Mindful decision making and inhibitory control training as complementary means to decrease snack consumption

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Abstract

Objective: Obesity is largely attributable to excess caloric intake, in particular from “junk” foods, including salty snack foods. Evidence suggests that neurobiological preferences to consume highly hedonic foods translate (via implicit processes) into poor eating choices, unless overturned by inhibitory mechanisms or interrupted by explicit processes. The primary aim of the current study was to test the independent and combinatory effects of a computerized inhibitory control training (ICT) and a mindful decision-making training (MDT) designed to facilitate de-automatization.

Methods: We randomized 119 habitual salty snack food eaters to one of four short, training conditions: MDT, ICT, both MDT and ICT, or neither (i.e., psychoeducation). For 7 days prior to the intervention and 7 days following the intervention, participants reported on their salty snack food consumption 2 times per day, on 3 portions of their days, using a smartphone-based ecological momentary assessment system. Susceptibility to emotional eating cues was measured at baseline.

Results: Results indicated that the effect of MDT was consistent across levels of trait emotional eating, whereas the benefit of ICT was apparent only at lower levels of emotional eating. No synergistic effect of MDT and ICT was detected.

Conclusions: These results provide qualified support for the efficacy of both types of training for decreasing hedonically-motivated eating. Moderation effects suggest that those who eat snack foods for reasons unconnected to affective experiences (i.e., lower in emotional eating) may derive benefit from a combination of ICT and MDT. Future research should investigate the additive benefit of de-automatization training to standard weight loss interventions.

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Mulkens, & Jansen, 2007).

Inhibiting a hedonically-driven response may involve complex, higher-order decision making processes in which one deliberately chooses a behavior in line with explicit longer-term personal goals by purposely overruling implicit drives to the contrary (Hofmann, Friese, & Wiers, 2008; Strack & Deutsch, 2004). Yet, inhibition may also depend on a basic cognitive capacity to inhibit a specific behavioral response that has been triggered by a prepotent drive (Adriaanse, de Ridder, & Evers, 2011; Nigg, 2000). Theoretically then, reducing the likelihood of acting on an urge to consume palatable foods may be achieved procedurally (e.g., via repeated practice of motor inhibition) or deliberately (e.g., via training de-automatization of decision-making).

1. Mindful decision-making training

Mindfulness (i.e., awareness and acceptance of internal experiences) is a mental state that can interrupt automatic responding towards highly palatable food stimuli (Papies, Barsalou, & Custers, 2012). Mindfulness is thought to aid in the self-regulation of behavior by “de-automatizing” the cognitive processes that generally provoke habitual (or automatic) responding (Cahn & Polich, 2006; Jha, Krompinger, & Baime, 2007; Lutz, Slagter, Dunne, & Davidson, 2006), and has been linked to decreased disinhibition and impulsivity (Lattimore, Fisher, & Malinowski, 2011; Peters, Erismann, Upton, Baer, & Roemer, 2011). In-person mindfulness trainings produce reductions in alcohol consumption and binge eating, and facilitate weight loss (Dalen et al., 2010; Kristeller, Wolever, & Sheets, 2013; Miller, Kristeller, Headings, Nagaraja, & Misra, 2012; Ostafin, Bauer, & Myxter, 2012; Tapper et al., 2009). Trainings focused specifically on mindful decision making (MDT; anticipating and overriding drives to consume in favor of deliberate, purposeful choices) aid in the ability to lose and maintain weight (Forman, Butryn, Hoffman, & Herbert, 2009; Forman, Butryn, et al., 2013) and help individuals cope with food cravings (Forman, Hoffman, Juarascio, Butryn, & Herbert, 2013; Forman et al., 2007). Consistent with Kang, Gruber, & Gray’s (2013) analysis of mindfulness, the mindful decision-making training incorporates “mindset-oriented” (rather than meditation-oriented) mindfulness, meaning that it “enables individuals to observe their automatic reactivity to mental events,” thus opening “a gateway to discontinuing undesirable automatized behaviors.” The training’s goal is to prevent the quick reaction of the impulsive system, thus giving room for the more deliberate system processes to take place.

Collectively, these findings suggest that MDT help individuals move to a more deliberate and less automatic mode of responding that will better enable successful restraint. As such, this form of training may reduce consumption of tempting foods that threaten health goals.

2. Inhibitory control training

Inhibitory control trainings (ICT) strengthen motor response inhibition procedurally, utilizing the classic stop-signal (or similar go-no-go) paradigm (Spieler, Chavan, & Manuel, 2013). Target stimuli are presented on a computer and participants are instructed to respond as quickly as possible (via a key press), unless a “stop” signal is present. The delay between the presentation of the image and the stop-signal is lengthened as participants improve in order to adaptively increase task difficulty. Single-bout ICT using stimuli specific to the target has produced immediate reductions in consumption of snacks, chocolate and beer, compared to a sham training (Evers, de Ridder, & Adriaanse, 2009; Houben, 2011; Houben & Jansen, 2011; Houben, Nederkoorn, Wiers, & Jansen, 2011; Koningsbruggen, Veling, Stroebbe, & Aarts, 2013; Veling, Aarts, & Papes, 2011). However, results have been mixed for behavioral effects beyond the laboratory session in which the ICT takes place and a recent review of ICTs pointed to the conflicting evidence of its ability to produce persistent real-world behavioral changes (Spieler et al., 2013). For example, in a recent study that compared two types of ICT, the trainings were successful in improving inhibitory control at post-treatment, but there were no effects of ICT on eating behavior or BMI at follow-up (Allom & Mullan, 2015). Converging results of other types of cognitive training (e.g., working memory) suggest that the reason for conflicting findings (related to persistence) may be the low frequency and intensity of training (Vinogradov, Fisher, & de Villers-Sidani, 2011). Thus, repeated training bouts may be necessary to achieve persistence of effect with cognitive training paradigms such as ICT.

3. Synergy hypothesis

MDT and ICT could be expected to operate synergistically. MDT helps individuals (a) to move from a fast, automatic, implicit decision process to a slower, deliberative, explicit decision process, (b) prime a longer-term health goal in response to snack food stimuli and (c) introduce a cognitive “stop” along the route from stimulus to behavior (i.e., instead of stimulus direct to approach behavior, an individual exhibits the thought that he wants to approach in response to the stimulus). Hedonic eating decisions pit strong automatic tendencies against intentional stopping. MDT ought to weaken the automatic processing, and ICT should strengthen stopping. Thus their joint operation is hypothesized to lead inhibition to prevail over automatic tendencies. Put another way, MDT creates favorable conditions for inhibitory training effects to be observed in actual behavior (Hofmann, Schmeichel, & Baddeley, 2012).

4. Moderating effect of trait dietary disinhibition

People are known to vary in trait dietary “disinhibition,” i.e., the extent to which they are susceptible to “break-through” eating triggered by both internal (e.g., emotional) and external (e.g., the sight of food) cues. Disinhibition is one of the only robust predictors of weight loss success (Bryant, King, & Blundell, 2008; Cuntz, Leibbrand, Ehrig, Shaw, & Fichter, 2001). One reason to speculate that the efficacy of MDT might depend on disinhibition, is that those with higher eating-specific disinhibition were especially responsive to a weight loss intervention incorporating mindful decision making components, relative to a standard behavioral comparison intervention (Forman et al., 2009; Forman, Butryn, et al., 2013). The efficacy of ICT might be moderated by food-linked disinhibition given that the training operates by interrupting the process by which food triggers eating behavior. Indirect support for this notion comes from the finding that the impact of ICT on response to palatable food stimuli was much stronger for chronic dieters, who are known to be more responsive to food cues, than on a comparison group (Veling et al., 2011). Conversely, those who eat in response to emotions might be less responsive to ICT because the training does not include emotional cues.

5. Current study

In sum, dual-process models posit that the outcome of the conflict between the impulsive system (e.g., hedonic drives) and the reflective system (e.g., health-related goals) depends on the strength of inhibitory capacities. Given that successful inhibition may require complex decision-making ability in combination with a basic cognitive capacity to inhibit a behavioral response, both
inhibitory and de-automatization trainings are expected to be efficacious and a combination may prove synergistic. The primary aim of the current study is to test the independent and combinatory effects of two mindful decision-making training (MDT) and inhibitory control training (ICT) on consumption of hedonic eating. As such, we randomized 119 habitual salty snack food eaters (i.e., consumed ≥ 4 salty snack food servings) to receive MDT, ICT, a combination of both, or neither. We tracked snack food consumption for a week pre- and post-training. Two measures of dietary disinhibition were also administered to examine exploratory moderation hypotheses concerning these variables.

6. Methods

6.1. Participants

Participants were 119 undergraduate students enrolled at two large, urban universities. Participants were between the ages of 18 and 47 years ($M_{age} = 22.71, SD = 5.49$); 62.2% were female. The sample was 58.3% Caucasian, 27.8% Asian, 11.3% African American, and 2.5% multiracial; 0.9% also identified as Hispanic. In terms of body mass index, 31.6% were overweight or obese ($M = 24.45$ kg/m$^2$, range = 18.40–46.72, $SD = 5.30$). A minority (18.6%) was currently dieting to lose weight.

Recruitment was conducted through the posting of fliers, e-mail listservs, in-class announcements, and a website listing research opportunities qualifying students for extra credit in psychology courses. Eligibility requirements for the study were consuming salty snack foods four times a week or more, expressing desire to cut back on consumption, and having access to a smartphone with a data plan. Exclusion criteria were a history of and/or current diagnosis of an eating disorder or a serious psychiatric condition likely to impair participation (e.g., bipolar disorder with psychotic features). Upon completion of the study, participants received either extra credit in a psychology course or up to $25.00 in monetary payment based on their participation.

6.2. Measures

6.2.1. Salty snack food consumption

Salty snack food consumption was measured utilizing Ecological Momentary Assessment (EMA; Stone & Shiffman, 1994). EMA allows for the collection of data in the participants' natural environment, thus increasing the accuracy of reporting (Shiffman, Stone, & Hufford, 2008). To increase compliance and reliability of reporting, the current study utilized participant-owned smartphones with web access. EMA prompts were delivered twice daily via text and email, and contained links to brief surveys. Surveys contained questions regarding salty snack food consumption since the previous prompt as well as since specific time markers (e.g., “How many servings of salty snack foods did you have between waking up and now?”). Participants were asked to respond by selecting among four multiple choice options which specified different sizes of snack servings (i.e., 0, 1, 2–3, or 4 or more servings), each of which was presented using common equivalents of the specified serving size, e.g., “one snack size bag of Doritos or Tortilla chips.” For the purpose of data analysis, snack consumption at each time point was treated as a Likert scale (scores 0–3).

6.2.2. Trait dietary disinhibition

Trait dietary disinhibition was assessed using two measures. The disinhibition subscale of the Eating Inventory (EI; formerly, Three-Factor Eating Questionnaire; Karlsson, Persson, Sjöström, & Sullivan, 2000) was used to measure disinhibited eating. High scores indicate susceptibility towards eating in response to internal and external cues. The EI requires participants to rate how well a particular statement applies to them (e.g., “When I see something that looks very delicious, I often get so hungry that I have to eat right away”). The EI has shown strong psychometric properties (Cappelleri et al., 2009). In addition, the tendency to eat in response to emotions was measured using the emotional eating subscale of the Dutch Eating Behavior Questionnaire (DEBQ; Van Strien, Frijters, Bergers, & Defares, 1986). This 13-item subscale consists of questions regarding eating based on feelings rather than hunger (e.g., “Do you have a desire to eat when you are depressed or discouraged?”) and is scored on a 5-point Likert scale (1 = never, 5 = very often). The DEBQ has shown high internal consistency and high convergent and discriminative validity (Van Strien, 2002; Van Strien et al., 1986).

6.3. Procedure

Prior to attending the baseline session, participants completed a brief online survey assessing eligibility. Participants then attended a baseline assessment in which consent was obtained, the purpose and procedures of the study were outlined, and disordered eating behavior was assessed for exclusion purposes. At this time, participants were also required to complete a baseline questionnaire containing demographic information and measures of dietary disinhibition and emotional eating. After completing the baseline assessment, participants were randomly assigned by means of a computer-generated random number generator to one of four training conditions: inhibitory control training only, mindful decision-making training only, both inhibitory control and mindful-decision making, or psychoeducation only (control). Participants could not be fully blinded because unique aspects of the trainings were readily apparent. However, they were given information about the study designed to be neutral about the expected efficacy of any particular study condition, i.e., that the purpose of the study is to examine the efficacy of two types of behavioral control trainings for producing changes in salty snack intake. All participants, regardless of condition assignment, received a group training with other participants in the same condition. All trainings were focused on salty snack foods on the assumption that a narrower assessment would yield more accurate estimates of consumption and that a narrower intervention focus would be more effective, especially considering (a) the brevity of the interventions and (b) the evidence that ICT is target-specific (Houben, 2011).

Participants began receiving EMA prompts (e-mails and texts) on their smartphones one week prior to their training date. Prompts were administered in the afternoon (2:00 p.m.) and evening (10:00 p.m.) each day. If participants did not respond within 90 min, one reminder was sent. Consistent with standard EMA procedures, participants were not asked to report missing survey data at the next prompt.

The afternoon prompts consisted of two questions, one inquiring about salty snack food intake between the previous night’s prompt and sleep (i.e., from 10:00 p.m. until falling asleep), the other inquiring about salty snack food intake between waking up and the current time (i.e., snacks eaten throughout the day until 2:00 p.m.). The evening prompt consisted of one question regarding salty snack food intake between the previous prompt and the current time (i.e., 2:00 pm and 10:00 pm). Therefore participants logged a total of three salty snack food intake ratings per day, for seven days prior to the training intervention delivery.

Participants then attended a second visit and received their
within one day following all interventions, participants again received twice-daily EMA prompts to enter salty snack consumption, i.e., participants recorded three snack food entries per day for seven days following the intervention delivery. Participants could choose between two reimbursement options, $25 or 4 extra credit points in a participating university course. Reimbursement was pro-rated based on completion of study assessments, including timely EMA responding. At the final study appointment, participants were debriefed to their condition assignment, and provided the opportunity to ask questions about the other study conditions.

6.4. Interventions

6.4.1. Inhibitory control training (ICT)

To procedurally train stimuli-specific inhibitory control towards salty snack foods, participants completed a 20-min computer-based (Inquisit 4.0.40, 2013) modified stop signal task (Verbruggen & Logan, 2008) During the task, participants were presented with one image at a time and asked to respond as quickly as possible to salty snack food-related stimuli (e.g., potato chips, nuts, pretzels, corn chips, tortilla chips, popcorn) and filler stimuli (i.e., pictures of chairs) by pressing using the keyboard to categorize the objects as either food or chairs. These instructions were counterbalanced across task blocks so that both food and chair stimuli were assigned to the left ("e") and the right ("v") keys for an equal number of trials. If the participant did not answer quickly enough (within 1500 ms), the task gave them a message (e.g., "Respond as quickly and accurately as possible! Press space to continue"). An auditory prompt served as a stop-signal, indicating to the participant when to inhibit responses (i.e., do not press any keys). To train inhibitory control, this auditory stop-signal was only presented when pictures of salty snack foods were displayed. The signal was presented through headphones on 25% of the trials. The low proportion of delays with stop trials was modeled after other successful ICTs (e.g., Houben, 2011), as research suggests that participants proactively slow their reaction times when stop signals are expected. In order to ensure that participants did not change response thresholds and suppress motor reactions to stimuli, we kept the proportion of stop signals as low as possible (while still frequent enough to train inhibitory control), which consistent with standard recommendations for using stop signal tasks (Verbruggen & Logan, 2009). In order to train participants, the delay between the stimuli and the stop signal was variable (i.e., 100, 200, 300, or 400 ms after onset of stimulus) and was dependent upon performance, with stop delays increasing with successful inhibition (thus making stopping more difficult) and decreasing with unsuccessful inhibition (thus making stopping easier).

Consistent with Houben (2011), the training task consisted of 6 blocks of 48 trials each. During each block, 24 trials presented salty snack food stimuli and 24 trials consisted of filler stimuli. All pictures were presented twice within each block. Participants completed the ICT once in the laboratory and, as a booster, were asked to repeat it once a day for the next three days on their own computers (via a javascript implementation created by Inquisit 4.0). Participants received reminders to complete the boosters via text message.

6.4.2. Mindful decision making training (MDT)

This 60-min in-person group intervention focused on understanding the automatic processes through which we mindlessly make hedonic eating decisions, and on developing the skills to become aware of and override these processes. The intervention is intended to de-automatize behavior through brief training exercises designed to help individuals increase awareness of the perceptual, cognitive, and affective experiences that drive decisions to eat salty snack foods. For example, participants completed an exercise in which they were given salty snacks on a plate, asked to refrain from consuming the snack for a brief period, to take one bite, and then eventually to throw the food into a trash bin. During this exercise, participants were slowly instructed to notice internal (e.g., urges, salivation) and external (e.g., smell, sight) cues to eat the snack. Using these types of experiential exercises, participants were taught to slow down and pay deliberate attention, thus making more “mindful” eating decisions and de-automatizing the typical snacking process. Exercises also emphasized interrupting automatic reactions to specific internal experiences, e.g., urges to eat, snack cravings, and thoughts about eating snacks. In addition, participants were encouraged to let their explicit health goals guide their eating decisions rather than automatically choosing the most pleasurable path (e.g., eating salty snacks). Following the intervention, participants received one text message per day for three successive days with MDT-based content (e.g., “Stop, think, and slow down before, during, and after snacking; just like we practiced in group with the carrots and chips.”).

6.4.3. Psychoeducation

This 60-min intervention taught participants how to read labels, and provided information about the unhealthy contents of salty snack foods (e.g., sodium, fat) and their long-term effects on health. For example, the risks of diets high in sodium and in trans fatty acids were discussed (e.g., cardiovascular disease). Participants were encouraged to reduce salty snacks in their diets by “being a calorie detective” which included how to read food labels and to pay close attention to key details such as serving size, calorie, fat and sodium content.

6.5. Analytic strategy

Generalized estimating equation models with an autoregressive (AR (1)) correlation structure were used to examine changes in snack consumption frequency because they provide robust standard errors and take into account the non-independence of measurements collected from the same individual (Zeger, Liang, & Albert, 1988). Time was modeled using both categorical (pre-vs. post-intervention) and continuous variables (day and time of day). Study condition was modeled as two categorical variables in a 2 × 2 design reflecting the presence or absence of each training condition (ICT and MDT), and both condition variables were entered into the model with the control group as the reference category. To investigate the effect of the trainings on change in snack consumption, two- and three-way interaction terms were computed between the training conditions and the categorical time variable (pre-vs. post-intervention). The three-way interaction was used to test whether combining the interventions enhanced their efficacy (synergy hypothesis). Given that snack consumption was a rank-ordered scale, a Poisson distribution using a log link function was specified. The data were analyzed using SPSS 20.0 software, and the alpha level for all analyses was set at 0.05.

After examining the basic model, each moderator (EI, DEBQ) was entered into a separate GEE model, such that three total analyses were conducted. Each moderation analysis included baseline scores on the moderator entered as a continuous covariate along with two-, three-, and four-way interactions between the moderator and the time and training condition variables.
7. Results

During the one-week pre-intervention EMA recording period, participants responded to an average of 18.1 of 21 prompts (86.1%, Median = 19, range: 3–21). Nearly all participants (n = 117, 98.3%) reported consuming at least one salty snack serving during the pre-intervention period, and the average participant reported having consumed one or more snack servings in 50.4% of their EMA responses (SD = 20.9%, range: 0–94.7%). During the post-intervention EMA recording period, participants responded to an average of 17.2 of 21 prompts (81.9%, Median = 19, range: 0–21, see Table 1). Participants in the ICT condition completed an average of 1.56 (SD = 1.59) out of the 3 requested home booster trainings.

A series of 2 × 2 factorial ANOVA's were used to examine differences in EMA compliance (number of responses recorded) and average snack consumption by condition during the pre-intervention period, as well as in EMA compliance during the post-intervention period. During the pre-intervention period, EMA compliance differed between those who received ICT (M = 17.2, SD = 4.5) and those that did not (M = 18.9, SD = 2.3, F(1,99) = 5.86, p = .02). During the post-intervention period, those who received ICT responded less frequently (M = 16.1, SD = 6.7) than those who did not (M = 18.2, SD = 3.7, F(1,99) = 4.17, p = .04). No other main or interaction effects on compliance or pre-intervention snack consumption were observed. To account for the potential influence of compliance differences, continuous scores for pre- and post-intervention compliance were added to the original GEE models described above in all of the models presented below.

7.1. Effect of intervention component on snacks consumed

A decrease in reported snack consumption from pre-to post-intervention was noted (main effect of time Wald $\chi^2 = 24.54$, $p < .001$), with evidence for the independent efficacy of mindfulness training components (MDT x time Wald $\chi^2 = 3.99$, $p = .046$) but not ICT (ICT x Time interaction Wald $\chi^2 = 0.73$, $p = .39$). No synergistic effect (i.e., the three-way interaction between the training conditions and time) was observed (Wald $\chi^2 = 0.08$, $p = .78$).

Fig. 1 and Table 2 depict how component effects manifested in the four treatment conditions. To better understand the effect of each condition, we conducted exploratory follow-up analyses by examining change within each treatment condition and by comparing the four treatments on post-intervention snack consumption. Reduction in snack consumption from pre-to post-was most tenuous in the control condition ($p = .05$). MDT, ICT, and the combined treatment all produced significant reductions in snack consumption from pre-to post-intervention ($p < .001$). At post-treatment, the combined condition ($p = .02$) and MD ($p = .14$), but not ICT ($p = .46$), potentially differed from the control group on snack consumption. Of note, interpretation of these effects by condition (four groups) is more difficult given the lack of power relative to the initial analyses by treatment component (two × two factorial).

In terms of moderator effects, when DEBQ was added to the model, the ICT x time effect was qualified by emotional eating (Wald $\chi^2 = 7.40, p < .01$; see Fig. 2). Slope difference tests revealed a greater decrease in reported snack consumption in participants who received ICT at lower ($t = -2.11, p = .04$), but not at higher levels of emotional eating ($t = 1.24, p = .22$, slopes compared at one standard deviation above and below the mean of DEBQ). No evidence for a moderating effect of emotional eating on the efficacy of MDT ($p = .92$) or the combined efficacy of the treatments (i.e., the four-way interaction, $p = .94$) was observed. In the second moderation model, no interaction between the disinhibition subscale (EI) and any of the effects of interest was detected.

Fig. 2 depicts the moderating effect of emotional eating across treatment conditions. To better understand the effect of emotional eating, we conducted exploratory follow-up analyses by examining the moderating effect of DEBQ separately by condition. In the ICT and MDT groups, DEBQ did not moderate change from pre-to post-treatment ($p = .73$ and $p = .34$, respectively). In the control group, DEBQ significantly moderated change ($p = .03$) such that participants with higher DEBQ scores showed greater reduction in snack consumption. In the combined group, DEBQ showed a trend towards moderating change ($p = .07$) such that participants with lower DEBQ scores showed greater reduction in snack consumption.

8. Discussion

The current study tested the independent and combinatorial effects of computerized inhibitory control and mindful decision-making trainings that were designed to reduce hedonically-motivated eating, compared to a psychoeducation control. Overall, results suggested that the mindful decision-making training led to greater decreases in reported snack consumption across the week following the intervention. These results suggest that clinically significant reductions in hedonic consumption follow from training individuals to orient cognitive resources towards de-automatizing eating decisions that are normally guided by implicit, pleasure-oriented goals. Findings are consistent with current theories positing that cultivating “mindset-oriented” mindfulness enables individuals to observe and override automatic reactivity to mental events (Kang et al., 2013). Results also echo previous findings for the efficacy of broader interventions containing mindful decision skills training (Forman et al., 2009; Forman, Butryn, et al., 2013). However, in the present case, findings offer evidence for the MDT treatment component specifically; such pinpointing of efficacy is rarely achieved because most interventions are evaluated as

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Psychoed. (n = 27)</th>
<th>ICT (n = 27)</th>
<th>MDT (n = 27)</th>
<th>ICT + MDT (n = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>20.9 ± 2.9</td>
<td>24.0 ± 5.8</td>
<td>24.1 ± 7.1</td>
<td>22.4 ± 5.4</td>
</tr>
<tr>
<td>BMI</td>
<td>23.5 ± 3.6</td>
<td>26.3 ± 6.8</td>
<td>24.6 ± 5.4</td>
<td>24.3 ± 5.8</td>
</tr>
<tr>
<td>DEBQ</td>
<td>35.2 ± 12.7</td>
<td>32.2 ± 11.1</td>
<td>37.9 ± 11.4</td>
<td>32.1 ± 11.6</td>
</tr>
<tr>
<td>EI</td>
<td>7.3 ± 3.5</td>
<td>7.9 ± 3.2</td>
<td>7.7 ± 2.9</td>
<td>6.3 ± 3.1</td>
</tr>
<tr>
<td>Pre-intervention EMA Compliancea</td>
<td>18.6 ± 2.6</td>
<td>17.4 ± 4.1</td>
<td>19.2 ± 1.9</td>
<td>17.0 ± 5.0</td>
</tr>
<tr>
<td>Post-intervention EMA Complianceb</td>
<td>18.9 ± 1.9</td>
<td>17.4 ± 4.8</td>
<td>16.9 ± 5.7</td>
<td>15.2 ± 7.7</td>
</tr>
</tbody>
</table>

Note. Group means for possible intervention combinations are presented for ease of interpretation, however all analyses were conducted using a 2 × 2 factorial design based on the presence/absence of each intervention factor. BMI = Body mass index. DEBQ = Dutch Eating Behavior Questionnaire. EI = Eating Inventory.

Psychoed. = psychoeducation. ICT = Inhibitory control training. MDT = Mindful decision making training.

a There was a significant difference in pre-intervention compliance between groups receiving ICT and no ICT.

b There was a significant difference in post-intervention compliance between groups receiving MDT and no MDT.
a complete package.

Contrary to our hypothesis, there was no independent effect of the ICT training on snack consumption. Exploratory follow-up analyses indicated that individuals in the ICT-only group (along with the MDT and combined groups) showed a significant reduction in snack consumption from pre-to post-intervention, and that the combined condition showed the greatest advantage over the control group at post-intervention. These findings tentatively suggest that ICT did confer some additional benefit, though likely small in magnitude and not as robust as in some previous reports (Houben, 2011; Veling et al., 2011). The size of the ICT effect, which was measured relative to an active control condition, should be considered in the context of the control condition producing a reduction in overall snack consumption. Two other explanations for weaker ICT effects are the relatively low dosage of training (one 20-min training bout plus 3 boosters) and relatively distant measurement points (days after the training). Of note, participants only completed 50% of the three prescribed booster trainings, on average, raising the possibility that higher booster adherence would have increased the efficacy of ICT. Future research should seek to examine whether dose and intensity of ICT moderate transfer effects, and should examine ways to enhance compliance with extended ICT training programs if additional trainings are found to be beneficial.

Other aspects of inhibitory training also bear further investigation, as we do not know the best choices for the proportion of stop signals. In fact, Allom and Mulian (2015) argue that the pattern of extant inhibitory training data suggests that the targeted (unhealthy food stimuli) should always be followed by stop signals. It is possible that an ICT training using consistent stop signals would have shown a larger benefit.

We tested the exploratory hypothesis that the impact of the trainings would be moderated by trait dietary disinhibition and susceptibility to emotional and food-related cues. While general dietary disinhibition did not appear to moderate training effects, tendency to eat in response to emotional cues did appear to impact the effectiveness of ICT. However, when follow-up tests were conducted, the moderation effect was found to be primarily driven by individuals in the control condition (who benefited more from that intervention if they had higher susceptibility to emotional cues), and those in the combined condition (who showed a trend towards receiving greater benefit as that susceptibility decreased). It should be noted that these follow-up tests (by condition) were likely underpowered.

The fact that those with higher levels of emotional eating experienced decreased benefit from the combined condition (at the trend level) is consistent with other studies which have observed a lowered response to standard behavioral weight loss programs among disinhibited eaters (Elfhag & Rössner, 2005; Wing & Phelan, 2005). Previous studies have also indicated that individuals who

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**Table 2**

Percent of prompts in which each snack frequency was reported at pre-intervention and by condition at post-intervention.

<table>
<thead>
<tr>
<th>Snack frequency</th>
<th>Pre-intervention (N = 2136)</th>
<th>Post-intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Psychoed. (n = 529)</td>
<td>ICT (n = 526)</td>
</tr>
<tr>
<td>0 Servings</td>
<td>48.2%</td>
<td>60.1%</td>
</tr>
<tr>
<td>1 Serving</td>
<td>33.1%</td>
<td>28.5%</td>
</tr>
<tr>
<td>2–3 Servings</td>
<td>14.3%</td>
<td>8.5%</td>
</tr>
<tr>
<td>4 or more Servings</td>
<td>4.4%</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

Note. Conditions differed minimally in frequency distribution at pre-intervention.
triggered eating (Forman, Butryn, et al., 2013). Thus, more targeted interventions that include strategies for managing emotionally-struggle with emotional eating perform better in weight loss in-\textit{terventions for reduction of excess calorie intake, and potentially additional bene} of standard or acceptance-based treatments for weight control. The either stand-alone, adjunctive sessions, or included as a component discretionary food consumption and lose weight if developed into weight loss. MDT could help enhance individuals’ ability to reduce interventions for those who eat in response to emotional experiences are likely warranted. For example, both mindful decision making and inhibitory training could be enhanced for those with emotional eating by incorporating emotionally-relevant stimuli, or being deliver within the context of a negative mood induction.

Our hypothesis that the two types of trainings would be synergistic was not supported, i.e., the outcomes were no better or worse than would be expected by the combination of these two effects. The lack of observed synergy between the two trainings could be attributable to a ceiling effect, as the combinatoric effect was already reducing snack consumption to near-zero.

Results from the current study suggest that MDT could provide additional benefit to those receiving traditional behavioral interventions for reduction of excess calorie intake, and potentially weight loss. MDT could help enhance individuals’ ability to reduce discretionary food consumption and lose weight if developed into either stand-alone, adjunctive sessions, or included as a component of standard or acceptance-based treatments for weight control. The ICT training tested in the current study might enhance this benefit, although future research should examine whether modifying the dose or method of training would result in a stronger effect of an ICT component. Because ICT is a widely-disseminable mode of intervention (e.g., participants could complete it on their home computers or even smartphones), it could easily and inexpensively be distributed as an adjunctive treatment component. Future research should develop and test higher-intensity versions of MDT + ICT, and test whether the effects of these interventions are robust enough to enhance weight outcomes either alone, or in conjunction with behavioral interventions that achieve significant weight loss in the short-term. Training other aspects of neurocognition implicated in hedonic pursuit (e.g., attention bias, implicit attitudes and working memory) should also be investigated, both individually and in combination with inhibitory control and de-automatization.

A number of limitations of the study should be considered, including the fact that the moderate sample size and use of an active control condition may have left the study underpowered. Participants were predominately college-aged, female, and largely within a healthy weight range, which may limit generalizability to individuals seeking weight loss treatment. Additionally, due to the analog nature of the study, the highly abbreviated nature of the trainings, and the relatively short follow-up period, and the trend-level of certain results, we cannot draw firm conclusions about the potential impact of more intensive versions of these interventions on eating and weight over time. It should also be noted that while consumption was assessed frequently, it was measured via self-report and is thus subject to limitations of recall and bias making under-reporting a de-automatization.

Struggle with emotional eating is confounded with gender. Balancing these limitations were several strengths including a highly specific intervention target that has real-world relevance, the use of ecological momentary assessment, and a factorial design that allowed for the examination of both independent and synergetic effects of the specific intervention components. Results from this analog pilot study warrant replication using more intensive interventions, clinically overweight and obese samples, longer-term
outcomes that include weight change, and broader intervention targets (e.g., high fat, high sugar foods).

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References


