2012.04.016.
Tsai, A. G., & Wadden, T. A. (2009). Treatment of obesity in primary care practice in the United States: A systematic review. *Journal of General Internal Medicine, 24,* 1073–1079.
Turton, R., Bruidegom, K., Cardi, V., Hirsch, C. R., & Treasure, J. (2016). Novel methods to help develop healthier eating habits for eating and weight disorders: A systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews, 61,* 132–155.
Unity3D Game Engine. (2016). *Unity*. Retrieved December 10, 2018 from http://unity3d.com.
US Department of Health & Human Services. (2017). *Dietary guidelines for Americans 2015–2020*. New York: Skyhorse Publishing Inc.
Van Schie, S., & Boendermaker, W. (2014). Measuring attentional bias towards alcohol in adolescents using motivating game elements. Unpublished master's thesis.
Veling, H., Aarts, H., & Papies, E. K. (2011). Using stop signals to inhibit chronic dieters' responses toward palatable foods. *Behaviour Research and Therapy, 49,* 771–780.
Veling, H., Lawrence, N. S., Chen, Z., van Koningsbruggen, G. M., & Holland, R. W. (2017). What is trained during food go/no-go training? A review focusing on mechanisms and a research agenda. *Current Addiction Reports, 4,* 35–41.
Veling, H., van Koningsbruggen, G. M., Aarts, H., & Stroebe, W. (2014). Targeting impulsive processes of eating behavior via the internet. Effects on body weight. *Appetite, 78,* 102–109.
Verbeken, S., Braet, C., Goossens, L., & Van der Oord, S. (2013). Executive function training with game elements for obese children: A novel treatment to enhance self-regulatory abilities for weight-control. *Behaviour Research and Therapy, 51,* 290–299.
Vinogradov, S., Fisher, M., & de Villers-Sidani, E. (2012). Cognitive training for impaired neural systems in neuropsychiatric illness. *Neuropsychopharmacology, 37,* 43–76.
World Health Organization. (2015). *Sugar intake for adults and children: Guideline*. http://www.who.int/nutrition/publications/guidelines/sugars_intake/en. Accessed May 10, 2016.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.