Gender differences in the effect of gamification on weight loss during a daily, neurocognitive training program

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Abstract

A major contributor to the obesity epidemic is the overconsumption of high-calorie foods, which is partly governed by inhibitory control, that is, the ability to override pre-potent impulses and drives. Computerized inhibitory control trainings (ICTs) have demonstrated qualified success at affecting real-world health behaviors, and at improving weight loss, particularly when repeated frequently over an extended duration. It has been proposed that gamification (i.e., incorporating game-like elements such as a storyline, sounds, graphics, and rewards) might enhance participant interest and thus training compliance. Previous findings from a mostly female sample did support this hypothesis; however, it might be expected that the effects of gamification differ by gender such that men, who appear more motivated by gaming elements, stand to benefit more from gamification. The present study evaluated whether gender moderated the effect of a gamified ICT on weight loss. Seventy-six overweight individuals received a no-sugar-added dietary prescription and were randomized to 42 daily and 2 weekly ICTs focused on sweet foods that were either gamified or nongamified. Results supported the hypothesis that gamification elements had a positive effect on weight loss for men and not women ($p = .03$). However, mechanistic hypotheses for the moderating effect (in terms of enjoyment, compliance, and improvements in inhibitory control) were generally not supported (p 's $> .20$). These results suggest that gamification of ICTs may boost weight loss outcomes for men and not women, but further research is needed to determine the specific mechanisms driving this effect and to arrive at gamification elements that enhance effects for both men and women.

Keywords

Weight loss, Inhibitory control training, Gamification, Gender

INTRODUCTION

The majority of Americans are overweight, and excess consumption of high-calorie foods is a major contributor [1]. A significant obstacle to successful weight control is the regulation of biological drives towards high-calorie foods [2–4], with sugar being of particular concern [5,6]. Prior research supporting a dual-process model of self-control has suggested that consumption of hedonic foods (e.g., sweets) is regulated by two competing systems: an impulsive system consisting of powerful, prepotent impulses towards reward-driven behavior, and a reflective system that

Implications

Practice: Inhibitory control trainings (ICTs) targeting weight loss may be more effective for men, but not women, when incorporating game-like elements (e.g., storylines, sounds, graphics, and rewards), suggesting that this technique (gamification) could be used to enhance compliance, retention, and outcomes for men who enroll in weight loss programs.

Policy: Given that men show lower rates of participation in weight loss programs, policymakers who want to combat the overweight/obesity epidemic should consider funding research on intervention techniques such as gamification that appear to enhance outcomes for men. Relatedly, policymakers may also wish to provide health insurance coverage for weight loss treatments that involve gamification elements.

Research: Future research should investigate the specific mechanisms driving the effect of gender on weight loss following gamified ICTs and identify gamification elements that enhance effects for both men and women.

inhibits these impulses in order to adaptively restrain intrinsic drives and align behavior with long-term goals [7,8]. In order to successfully curb reward-driven impulses and control eating behavior, this reflective system employs a basic cognitive capacity known as inhibitory control (IC), that is, the ability to overrule impulsive reactions in order to achieve longer-term goals [9]. IC is strongly implicated in hedonically driven behavior such as the consumption of high-calorie and high-sugar foods [10,11], and lower IC is associated with increased likelihood of weight [12]. Thus, to the extent IC can be trained, it represents a potential means to enhance the impact of conventional weight loss programs [13].

Computerized inhibitory control trainings (ICT), which involve repeated practice at inhibiting responses to a relevant stimulus presented on a computer screen through key presses, have been

developed and tested for the purpose of reducing high-calorie food intake [14–16]. For instance, a daily-completed computerized Go/No Go task was shown to result in increased food-specific inhibitory control as well as significant weight reduction in a sample of adults with obesity [17]. The extant ICT research base is limited by factors such as poor ecological validity, lack of personalized stimuli, and use of low-duration trainings. However, ICTs have demonstrated the ability to reduce consumption of targeted foods/beverages including chocolate [18], snack foods [19], and beer [20], as well as improving short-term weight loss [17,21,22]. In addition, our research group has recently reported that a computerized ICT targeting consumption of sweets produced weight loss benefits for individuals with higher-than-average implicit preferences for high-sugar foods [23].

One significant challenge to ICTs targeting real-world health behaviors such as eating is the need to sustain participant compliance with repeated trainings over an extended duration [24,25]. One method for enhancing participant interest and engagement is “gamification,” that is, incorporating elements such as feedback (e.g., sounds or graphics), rewards for satisfactory performance and a unified storyline [26]. Gamification strategies have been successfully applied to a number of cognitive training domains [27–30] and have also shown promise for training executive function and enhancing weight loss in children with obesity [31].

Conversely, research from our group has indicated that gamification (the addition of graphics depicting quickly moving down supermarket aisles and grabbing food to place in a shopping cart, and featuring animation, sound, points, levels, and badges) yields no advantage in compliance and may even reduce the effects of traditional ICT on weight loss [23] (e.g., by distracting from effective elements of the task). However, one significant limitation of these results is that our participant sample was predominantly female, and there are reasons to suspect that the impact of gamification may differ by gender. For instance, men have reported being more motivated by gaming elements than women [32], men are more motivated to play online games for achievement-oriented reasons relative to women [33], and three times as many men as women make video game purchases (though women appear to be play free, mobile games as or more often than men) [34].

In the present follow-on study, we sought to determine (in a larger sample) whether gender moderated the effect of gamification on weight loss by recruiting an additional cohort of overweight men and randomly assigning them to the same gamified or a nongamified ICT conditions, that is, 42 daily and 2 weekly home computer-based 10 min trainings targeting sweetened foods. Based on our conceptual model (Fig. 1), the primary aim of the study was to test the hypothesis that the effects of gamification on weight loss would be stronger for men than for women. We also aimed to test the hypothesis that the effect of gamification on enjoyment, compliance, and inhibitory control would be moderated by gender. Finally, we aimed to test the hypothesis that a mediating effect of enjoyment, compliance, and inhibitory control on weight loss would be moderated by gender.

METHODS

Design and participants

Participants were recruited in two cohorts. The first cohort consisted of 56 (5 men, 51 women) who, in a larger study (see [23] for details), were randomly assigned to a gamified or nongamified ICT. We chose not to include the 50 participants assigned to a sham control condition from the first cohort, given the current study’s aims to understand whether gender moderates the effect of gamification on weight loss. The second cohort consisted of an additional 20 overweight, sweets-consuming men who were recruited from the community by means of advertising placed in social media and on the radio. The inclusion criteria were ages 18–65, BMI 25–50 kg/m², baseline consumption of ≥3 servings of high-sugar foods daily, and an internet-enabled computer in the homes. Exclusion criteria included medical or psychiatric conditions that could interfere with the ability to comply with diet recommendations, pregnancy, breastfeeding, history of bariatric surgery, ≥5% weight loss within the last 6 months, and beginning or changing a dosage of a weight-affecting medication within the last 3 months.

Procedure

As per [23], participants were deemed eligible via a preliminary phone screen followed by an in-person baseline assessment. Eligible participants attended a 2 hr small-group workshop in which they were

Fig. 1 | Conceptual model in which gender moderates the impact of gamification on weight loss, as well as the mediating effect of enjoyment, compliance, and inhibitory control on weight loss.

trained to adhere to a diet absent foods with added sugar (with certain exceptions, e.g., certain very low-sugar breakfast cereals). Sweets were targeted because they are a narrow food group amenable to an ICT with a limited set of stimuli (see below) that, nevertheless, represent a substantial portion of excess calories [35]. Guidance included food purchasing, dietary modifications, and cooking, and a comprehensive set of printed handouts were distributed.

Following the workshop, participants were randomly assigned to gamified or nongamified ICT. Participants completed 42 daily and 2 weekly 10 min ICTs, over 8 weeks, delivered on their home computers, via the Unity3D Game Engine [36]. Each ICT consisted of 400 Go/No Go (GNG) trials [22]. In these trials, participants were presented with a stimuli (image) and either a Go or No Go signal. 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. No Go required inhibiting the impulse to hit a key. Stimuli were either 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). High-sugar foods were selected to match each participants’ dietary habits (e.g., participants who ate Honey Nut Cheerios and drank Sprite were presented with stimuli depicting these foods.) After each trial, during a 1000 ms inter-stimulus interval, participants received feedback, that is, correct (checkmark) or incorrect (“X” symbol) that also served as a fixation point. Given evidence that effects are enhanced when difficulty of training is optimized [37], the difficulty of the training adapted to participant performance. Specifically, the time participants were allowed to respond (on Go trials)

started at 1000 ms and decreased by 50 ms (down to 600 ms) every time the participant scored above an accuracy threshold.

Gamification

The trials, timings, stimuli, Go/No Go signals, and instructions were identical for both the nongamified and gamified conditions. However, participants randomized to the gamified condition were provided a backstory (i.e., told that they needed to move as fast as possible through a grocery store and put the correct food in a grocery cart) and matching graphics (grocery store, aisles, and shopping cart) and sounds (background music and action sounds) were added (see Fig. 2), in addition to rewards/reinforcements (points, badges, and levels).

Measures

Enjoyment

Participants used a Likert scale of 1 (Completely Disagree) to 5 (Completely Agree) to rate how “fun” they found the computerized training at post-treatment.

Compliance

Compliance was indexed by the number of trainings completed out of 44 possible trainings.

Weight

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

Inhibitory Control

As mentioned above and described more thoroughly in [23], we modified the Go/No Go Task such that as the participant’s accuracy on the Go/No Go task increased, the task become more difficult by reducing the allowable time to respond. Reducing allowable time to respond makes “Go” responses

Fig. 2 | Screenshots of nongamified and gamified versions of inhibitory control training.

more automatic, thus increasing the difficulty of withholding such responses. Thus, allowable time to respond was utilized as the measure of inhibitory control, with lower allotted time representing greater inhibitory control ability. (In nonadaptive ICTs, accuracy [or its converse, i.e., of omission and commission error rate] itself can be used to measure inhibitory control ability; however, in adaptive ICTs accuracy is instead kept at near-constant levels by the changes in difficulty that occur once certain accuracy thresholds are met.)

Statistical analyses

Analyses were conducted in SPSS version 25. Data were inspected visually for outliers; none were found. All analyses were conducted using imputed values (i.e., based on an intent-to-treat approach [38]) and with available data. The expectation maximization algorithm was used to impute missing weight data to account for the impact of missingness on other variables. (As a check, we repeated analyses using a last observation carried forward imputation, and results were largely unchanged.) To examine moderator effects, 2 (gender) $\times$ 2 (gamification) general linear models were utilized for continuous variables and logistic regression for the dichotomized variables. To examine mediational models, moderated mediation bootstrapping was conducted using the Hayes [39] SPSS Process Macro, Model 8.

RESULTS

Baseline characteristics

Baseline mean for BMI was 33.38 ± 5.38 kg/m², mean age was 46.68 ± 9.39 , and the sample was 77.1% white, 16.2% black, 4.8% Hispanic, 1.0% Asian, and 1.0% Multi-racial. Table 1 provides descriptive information and illustrates group differences across treatment condition. Baseline and post-intervention weight, enjoyment, compliance, and inhibitory control means and standard deviations by gamification and gender are reported in Table 2. Males were significantly younger than females, and as such, age was included as a covariate in all analyses.

Weight loss

The effect of gamification on weight loss was strongly moderated by gender [$F(1,59) = 5.24$, $p = .03$, partial eta squared = .07]. Specifically, gamification produced enhanced 8 week weight loss for men (4.1%, $SD = 2.7$ gamified vs. 2.5%, $SD = 2.5$ nongamified), but attenuated weight loss for women (1.8%, $SD = 2.5$ vs. 3.1%, $SD = 2.4$; Fig. 3). We also examined proportions reaching a clinically significant weight loss by 8 weeks (which we defined as $\geq 3\%$ given that this is an appreciable loss that represents a success for this period of time, especially in a remote intervention). Proportions of men reaching clinically significant weight loss were higher in the

gamified condition (58.3% vs. 38.5%), but this was not the case for women (25.0% vs. 48.1%; interaction effect Wald $\chi^2 = 3.23$, $p = .07$, $OR = 6.24$).

Enjoyment

The hypothesis that gamification would boost enjoyment ratings for men more so than women was not supported. The interaction effect was small and nonsignificant, and men's ratings were not enhanced by gamification ($M_{\text{Gamified}}: 3.00 \pm 1.34$; $M_{\text{Non-Gamified}}: 3.17 \pm 1.19$).

Compliance

The gender by gamification interaction effect on compliance did not reach statistical significance [$F(1,59) = 1.60$, $p = .21$], though it was in line with hypotheses; that is, gamification increased compliance by 9.1% in men, but decreased compliance by 3.2% in women. Of note, overall compliance with daily trainings was higher for women compared to men [89.8% vs. 81.1%, $t(74) = 2.24$, $p = .03$].

Inhibitory control

Gamification did not improve inhibitory control significantly more for men ($M_{\text{pre}} = 866.63$, $SD = 39.20$; $M_{\text{post}} = 645.32$, $SD = 44.27$) than for women ($M_{\text{pre}} = 889.59$, $SD = 46.07$; $M_{\text{post}} = 696.18$, $SD = 71.90$); $F(1,59) = 1.31$, $p = .26$, $\eta^2 = .02$. Complicating the interpretation of these results is that most (93.3%) reached the pre-designated ceiling for inhibitory control levels; that is, the improvement-based difficulty (allotted time) variable of the training reached its floor of 600 ms.

Mediation

The hypotheses that gender would moderate the mediating effects of gamification on weight loss through compliance, enjoyment, boredom, and inhibitory control were not supported. Moderated mediation bootstrapping results indicated that the indirect mediational paths were generally stronger for men ($bs = .40$, $SEs = .12-.43$) than for women ($bs = -.04, .00, .01$, $SEs = .10-.19$). However, the indices of moderated mediation were statistically nonsignificant (all confidence intervals included zero).

DISCUSSION

The current study sought to examine differences by gender on enjoyment, compliance, inhibitory control enhancement, and weight loss following an inhibitory control training designed to reduce sweets consumption and facilitate weight loss. As such, 76 overweight individuals who were habitual sweets eaters received a post-psychoeducational workshop and a no-sugar-added dietary prescription, and then were randomized to 42 daily and 2 weekly ICTs that were either gamified or nongamified.

Results suggest that the gamification elements employed had a positive effect for men, but not

Table 1 | Participant characteristics by gender

Demographics	Men (n = 25)		Women (n = 51)		p-value
	Mean	SD	Mean	SD	
Age	43.4	11.8	48.3	7.56	.07 ^a
BMI (kg/m ²)	33.2	4.6	33.4	5.76	.89
	Number	%	Number	%	
Race/Ethnicity					.63
White/non-Hispanic	20	80.0%	39	76.5%	
Black	2	8.0%	8	16.0%	
Other	3	12.0%	4	8.0%	
Marital status					.67
Single	6	24.0%	8	15.7%	
Married	16	64.0%	33	64.7%	
Living with a partner (not married)	2	8.0%	3	5.9%	
Not living with current partner	0	0.0%	2	3.9%	
Divorced	1	4.0%	5	9.8%	
Widowed	0	0.0%	0	0.0%	
Employment status					.20
Employed full-time	17	68.0%	40	78.4%	
Full-time student	3	12.0%	1	2.0%	
Employed part-time	3	12.0%	5	9.8%	
Occasional/per diem	0	0.0%	3	5.9%	
Disability/SSI	0	0.0%	0	0.0%	
No income	0	0.0%	1	2.0%	
Other	2	8.0%	1	2.0%	
Income					.85
US\$0–US\$24,999	0	0.0%	2	3.9%	
US\$25,000–US\$49,999	2	8.0%	3	5.9%	
US\$50,000–US\$74,999	5	20.0%	13	25.5%	
US\$75,000–US\$124,999	7	28.0%	16	31.4%	
US\$125,000–US\$199,999	5	20.0%	9	17.6%	
US\$200,000 and above	5	20.0%	5	9.8%	
Prefer not to answer	1	4.0%	3	5.9%	

^aEqual variances not assumed.

for women. In fact, women's weight losses were lessened by gamification. One potential explanation of these findings is that gamification elements were distracting and thus detracted from the core inhibitory control training elements of the ICT, consistent with evidence that gamification may increase cognitive load and distract from performance under some circumstances [40,41]. Perhaps in men, the distracting effects of gamification were modestly overcome by its positive effects on engagement. Women's compliance, on the other hand, was very high (~90%) overall, and thus may have been at a ceiling that could not be improved through gamification.

The key rationale supporting gamified neurocognitive trainings is that compliance decreases over time due to declining participant engagement. Limited prior evidence suggests that gamification can increase engagement and enjoyment and thus adherence to ICTs [26,41], with other evidence suggesting that the positive effects of gamification

on compliance and eating behavior subside after a short period. In this trial, gamification showed no effect on enjoyment, and only a modest, and statistically insignificant, moderating effect on compliance (boosting men's, but not women's, compliance with the 44 ICTs). Moreover, men (cf. women) showed no boost in inhibitory control improvement from gamification of training, despite this being a hypothesized mechanism of action for the training, and a test of moderated mediation did not achieve statistical significance. However, these latter results may have been compromised by an artificial ceiling our methodology set on how much inhibitory control improvement could be attained and measured. Gamification may also have differentially affected a variable not investigated by the current study, such as training task focus or engagement. Indeed, increased engagement with training is considered one of the most significant factors underlying the effects of gamification on health-related behavior change [41–43], suggesting that future studies should assess

Table 2 | Descriptive statistics of key study variables by gamification and gender

	Gamified (<i>n</i> = 36)				Nongamified (<i>n</i> = 40)			
	Men (<i>n</i> = 12)		Women (<i>n</i> = 24)		Men (<i>n</i> = 13)		Women (<i>n</i> = 27)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Baseline weight	231.72	39.55	194.41	27.81	237.52	26.40	192.68	37.27
Posttreatment weight	221.63	39.25	188.44	22.92	227.26	24.62	186.35	37.85
Computerized training enjoyment (Fun)	3.00	1.34	3.48	1.078	3.17	1.19	3.44	1.15
Compliance (% of 44 training sessions completed)	84.72	11.14	88.29	15.81	77.66	23.76	91.16	13.49
Inhibitory control at posttreatment (allowed-time-to-respond; ms)	665.13	57.90	696.18	71.90	686.38	64.95	692.32	84.14

Fig. 3 | The effect of gamification on weight loss was moderated by gender. Note: The effect of treatment condition on percent weight loss was moderated by diet type.

this variable in relation to the effects of gender on response to gamified ICT.

Taken as a whole, results suggest that we have much to learn about how to use gamification to enhance engagement with, and effects of, computerized neurocognitive training. On the one hand, certain groups, such as men may benefit from gamification elements. Men may be more influenced by gaming elements which evoke competition and achievement-based motivation than women [32,33], which may translate into improved outcomes with gamified ICTs. Developing more sophisticated and engaging game elements may thus attract such groups to join the program, may improve compliance, and may enhance effects. Such impacts would be especially notable among overweight men because this group is known to have particularly low rates of enrolling in conventional weight loss programs [44–47]. Still, women may respond well to other forms of gamification that were not investigated by the current study, which incorporated a backstory, graphics/sounds, and rewards/

reinforcements but did not investigate other commonly used gaming elements, for example, social-interactive components (e.g., competing as a member of a team) [48–50] or incentives to collaborate with other participants to achieve weight loss goals [51]. Indeed, some evidence suggests that female game players prefer cooperative or collaborative features in games [52], are more likely to engage in peer discussions with fellow gamers [53], and are generally more sociable in the context of gaming [54]. Potentially, future studies could also attempt to identify elements of gamification that enhance weight loss for men as well as women.

On the other hand, gamification clearly has its limitations and may even be iatrogenic with some samples. Thus, another line of research should concern elements of gamification that do and do not detract from the targeted impact of the trainings on neurocognitive capacities and related outcomes. For example, certain basic gaming elements such as the presence of “levels” or having persistent points/score display may have no effect

on or even worsen outcomes in ICT, potentially because they induce additional stress or increase cognitive load [41,55]. By contrast, aspects of gamification that increase social support and accountability (e.g., integration with social media or web-based sharing platforms) may be effective for enhancing engagement [56–58]. Future research should also allow for a greater range of improvement and measurement of inhibitory control, in order not to artificially constrain training efficacy or the ability to test inhibitory control improvement as a mechanism of action.

A limitation of the current study is its small sample size and modest statistical power. Another potential limitation is that while our second cohort of subjects began enrollment only 1 month after enrollment of the first cohort ended, the first cohort was enrolled over the course of an entire year whereas the second cohort was enrolled only during February through September, which could have introduced period of the year as a confound in our results. An additional potential limitation of the present study is that, in prescribing a no-sugar-added diet rather than an alternative (e.g., a calorie reduction diet), the observed effects on weight loss may have been weakened. Moreover, there was potential for dietary compensation to occur with low-sugar hedonic foods (e.g., high-fat foods), which may also have affected weight losses; however, given that notable weight losses were observed, any potential dietary compensation was unlikely to have constituted total replacement of high-sugar foods with hedonic alternatives. Future studies should evaluate the effects of tailoring ICTs to target a broader range of hedonic foods.

In summary, the results of the current study indicated that the inclusion of gaming elements improved weight loss outcomes for men but attenuated them for women, suggesting a gender-specific effect of gamification on ICTs targeting sweet food consumption. Future studies should investigate specific elements of gamification that may enhance or hinder the effects of neurocognitive trainings on weight loss, and to arrive at gamification elements that enhance effects for both men and women. Additionally, to the extent that gamification is able to boost outcomes for men, gamification should be explored as a means to address underenrollment of men in weight loss programs.

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Compliance with Ethical Standards

Conflicts of Interest: None of the authors report a conflict of interest.

Authors' Contributions: EF oversaw the design and implementation of the study, along with analyses and manuscript writing. SM analyzed data and contributed to manuscript writing. DD collected and analyzed data, and

contributed to study coordination and manuscript writing. RC collected data and contributed to manuscript writing. MB contributed to manuscript writing. MB and AJ contributed to study design and manuscript writing.

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.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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