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Targeting Executive Function for Weight Loss in Adults with Overweight or Obesity

Dawn M. Eichen[a,*], **Ellen K. Pasquale**[a], **Elizabeth W. Twamley**[b,c], **Kerri N. Boutelle**[a,b,d]

[a]Department of Pediatrics, University of California San Diego, 9500 Gilman Dr, San Diego, CA 92093 USA

[b]Department of Psychiatry, University of California San Diego, 9500 Gilman Dr, San Diego, CA 92093 USA

[c]Center of Excellence for Stress and Mental Health and Research Service, VA San Diego Healthcare System

[d]Herbert Wertheim School of Public Health and Human Longevity Science, University of California San Diego, 9500 Gilman Dr, San Diego, CA 92093 USA

Abstract

Obesity is associated with a multitude of negative health sequalae. Behavioral weight loss (BWL) is currently the recommended behavioral treatment for obesity; however, it is not effective for approximately half of the individuals who participate. BWL requires individuals to carry out many tasks requiring executive function (EF; i.e., higher order cognitive functions such as planning and problem solving) in order to be successful. Growing research supports that lower EF may be associated with attenuated weight loss following BWL, and targeting EF in treatment could improve outcomes. This paper aims to describe the rationale for the development of Novel Executive Function Training for Obesity (NEXT), which adapts Compensatory Cognitive Training to be delivered in conjunction with BWL. We summarize evidence relating EF to obesity and reduced weight loss following BWL, as well as the past success of cognitive training on EF. Then we describe the treatment model for NEXT followed by initial data suggesting that NEXT is feasible and acceptable and may impact EF and weight. Obesity treatments incorporating cognitive training, especially those that train compensatory strategies, may improve weight-loss outcomes and provide a more durable treatment than traditional interventions, but larger randomized control trials are necessary.

Keywords

Cognitive Training; Executive Function; Weight Loss; Eating Behavior; Physical Activity

*Corresponding Author: Dawn M. Eichen, Department of Pediatrics, University of California San Diego, 9500 Gilman Dr., San Diego, CA 92093 USA; deichen@ucsd.edu.

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1. Introduction

Obesity is a national and global public health crisis: approximately 70% of adults in the United States have overweight or obesity and rates continue to rise worldwide.[1,2] Obesity increases risk for >250 comorbidities and associated health consequences, including cardiovascular disease, type 2 diabetes, cancer, depression, and poor quality of life.[3,4] Healthcare expenditures for obesity and obesity-related conditions in the United States total over $200 billion annually,[5] and these costs are projected to rise $48–$66 billion per year by 2030.[6] Most adults with overweight or obesity in the United States have tried to lose weight,[7] but few are successful and 80% are unable to maintain weight lost over time.[8] Improvements to current behavioral treatments are imperative to address the widespread prevalence, associated comorbidities and economic burden of overweight and obesity.

Currently, the most successful behavioral treatment for obesity is behavioral weight loss (BWL), a comprehensive lifestyle-modification treatment aimed at improving nutrition and increasing physical activity (PA).[9–15] Important tenets of BWL include calorie reduction and increased PA, as well as behavioral skills such as self-monitoring, goal setting and stimulus control.[16] However, BWL is only effective in approximately 50% of adults, and most initial responders do not maintain a clinically significant weight loss over time.[12–15] This lack of clinical response and maintenance suggests that most individuals are unable to implement BWL skills and effectively maintain them. Understanding mechanisms related to attenuated weight loss following BWL is necessary to identify potential treatment targets that may improve outcomes.

Adherence to BWL recommendations requires significant planning, decision making and problem solving, all which are executive function-related constructs.[17] Executive function (EF) broadly refers to cognitive control processes that dictate goal-oriented behavior.[18] There is a growing body of literature supporting an association between EF deficits and overweight and obesity, although there still remain gaps in understanding the nature and directionality of this relationship and if associations apply to EF broadly or are domain-specific.[19,20] EF is important for implementing BWL skills, including self-monitoring, planning ahead, suppressing undesirable behavior and creating alternatives, all of which are implicated in maintaining a healthy weight.[21–23] Thus, it is logical that lower EF may contribute to reduced weight loss in BWL and represents a potential mechanism to target in treatment.

Currently the role of EF in weight loss is emerging in the literature. This paper describes the development of a new treatment that aims to improve EF, which has the potential to result in better weight-loss outcomes. The goal of this paper is to describe the rationale for the development of Novel Executive Function Training for Obesity (NEXT), an adaptation of Compensatory Cognitive Training[24,25] delivered in conjunction with BWL, and provide initial pilot data from NEXT. To do so, we examine the literature on the relationships between EF and other cognitive mechanisms with obesity and obesity-related behaviors. We also summarize the literature that evaluates the role of EF on weight-related outcomes in the context of weight-loss interventions. Additionally, we summarize treatments designed to target EF and other cognitive functions, including preliminary research on use of these treatments to modify eating behavior and/or weight. As several meta-analyses and reviews already exist,[19–21] the purpose of this paper is not to duplicate these efforts, but rather to summarize these findings to demonstrate the research that influenced the development of our treatment model. Accordingly, we briefly discuss our model for incorporating strategies for compensating for cognitive limitations as part of BWL to improve weight-loss outcomes. Finally, we provide preliminary feasibility and acceptability data from the initial pilot study of NEXT, our treatment targeting EF as a mechanism for weight loss, and discuss implications for future research.

2. Theoretical Basis and Associations Between Executive Function, Obesity & Obesity-Related Behaviors

2.1 Self-Regulation, Executive Function, and Obesity

According to the dual-process theory of behavior, self-regulation is carried out by balancing two competing systems: the executive and the impulsive.[26,27] Bottom-up, reward-driven impulses (i.e., the consumption of palatable foods) are in conflict with top-down cognitive control processes (planning ahead, delaying gratification, etc.). Both strong internal drives and external obesogenic factors must be overcome by self-regulatory mechanisms to balance the competing systems and remain persistent in long-term health goals.[26,28,29] Many conclude that EF underlies successful self-regulation and is also responsible for the failure of self-regulation in tempting environments.[23] Thus, when hedonic impulses are not sufficiently regulated or suppressed by EF, overeating and ultimately weight gain result.[23,28]

There is a broad consensus in the literature that the three major domains of EF are working memory (WM), inhibition, and cognitive flexibility (see Table 1 for definitions of EF domains and EF-related constructs), all of which play important roles in energy balance-related behaviors.[18,23,30–34] From the three core EFs, higher-order EFs are built, which include reasoning, problem solving and planning, which also play important roles in self-regulation through learning, decision-making, and adaptation (see Table 1 for examples of relation to weight management).[35,36] From a dual-systems perspective, it follows that strengthening EF skills and therefore self-regulatory abilities would increase capacity to override impulsive and automatic behavior to tip the balance between the two competing systems and generate weight loss.[26,28]

EF skills are required for successful adherence to BWL program recommendations (see Table 1). For example, the self-monitoring component alone requires: 1) remembering to self-monitor; 2) being able to obtain the information (i.e., look up the calorie information or make estimates from information available); 3) recording the information in a consistent manner. To self-monitor consistently involves the use of memory, organization, and planning. Reducing calories involves self-monitoring as well as planning meals in advance, problem solving challenging situations, and resisting temptations; these behaviors involve the EF skills of planning, problem solving and inhibition. Contextual factors such as socioeconomic status (SES) can impact one’s ability to engage in self-regulatory behavior when financial resources and time are constrained.[37] Given that individuals with lower SES may be at greater risk for overweight or obesity,[38,39] it is important that these factors are taken into consideration. Taken together, BWL programs require well-developed facets of EF and constrained resources may further impact one's ability to adhere to program recommendations.

2.2 Cross-Sectional Associations between Executive Function, Obesity & Obesity-Related Behaviors

Several review papers and meta-analyses suggest growing support for associations between lower EF and obesity.[17,19,20,43–45] The relationship between lower EF and obesity is evident throughout the lifespan with findings stemming from research conducted among children through older adults.[17,20,43] A review of primarily cross-sectional studies between cognitive function and obesity across the lifespan shows a strong negative association between EF and obesity from childhood through old age, independent of other factors.[17] Research suggests that individuals with obesity demonstrate difficulties across numerous EF-related constructs, including worse performance on measures of decision-making,[46–48] set-shifting,[49,50] planning,[44] inhibition,[17,28] fluency,[17] and WM.[51] Altogether, evidence suggests there is a strong relation between EF and weight status with lower EF found among individuals with higher weight. It is important to note that while EF is lower among individuals with overweight or obesity and clinically impacts behaviors, the deficiency is subtle enough and likely modifiable in comparison to the severe impairment found in neurological disorders such as Alzheimer's Disease.[52]

There is also evidence that EF is associated with energy balance-related behaviors such as eating and PA, which underlie weight status. A review of EF and eating behavior shows that facets of EF (WM, inhibitory control, and cognitive flexibility) are related to successful self-regulation of eating behavior.[21] Several studies show that lower EF is related to overeating,[33,53] increased consumption of high-fat foods,[54,55] increased snacking,[56] and poorer diet.[23,57] Conversely, several studies, including one meta-analysis, show that stronger EF is positively related to fruit and vegetable consumption[56] and greater consumption of low energy-dense foods in the lab.[58] Relatedly, increased self-reported levels of PA are associated cross-sectionally with stronger EF among university students[59,60] and older adults.[61,62] In sum, cross-sectional studies demonstrate an association between EF and obesity and obesity-related behaviors. This evidence suggests even mildly lower levels of EF can limit one's ability to make healthy choices, resulting in overeating, weight gain and the maintenance of unhealthy lifestyle behaviors.[52]

2.3 Longitudinal Associations between Executive Function, Obesity & Obesity-Related Behaviors

Although fewer studies have examined the longitudinal relationship between EF and obesity, data suggest initial performance on measures of EF predicts weight-loss treatment outcomes in both children and adults.[28,63,64] In adults with obesity, WM and inhibitory control predict greater weight loss in both a multidisciplinary weight-loss program[28] and a pre-operative bariatric surgery sample.[65] In a separate bariatric surgery sample, baseline scores of attention and EF predicted weight loss at 12-month follow-up in adults with obesity who underwent bariatric surgery,[64] and these improvements on measures of EF were seen and persisted for up to 36 months post-surgery.[66] Baseline levels of EF predicted weight loss and

PA in a lifestyle modification treatment, suggesting that EF is a determining factor in how difficult or feasible it is for adults to change their behavior.[67] Among parents participating in a family-based behavioral weight loss program, there was a reciprocal relationship between BMI and EF as time-varying effects of EF predicted change in parent BMI and vice versa.[68] Relatedly, a few studies also found poorer EF resulted in less weight-loss following intervention among children participating in an 8-week BWL program,[69] adults in both BWL and an acceptance-based behavioral weight-loss program[70] and adults enrolled in a medically supervised weight loss program.[71] Accordingly, this body of literature supports the concept that EF skills are important for weight loss and maintenance.

Although the literature suggests EF skills are important for weight loss, it is also possible that weight loss is related to changes in EF, as demonstrated in the bariatric surgery sample.[66] Furthermore, a meta-analysis of weight-loss interventions shows associations between weight loss and significant improvements across cognitive domains including attention and memory.[72] Recent reviews of the relationship between obesity and EF suggest the relationship between the two could be bidirectional, as there is evidence for both poor EF leading to increased weight and increased weight resulting in poorer EF.[17,20,73] Similarly, the literature supports a bi-directional relationship between diet and PA and EF.[17,62,73–78] It is theorized that a positive feedback loop exists between EF and obesogenic behaviors, so that behavior change-induced improvements in EF influence the frequency of future health-promotion behaviors, which in turn sustain both a high level of EF and good health.[73] Taken together, these findings suggest not only that EF skills are helpful in maximizing weight-loss outcomes, but also that EF skills are not static and can possibly be improved.

In summary, individuals with overweight or obesity are more likely to have lower EF, and EF plays an important role in carrying out and maintaining healthy lifestyle behaviors such as healthy eating and PA. Impaired neurocognitive mechanisms involved in EF may make it difficult for individuals to adhere to a treatment regimen, carry out the recommendations of BWL, and maintain behavior changes over time. For individuals who have lower EF, calling upon their own EF abilities is not sufficient, and they may need support in remembering what they need to do to adhere to the program, to be more organized, and/or to plan ahead more effectively. Thus, EF is a promising target in weight-loss treatment that could improve treatment adherence, success, and maintenance.

3. Cognitive Training

Cognitive training is a psychosocial intervention that teaches theoretically derived skills to optimize cognitive functioning.[79] Cognitive training is employed as a stand-alone intervention or in conjunction with other psychiatric rehabilitation components such as in several cognitive remediation programs.[80] Interventions may address one domain of cognition, such as WM training, or EF more broadly by addressing multiple domains. The majority of cognitive training programs, including cognitive remediation programs and drill and practice models, aim to improve cognitive performance directly, while Compensatory Cognitive Training programs aim to teach skills to compensate for and work around the deficits (like using a support to aid walking). Cognitive training was first developed to rehabilitate individuals with neurological injury or disease, with a goal of restoring previous neurological functioning.[81] Computerized cognitive training programs typically employ a drill and practice model where tasks or exercises are repeated at a prescribed frequency to train specific cognitive functions. For example, inhibitory control is typically trained through a go/no-go task where individuals practice inhibiting their response to certain stimuli by pressing or not pressing a key on a keyboard.[82] Computerized cognitive training approaches improve cognitive function across healthy aging adults,[83] individuals with schizophrenia,[84–86] and older adults with mild cognitive impairment;[87] however, functional gains are limited with computerized cognitive training alone.[88] In-person cognitive trainings such as cognitive remediation, a form of cognitive training with the goal of durability and generalization, improve cognitive functioning and quality of life in both healthy populations and populations with cognitive impairment.[80,89–93]

3.1 Computerized Cognitive Training for Eating and Weight Change

Computerized cognitive training programs typically target inhibitory control or attention to change behavior. Inhibitory control training (ICT) programs have been applied to populations with overweight and obesity with the goal of improving inhibitory control capacity to suppress reward-driven behavior.[94,95] ICT paradigms reduce food intake, facilitate short-term weight loss, and reduce impulsive eating.[96–100] Attentional Bias Modification Programs (ABM) have been developed to train attention away from unhealthy food cues and towards healthy food cues or neutral non-food cues.[101] ABM reduces food intake,[102,103] increases healthier snack choices,[104] and shows potential for decreasing weight and reducing binge eating.[101]However, some more recent studies fail to demonstrate an effect.[105,106] Approach and avoidance training (AAT) is a bias training that shows promise in the domain of alcohol dependency that has been applied to eating behavior with mixed success.[107–110] AAT has been compared to ICT and both had the same effects on influencing food choices.[111] Daily WM training reduced emotional eating and eating psychopathology thoughts, although no changes in weight occurred.[112] One study found improvements in WM, meta-cognition and weight loss maintenance outcomes in children,[113] while another found improvements in WM and short-term eating behavior in adults, but no longer-term effects on BMI.[114] In sum, even though many computerized cognitive trainings demonstrate effects on eating behavior in lab-based tasks, reviews and meta-analyses suggest few studies examine behavior change outside of the lab, most fail to include a control group, and many focus on healthy weight samples, calling into question the generalizability of findings.[94,109,110]

3.2 Cognitive Remediation Therapy for Eating and Weight Change

Emerging research suggests cognitive training can be applied in a longer form non-computerized intervention to change eating behavior. Cognitive remediation as described above was adapted manualized to form Cognitive Remediation Therapy for Obesity (CRT-O), which focuses on changing thinking styles and relationships with food to improve EF and adherence to a weight-loss program. In this study, participants received three sessions of BWL and then were randomized to 4–6 weeks of CRT-O or a no-treatment control group.[115] Results from the study suggest CRT-O delivered after BWL, compared to no additional treatment after BWL, improved performance on measures of cognitive flexibility, resulted in greater weight loss and decreased binge eating. Further, cognitive flexibility mediated the effect of CRT-O on reduction of unhealthy eating and sedentary behavior habits.[116]

In summary, cognitive training has demonstrated efficacy in improving domains of EF and has shown preliminary efficacy in changing eating and weight behaviors. Although findings in the lab are promising, computerized cognitive training approaches may be less generalizable to real world settings to influence long-term weight change than manualized trainings delivered in-person.

3.3 Compensatory Cognitive Training in Non-Eating/Weight Contexts

In contrast to the drill and practice model of training, Compensatory Cognitive Training (CCT) is a form of cognitive training delivered in-person that teaches skills to compensate for and work around cognitive deficits.[90,117] CCT and Cognitive Symptom Management and Rehabilitation Therapy (CogSMART) are manualized interventions teaching compensatory strategies to improve EF and other cognitive domains, and are effective for individuals with a history of TBI or serious mental illness.[91,92,118,119] These interventions teach internal strategies, such as organization of information through categorization, or external strategies, such as developing associations with environmental cues, and relying on tools such as calendars, agendas, and notebooks.[117] The sessions incorporate both skill learning and practice, with an emphasis on practice time and the goal of turning skills into habits that can be applied in the real world. In between sessions, homework is assigned to encourage skill use in daily life.[117] CCT focuses on habit learning related to these new cognitive strategies (e.g., calendar use). Training helps participants develop these cognitive habits by using internal and external cues and routine, such as linking a new behavior to a routine behavior to form new cues and associations. For example, pairing checking the calendar with eating breakfast allows eating breakfast to become a cue for checking the calendar. Initially, additional supports such as sticky notes and alarms are encouraged to cue the new behavior until the habit is established. Furthermore, strategies on how to more effectively use the calendar are taught (e.g., breaking up larger tasks into smaller individual tasks) such that they rely less on EF to be accomplished successfully. The interventions are practical and deliverable in a variety of settings without requiring extensive clinician training.[92] Besides improving EF, functional outcomes such as quality of life and psychosocial functioning are improved in individuals with schizophrenia and TBI.[80,92,118] Although these populations have more severe impairments in EF than do adults with obesity, these data suggest that cognitive training can target EF as a mechanism during treatment, supporting its adaptation for adults with obesity. Past research suggests teaching strategies to compensate for more subtle EF deficiencies may be an effective approach to improve weight-loss outcomes.[52] Thus, modifying and applying CCT/CogSMART to circumvent EF difficulties found in individuals with overweight or obesity in conjunction with a BWL program is a novel approach that could improve treatment adherence, weight loss, and maintenance outcomes.

4. A Novel Approach Teaching Compensatory Strategies to Improve Eating and Decrease Weight

Given the lack of generalizability of behavior change from drill-and-training models and the success of CCT at modifying EF among other populations, we developed a Novel Executive Function Training (NEXT) for weight loss by adapting CCT/CogSMART to be delivered to treatment-seeking adults with overweight or obesity and EF deficits in conjunction with BWL. Given the difficulty of consistent adherence to BWL programs, we felt the evidence-based strategies from CCT/CogSMART could be applied to increase the habitual nature of behaviors required for success in BWL. The model for the treatment posits that success in BWL is tied to 1) attending treatment; 2) self-monitoring or tracking behaviors; 3) healthy eating; 4) PA; 5) maintaining a healthy home. Additionally, EF/EF-related domains essential for success in these areas include 1) prospective memory; 2) cognitive flexibility; 3) organization; 4) planning; 5) problem solving and 6) decision making. NEXT adapts skills from evidence-based CCT/CogSMART programs, applies them to BWL tenets, and trains these skills in weekly group sessions in conjunction with standard BWL. While some of the cognitive skills and strategies from CCT/CogSMART may overlap with those discussed in BWL, greater detail surrounding how to use these skills is provided in NEXT. A major difference is that NEXT teaches and provides much greater focus on how to use the skills and strategies that support the BWL tenets like calorie restriction. Additionally, time during each session is dedicated toward practicing and planning to incorporate these cognitive strategies. Accordingly, there is much more focus on experiential learning in session. For example, a typical BWL program might suggest participants schedule in PA to increase likelihood of exercising, and they must figure out how to effectively schedule in PA on their own. For individuals with lower EF, the suggestion alone to schedule in PA is often not sufficient and does not lead to the creation of routines and long-lasting habits. In contrast, during NEXT, these CCT strategies are routinely taught as part of the manualized curriculum so participants understand the most effective ways to use the strategy. Dedicated time during sessions is allocated to having participants practice implementing these strategies so participants are confident in their ability to use the strategies outside of group. For example, in NEXT participants are taught the benefits of calendar use as well as tips about how to increase the effectiveness of using a calendar. In the first week, participants are encouraged to select a calendar they are willing to carry with them daily. Time during each session is then dedicated to utilizing the calendar to schedule in time to practice strategies or schedule activities to help achieve weight loss goals (like scheduling in PA for the upcoming week). Participants are also taught to use their calendar to support all of the steps required to complete the PA. For example, they may put a note in their calendar the day before to put workout clothes in their car the night before. Table 2 shows additional details of how the CCT strategies support the BWL elements.

NEXT combines CCT with BWL. The CCT elements focus more on providing specific strategies that are designed help increase the frequency of desired behaviors and decrease the frequency of undesired behaviors for weight loss. The strategies help participants take the maximum advantage of the BWL content and provide the support needed to use the skills taught in BWL. There is a strong emphasis in the sessions on skill practice to increase the likelihood of implementation and to facilitate habit formation. NEXT supports the development of habits and routines for the behaviors needed to be maintained for success in BWL by working to automate these routines, reducing the cognitive load on the individual.

5. Feasibility and Acceptability of NEXT

We conducted an open-label pilot trial of NEXT (CCT+BWL), combining the cognitive skills most relevant for adhering to a weight-loss program with the traditional lifestyle modification recommendations of BWL. The purpose of the open-label pilot was to ensure the feasibility and acceptability of NEXT and to obtain stakeholder feedback to help refine treatment development.

5.1 Methods of Pilot Trial

5.1.1 Participants—Participants were recruited from a variety of sources including physician referrals, ResearchMatch (researchmatch.org; a recruitment tool that connects volunteers with researchers), and emails to listservs (e.g., university staff). Inclusion criteria were: 1) adults aged 18–60 years; 2) body mass index (BMI) >25 and ≤45 kg/m^2; 3) able to read English at a 6th grade level and 4) self-reported EF difficulties on a questionnaire created for the study. Exclusion criteria were: 1) medical condition that requires physician monitoring to participate in a weight control program or prohibits safely participating in recommended PA; 2) psychiatric condition that could interfere with program participation (e.g., acute suicidality; active psychosis); 3) pregnant or lactating; 4) enrolled in another organized weight control program; 5) change in medication that could influence weight in the previous three months; 6) history of bariatric surgery; and 7) history of a learning disorder, neurological condition or brain injury resulting in loss of consciousness for >30 minutes.

5.1.2 Procedures—Participants completed baseline assessments to verify inclusion criteria and provide baseline measurements. Following the final treatment group, participants completed a post-treatment assessment. Assessments included anthropometric data, surveys (including acceptability at post-treatment), and EF tasks. Height was taken in triplicate using a wall-mounted Seca 222 stadiometer by trained research assistants with the average of all three values used as height throughout the study. Weight was taken in duplicate on a digital Tanita scale at each assessment by trained research assistants. EF was assessed by the NIH Examiner,[120] an evidence-based battery across multiple EF domains, four subtests of the Delis-Kaplan Executive Function System (D-KEFS;[121] Color Word Interference [Inhibition], Trail Making Test [working memory; cognitive flexibility], Tower Test [planning & problem solving], and Design Fluency [fluency]), and via self-report by the Behavior Rating Inventory of Executive Function (BRIEF).[122] Participants were compensated $25 for completion of the baseline assessment and $50 for completion of the post-treatment assessment. All participants provided informed consent and the University of California San Diego Institutional Review Board approved all procedures.

5.1.3 Treatment—NEXT treatment consisted of 12, 75-minute group sessions over 12 weeks. Each group session started with conducting individual weekly weighing of participants followed by a weekly check-in to answer any questions about the previous week's materials, evaluate skill usage, and facilitate overcoming barriers to skill usage. For the remainder of each session, new BWL content and adapted CCT skills were taught and time during group was allotted to complete exercises to practice new skills. NEXT taught CCT skills concurrently with BWL content in each session so that the cognitive skills would help participants carry out the standard BWL program recommendations. The BWL content was based on empirically supported BWL programs focused on calorie reduction and increasing physical and lifestyle activity.[9–11,16] Participants were encouraged to self-monitor their food intake and PA daily. Participants were encouraged to self-monitor with the method they would use most frequently. Participants were provided a paper diary. For those interested in using an app, Myfitnesspal was recommended by the study team but participants were able to use any app they wished if they preferred a different one. Unlike in a standard BWL program, to improve rates of self-monitoring and encourage mastery, participants were encouraged to increase their tracking throughout the program. For the first cohort, participants were encouraged to add a meal each week to their tracking (start with dinner, then lunch & dinner) and then slowly start aiming for specific calorie ranges at each meal. Following feedback to introduce calories earlier, for the second cohort, participants were encouraged to track dinner the first week, then track dinner and aim for a specific calorie range at dinner, while also introducing tracking lunch the second week, slowly adding more meals and calorie goals each week. Each week, participants were provided their calorie range for weight loss, which was derived by multiplying their current weight in pounds by 12 and subtracting 500 and 1000. Males were instructed never to go below 1500 calories and females never to go below 1200 calories. Participants were instructed to use this daily range to set a specific target for each meal and snack.

5.2 Participant Characteristics

The sample included 19 participants from two cohorts of 10 and 9 participants. The sample was mostly female (n = 17; 89.5% female). Race/Ethnicity was self-reported and a slight majority of the sample identified as non-Hispanic White (n = 11; 57.9% non-Hispanic White, n = 5; 26.3% Hispanic). Participants ranged in age from 18–60 years (M = 48.11; SD = 11.54) and 14 (73.7%) had a starting BMI in the obesity range (>30kg/m^2; M = 33.2; SD = 5.1). Just over half the sample reported an income >$60,000 (n=11; 57.9%).

5.3 Feasibility & Acceptability of NEXT+BWL

Feasibility was assessed by the number of participants who were retained for the post-treatment assessment as well as attendance rates in treatment. Sixteen participants (84%) completed the post-treatment assessment. Nearly 75% of participants completed at least 50% of treatment sessions (n = 14; 74%) and over half completed at least 75% of the sessions (n = 11; 58%). The average number of sessions attended by all participants was 8 sessions (SD = 3.4).

Acceptability was assessed as part of a survey administered at the post-treatment assessment. Participants responded to several questions on a Likert scale with responses ranging from strongly disagree to strongly agree. Most participants (13/16; 81%) agreed or strongly agreed that they "enjoyed the NEXT program overall". Most participants (11/15; 73%)

agreed or strongly agreed that they would likely “refer someone to the NEXT program”. Most participants (12/16; 75%) agreed or strongly agreed that “the cognitive strategies taught in the NEXT program were useful for weight loss success.”

5.4 Preliminary Efficacy

We also explored preliminary efficacy of the treatment by descriptively evaluating the change in BMI and percent weight change for participants from baseline to post-treatment. Change in BMI ranged from −2.5 to +1.0 (M = −0.54; SD = 1.18) and percent weight change ranged from −8% to 3% (M = −1%; SD = 3%). Additionally, we descriptively evaluated the changes of the scores on EF measures (see Table 2). Effect sizes for several tasks suggested a small effect on EF. Change in BMI was not correlated with change in EF (*p*’s>.05; see Table 3)

6. Summary and Conclusions

Taken together, a breadth of research suggests that executive dysfunction can contribute to attenuated weight loss following BWL among individuals with overweight or obesity. Cognitive training approaches have been successfully applied to improve or compensate for lower EF in other conditions. Preliminary efforts to apply cognitive training to weight and eating behavior have been successful although the majority using drill-and-training approaches do not appear to generalize outside of the laboratory. We have created NEXT by adapting CCT/CogSMART and combining it with BWL. In our initial piloting of a brief 12-week intervention, as hypothesized our data show NEXT is feasible and acceptable. We descriptively explored change in weight and EF; however, given that these results are from an open-label pilot without a control group, these findings should be interpreted with caution. On average, BMI decreased and EF improved. Although weight change was lower than that reported in previous research following 12 weeks of lifestyle intervention,[123,124] NEXT takes a slower approach to initial weight loss and aims to break down the intervention to help encourage mastery of one step at a time. For example, in typical BWL programs, a calorie deficit range is provided at the second session. In NEXT, the full day calorie range wasn’t introduced until session 9 in cohort 1 and session 5 in cohort 2. Thus, it was expected weight loss would be lower than other 12 week BWL approaches. The slow approach to weight loss in NEXT was intentional to avoid the rebound effect typically seen in BWL approaches.[9,123,125–128] It is difficult to know whether the expected change in EF is above that expected from repeated assessment without a true randomized control trial; but the findings are promising as some of the effect sizes are in the medium range and are comparable to a previous 12-week CogSMART program.[91] Our effect sizes were smaller than the CRT-O study that had 11 sessions in 7–9 weeks and found large effect sizes for the two reported measures of EF.[115] However, EF measures have a lot of heterogeneity and all studies utilized different measures so it hard to make direct comparisons. NEXT demonstrated feasibility and acceptability, meeting the recommendations of what is to be explored in a pilot study.[129] No follow-up was conducted in our pilot study but it is hypothesized that the slow and steady approach of NEXT may improve weight-loss maintenance. Further, considering NEXT was only 12 weeks long when most treatments last at least 6 months, NEXT warrants further study through longer randomized controlled trials with follow-ups to understand long-term weight and EF impact and to properly evaluate efficacy. Future research should continue to evaluate the ability of cognitive training to improve weight-loss outcomes and overall executive function.

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7. References

1. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. JAMA. 2012;307(5):491–497. doi:10.1001/jama.2012.39 [PubMed: 22253363]
2. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet. 2014;384(9945):766–781. doi:10.1016/S0140-6736(14)60460-8
3. Dixon JB. The effect of obesity on health outcomes. Mol Cell Endocrinol. 2010;316(2):104–108. doi:10.1016/j.mce.2009.07.008 [PubMed: 19628019]
4. Seidell JC, Halberstadt J. The global burden of obesity and the challenges of prevention. Ann Nutr Metab. 2015;66 Suppl 2:7–12. doi:10.1159/000375143
5. Apovian CM. The clinical and economic consequences of obesity. Am J Manag Care. 2013;19(11 Suppl):s219–228.
6. Wang YC, McPherson K, Marsh T, Gortmaker SL, Brown M. Health and economic burden of the projected obesity trends in the USA and the UK. The Lancet. 2011;378(9793):815–825. doi:10.1016/S0140-6736(11)60814-3
7. de Ridder D, Adriaanse M, Evers C, Verhoeven A. Who diets? Most people and especially when they worry about food. Appetite. 2014;80:103–108. doi:10.1016/j.appet.2014.05.011 [PubMed: 24845781]
8. Wing RR, Phelan S. Long-term weight loss maintenance. Am J Clin Nutr. 2005;82(1):222S–225S. doi:10.1093/ajcn/82.1.222S [PubMed: 16002825]
9. Foster GD, Makris AP, Bailer BA. Behavioral treatment of obesity. Am J Clin Nutr. 2005;82(1 Suppl):230S–235S. doi:10.1093/ajcn/82.1.230S [PubMed: 16002827]
10. Wadden TA, Butryn ML, Wilson C. Lifestyle Modification for the Management of Obesity. Gastroenterology. 2007;132(6):2226–2238. doi:10.1053/j.gastro.2007.03.051 [PubMed: 17498514]
11. Wing RR, Hamman RF, Bray GA, et al. Achieving weight and activity goals among diabetes prevention program lifestyle participants. Obes Res. 2004;12(9):1426–1434. doi:10.1038/oby.2004.179 [PubMed: 15483207]
12. Diabetes Prevention Program Research Group. Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin. N Engl J Med. 2002;346(6):393–403. doi:10.1056/NEJMoa012512 [PubMed: 11832527]
13. Look AHEAD Research Group, Pi-Sunyer X, Blackburn G, et al. Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the look AHEAD trial. Diabetes Care. 2007;30(6):1374–1383. doi:10.2337/dc07-0048 [PubMed: 17363746]

14. Wadden TA, West DS, Neiberg R, et al. One-Year Weight Losses in the Look AHEAD Study: Factors Associated with Success. Obes Silver Spring Md. 2009;17(4):713–722. doi:10.1038/oby.2008.637
15. Wadden TA, Neiberg RH, Wing RR, et al. Four-year weight losses in the Look AHEAD study: factors associated with long-term success. Obes Silver Spring Md. 2011;19(10):1987–1998. doi:10.1038/oby.2011.230
16. Wadden TA, Butryn ML. Behavioral treatment of obesity. Endocrinol Metab Clin North Am. 2003;32(4):981–1003, x. doi:10.1016/s0889-8529(03)00072-0 [PubMed: 14711071]
17. Smith E, Hay P, Campbell L, Trollor JN. A review of the association between obesity and cognitive function across the lifespan: implications for novel approaches to prevention and treatment. Obes Rev Off J Int Assoc Study Obes. 2011;12(9):740–755. doi:10.1111/j.1467-789X.2011.00920.x
18. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. Cognit Psychol. 2000;41(1):49–100. doi:10.1006/cogp.1999.0734 [PubMed: 10945922]
19. Yang Y, Shields GS, Guo C, Liu Y. Executive function performance in obesity and overweight individuals: A meta-analysis and review. Neurosci Biobehav Rev. 2018;84:225–244. doi:10.1016/j.neubiorev.2017.11.020 [PubMed: 29203421]
20. Favieri F, Forte G, Casagrande M. The Executive Functions in Overweight and Obesity: A Systematic Review of Neuropsychological Cross-Sectional and Longitudinal Studies. Front Psychol. 2019;10. doi:10.3389/fpsyg.2019.02126
21. Dohle S, Diel K, Hofmann W. Executive functions and the self-regulation of eating behavior: A review. Appetite. 2018;124:4–9. doi:10.1016/j.appet.2017.05.041 [PubMed: 28551113]
22. Hall PA, Marteau TM. Executive function in the context of chronic disease prevention: Theory, research and practice. Prev Med. 2014;68:44–50. doi:10.1016/j.ypmed.2014.07.008 [PubMed: 25042899]
23. Hofmann W, Schmeichel BJ, Baddeley AD. Executive functions and self-regulation. Trends Cogn Sci. 2012;16(3):174–180. doi:10.1016/j.tics.2012.01.006 [PubMed: 22336729]
24. Twamley EW. Compensatory Cognitive Training for Clients with Psychiatric Illness. Unpublished treatment manual. 2011.
25. Twamley EW, Noonan SK, Savla GN, et al. Cognitive Symptom Management and Rehabilitation Therapy (CogSMART) for Traumatic Brain Injury. Unpublished treatment manual. 2011.
26. Hofmann W, Friese M, Strack F. Impulse and Self-Control From a Dual-Systems Perspective. Perspect Psychol Sci. 2009;4(2):162–176. doi:10.1111/j.1745-6924.2009.01116.x [PubMed: 26158943]
27. Strack F, Deutsch R. Reflective and Impulsive Determinants of Social Behavior. Personal Soc Psychol Rev. 2004;8(3):220–247. doi:10.1207/s15327957pspr0803_1
28. Dassen FCM, Houben K, Allom V, Jansen A. Self-regulation and obesity: the role of executive function and delay discounting in the prediction of weight loss. J Behav Med. 2018;41(6):806–818. doi:10.1007/s10865-018-9940-9 [PubMed: 29802535]
29. Teixeira PJ, Mata J, Williams GC, Gorin AA, Lemieux S. Self-Regulation, Motivation, and Psychosocial Factors in Weight Management. J Obes. 2012;2012:1–4. doi:10.1155/2012/582348
30. Lehto JE, Juujärvi P, Kooistra L, Pulkkinen L. Dimensions of executive functioning: Evidence from children. Br J Dev Psychol. 2003;21(1):59–80. doi:10.1348/026151003321164627
31. Kavanagh DJ, Andrade J, May J. Imaginary relish and exquisite torture: the elaborated intrusion theory of desire. Psychol Rev. 2005;112(2):446–467. doi:10.1037/0033-295X.112.2.446 [PubMed: 15783293]
32. Barrett LF, Tugade MM, Engle RW. Individual Differences in Working Memory Capacity and Dual-Process Theories of the Mind. Psychol Bull. 2004;130(4):553–573. doi:10.1037/0033-2909.130.4.553 [PubMed: 15250813]
33. Guerrieri R, Nederkoorn C, Schrooten M, Martijn C, Jansen A. Inducing impulsivity leads high and low restrained eaters into overeating, whereas current dieters stick to their diet. Appetite. 2009;53(1):93–100. doi:10.1016/j.appet.2009.05.013 [PubMed: 19467278]

34. Goschke T. Voluntary action and cognitive control from a cognitive neuroscience perspective. In: Voluntary Action: Brains, Minds, and Sociality. Oxford University Press; 2003:49–85.

35. Diamond A. Executive Functions. Annu Rev Psychol. 2013;64:135–168. doi:10.1146/annurev-psych-113011-143750 [PubMed: 23020641]

36. Collins A, Koechlin E. Reasoning, Learning, and Creativity: Frontal Lobe Function and Human Decision-Making. PLOS Biol. 2012;10(3):e1001293. doi:10.1371/journal.pbio.1001293 [PubMed: 22479152]

37. Hall PA, Fong GT. Temporal Self-Regulation Theory: Integrating Biological, Psychological, and Ecological Determinants of Health Behavior Performance. In: Hall PA, ed. Social Neuroscience and Public Health: Foundations for the Science of Chronic Disease Prevention. Springer; 2013:35–53. doi:10.1007/978-1-4614-6852-3_3

38. Pavela G, Lewis DW, Locher J, Allison DB. Socioeconomic Status, Risk of Obesity, and the Importance of Albert J. Stunkard. Curr Obes Rep. 2016;5(1):132–139. doi:10.1007/s13679-015-0185-4 [PubMed: 26746415]

39. Newton S, Braithwaite D, Akinyemiju TF. Socio-economic status over the life course and obesity: Systematic review and meta-analysis. PLoS ONE. 2017;12(5). doi:10.1371/journal.pone.0177151

40. Mackey AP, Hill SS, Stone SI, Bunge SA. Differential effects of reasoning and speed training in children. Dev Sci. 2011;14(3):582–590. doi:10.1111/j.1467-7687.2010.01005.x [PubMed: 21477196]

41. Goldstein FC, Green RC. Assessment of Problem Solving and Executive Functions. In: Mapou RL, Spector J, eds. Clinical Neuropsychological Assessment: A Cognitive Approach. Critical Issues in Neuropsychology. Springer US; 1995:49–81. doi:10.1007/978-1-4757-9709-1_3

42. Field M, Werthmann J, Franken I, Hofmann W, Hogarth L, Roefs A. The Role of Attentional Bias in Obesity and Addiction. Health Psychol. 2016;35:767–780. doi:10.1037/hea0000405 [PubMed: 27505196]

43. Pearce AL, Leonhardt CA, Vaidya CJ. Executive and Reward-Related Function in Pediatric Obesity: A Meta-Analysis. Child Obes. 2018;14(5):265–279. doi:10.1089/chi.2017.0351 [PubMed: 29874102]

44. Fitzpatrick S, Gilbert S, Serpell L. Systematic review: are overweight and obese individuals impaired on behavioural tasks of executive functioning? Neuropsychol Rev. 2013;23(2):138–156. doi:10.1007/s11065-013-9224-7 [PubMed: 23381140]

45. Liang J, Matheson BE, Kaye WH, Boutelle KN. Neurocognitive correlates of obesity and obesity-related behaviors in children and adolescents. Int J Obes 2005. 2014;38(4):494–506. doi:10.1038/ijo.2013.142

46. Danner UN, Ouwehand C, van Haastert NL, Hornsveld H, de Ridder DTD. Decision-making impairments in women with binge eating disorder in comparison with obese and normal weight women. Eur Eat Disord Rev J Eat Disord Assoc. 2012;20(1):e56–62. doi:10.1002/erv.1098

47. Davis C, Patte K, Curtis C, Reid C. Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. Appetite. 2010;54(1):208–213. doi:10.1016/j.appet.2009.11.002 [PubMed: 19896515]

48. Weller RE, Cook EW, Avsar KB, Cox JE. Obese women show greater delay discounting than healthy-weight women. Appetite. 2008;51(3):563–569. doi:10.1016/j.appet.2008.04.010 [PubMed: 18513828]

49. Gunstad J, Paul RH, Cohen RA, Tate DF, Spitznagel MB, Gordon E. Elevated body mass index is associated with executive dysfunction in otherwise healthy adults. Compr Psychiatry. 2007;48(1):57–61. doi:10.1016/j.comppsych.2006.05.001 [PubMed: 17145283]

50. Lokken KL, Boeka AG, Yellumahanthi K, Wesley M, Clements RH. Cognitive performance of morbidly obese patients seeking bariatric surgery. Am Surg. 2010;76(1):55–59. [PubMed: 20135940]

51. Coppin G, Nolan-Poupart S, Jones-Gotman M, Small DM. Working memory and reward association learning impairments in obesity. Neuropsychologia. 2014;65:146–155. doi:10.1016/j.neuropsychologia.2014.10.004 [PubMed: 25447070]

52. Gunstad J, Sanborn V, Hawkins M. Cognitive dysfunction is a risk factor for overeating and obesity. Am Psychol. 2020;75(2):219–234. doi:10.1037/amp0000585 [PubMed: 32052996]

53. Guerrieri R, Nederkoorn C, Jansen A. The interaction between impulsivity and a varied food environment: its influence on food intake and overweight. Int J Obes 2005. 2008;32(4):708–714. doi:10.1038/sj.ijo.0803770

54. Allom V, Mullan B. Individual differences in executive function predict distinct eating behaviours. Appetite. 2014;80:123–130. doi:10.1016/j.appet.2014.05.007 [PubMed: 24845785]

55. Limbers CA, Young D. Executive functions and consumption of fruits/vegetables and high saturated fat foods in young adults. J Health Psychol. 2015;20(5):602–611. doi:10.1177/1359105315573470 [PubMed: 25903247]

56. Gray-Burrows K, Taylor N, O'Connor D, Sutherland E, Stoet G, Conner M. A systematic review and meta-analysis of the executive function-health behaviour relationship. Health Psychol Behav Med. 2019;7(1):253–268. doi:10.1080/21642850.2019.1637740 [PubMed: 34040850]

57. Gazzaley A, D'Esposito M. Unifying prefrontal cortex function: Executive control, neural networks, and top-down modulation. In: The Human Frontal Lobes: Functions and Disorders, 2nd Ed. The Guilford Press; 2007:187–206.

58. Whitelock V, Nouwen A, van den Akker O, Higgs S. The role of working memory sub-components in food choice and dieting success. Appetite. 2018;124:24–32. doi:10.1016/j.appet.2017.05.043 [PubMed: 28554850]

59. Salas-Gomez D, Fernandez-Gorgojo M, Pozueta A, et al. Physical Activity Is Associated With Better Executive Function in University Students. Front Hum Neurosci. 2020;14. doi:10.3389/fnhum.2020.00011

60. Byrd-Bredbenner C, Eck KM. Relationships among Executive Function, Cognitive Load, and Weight-related Behaviors in University Students. Am J Health Behav. 2020;44(5):691–703. doi:10.5993/AJHB.44.5.12 [PubMed: 33121586]

61. Eggermont LHP, Milberg WP, Lipsitz LA, Scherder EJA, Leveille SG. Physical Activity and Executive Function in Aging: The MOBILIZE Boston Study. J Am Geriatr Soc. 2009;57(10):1750–1756. doi:10.1111/j.1532-5415.2009.02441.x [PubMed: 19702618]

62. Frederiksen KS, Verdelho A, Madureira S, et al. Physical activity in the elderly is associated with improved executive function and processing speed: the LADIS Study. Int J Geriatr Psychiatry. 2015;30(7):744–750. doi:10.1002/gps.4220 [PubMed: 25363336]

63. Best JR, Theim KR, Gredysa DM, et al. Behavioral Economic Predictors of Overweight Children's Weight Loss. J Consult Clin Psychol. 2012;80(6):1086–1096. doi:10.1037/a0029827 [PubMed: 22924332]

64. Spitznagel MB, Garcia S, Miller LA, et al. Cognitive Function Predicts Weight Loss Following Bariatric Surgery. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2013;9(3):453–459. doi:10.1016/j.soard.2011.10.008

65. Walø-Syversen G, Kvalem IL, Kristinsson J, Eribe IL, Rø Ø, Dahlgren CL. Executive Function, Eating Behavior, and Preoperative Weight Loss in Bariatric Surgery Candidates: An Observational Study. Obes Facts. 2019;12(5):489–501. doi:10.1159/000502118 [PubMed: 31505516]

66. Alosco ML, Galioto R, Spitznagel MB, et al. Cognitive function after bariatric surgery: evidence for improvement 3 years after surgery. Am J Surg. 2014;207(6):870–876. doi:10.1016/j.amjsurg.2013.05.018 [PubMed: 24119892]

67. Butryn ML, Martinelli MK, Remmert JE, et al. Executive Functioning as a Predictor of Weight Loss and Physical Activity Outcomes. Ann Behav Med Publ Soc Behav Med. 2019;53(10):909–917. doi:10.1093/abm/kaz001

68. Eichen DM, Matheson BE, Liang J, Strong DR, Rhee K, Boutelle KN. The relationship between executive functioning and weight loss and maintenance in children and parents participating in family-based treatment for childhood obesity. Behav Res Ther. 2018;105:10–16. doi:10.1016/j.brat.2018.03.010 [PubMed: 29609102]

69. Nederkoorn C, Jansen E, Mulkens S, Jansen A. Impulsivity predicts treatment outcome in obese children. Behav Res Ther. 2007;45(5):1071–1075. doi:10.1016/j.brat.2006.05.009 [PubMed: 16828053]

70. Manasse SM, Flack D, Dochat C, Zhang F, Butryn ML, Forman EM. Not so fast: The impact of impulsivity on weight loss varies by treatment type. Appetite. 2017;113:193–199. doi:10.1016/j.appet.2017.02.042 [PubMed: 28257940]

71. Galioto R, Bond D, Gunstad J, Pera V, Rathier L, Tremont G. Executive functions predict weight loss in a medically supervised weight loss programme. Obes Sci Pract. 2016;2(4):334–340. doi:10.1002/osp4.70 [PubMed: 28090338]
72. Veronese N, Facchini S, Stubbs B, et al. Weight loss is associated with improvements in cognitive function among overweight and obese people: A systematic review and meta-analysis. Neurosci Biobehav Rev. 2017;72:87–94. doi:10.1016/j.neubiorev.2016.11.017 [PubMed: 27890688]
73. Allan JL, McMinn D, Daly M. A Bidirectional Relationship between Executive Function and Health Behavior: Evidence, Implications, and Future Directions. Front Neurosci. 2016;10. doi:10.3389/fnins.2016.00386
74. Daly M, McMinn D, Allan JL. A bidirectional relationship between physical activity and executive function in older adults. Front Hum Neurosci. 2015;8. doi:10.3389/fnhum.2014.01044
75. Colcombe S, Kramer AF. Fitness effects on the cognitive function of older adults: a meta-analytic study. Psychol Sci. 2003;14(2):125–130. doi:10.1111/1467-9280.t01-1-01430 [PubMed: 12661673]
76. Smith PJ, Blumenthal JA, Hoffman BM, et al. Aerobic exercise and neurocognitive performance: a meta-analytic review of randomized controlled trials. Psychosom Med. 2010;72(3):239–252. doi:10.1097/PSY.0b013e3181d14633 [PubMed: 20223924]
77. Zhu L, Li L, Wang L, Jin X, Zhang H. Physical Activity for Executive Function and Activities of Daily Living in AD Patients: A Systematic Review and Meta-Analysis. Front Psychol. 2020;11. doi:10.3389/fpsyg.2020.560461
78. McAuley E, Mullen SP, Szabo AN, et al. Self-regulatory processes and exercise adherence in older adults: executive function and self-efficacy effects. Am J Prev Med. 2011;41(3):284–290. doi:10.1016/j.amepre.2011.04.014 [PubMed: 21855742]
79. Belleville S Cognitive training for persons with mild cognitive impairment. Int Psychogeriatr. 2008;20(1):57–66. doi:10.1017/S104161020700631X [PubMed: 17958927]
80. McGurk SR, Twamley EW, Sitzer DI, McHugo GJ, Mueser KT. A Meta-Analysis of Cognitive Remediation in Schizophrenia. Am J Psychiatry. 2007;164(12):1791–1802. doi:10.1176/appi.ajp.2007.07060906 [PubMed: 18056233]
81. Bahar-Fuchs A, Martyr A, Goh AM, Sabates J, Clare L. Cognitive training for people with mild to moderate dementia. Cochrane Database Syst Rev. 2018;2018(7). doi:10.1002/14651858.CD013069
82. Allom V, Mullan B, Hagger M. Does inhibitory control training improve health behaviour? A meta-analysis. Health Psychol Rev. 2016;10(2):168–186. doi:10.1080/17437199.2015.1051078 [PubMed: 26058688]
83. Lampit A, Hallock H, Valenzuela M. Computerized cognitive training in cognitively healthy older adults: a systematic review and meta-analysis of effect modifiers. PLoS Med. 2014;11(11):e1001756. doi:10.1371/journal.pmed.1001756 [PubMed: 25405755]
84. Greig TC, Zito W, Wexler BE, Fiszdon J, Bell MD. Improved cognitive function in schizophrenia after one year of cognitive training and vocational services. Schizophr Res. 2007;96(1):156–161. doi:10.1016/j.schres.2007.07.003 [PubMed: 17669629]
85. Fisher M, Subramaniam K, Panizzutti R, Vinogradov S. Computerized cognitive training in schizophrenia: current knowledge and future directions. In: Harvey PD, ed. Cognitive Impairment in Schizophrenia: Characteristics, Assessment and Treatment. Cambridge University Press; 2013:284–315. doi:10.1017/CBO9781139003872.017
86. Genevsky A, Garrett CT, Alexander PP, Vinogradov S. Cognitive training in schizophrenia: a neuroscience-based approach. Dialogues Clin Neurosci. 2010;12(3):416–421. [PubMed: 20954435]
87. Hill NTM, Mowszowski L, Naismith SL, Chadwick VL, Valenzuela M, Lampit A. Computerized Cognitive Training in Older Adults With Mild Cognitive Impairment or Dementia: A Systematic Review and Meta-Analysis. Am J Psychiatry. 2016;174(4):329–340. doi:10.1176/appi.ajp.2016.16030360 [PubMed: 27838936]
88. Harvey PD, McGurk SR, Mahncke H, Wykes T. Controversies in Computerized Cognitive Training. Biol Psychiatry Cogn Neurosci Neuroimaging. 2018;3(11):907–915. doi:10.1016/j.bpsc.2018.06.008 [PubMed: 30197048]

89. Wykes T, Huddy V, Cellard C, McGurk SR, Czobor P. A meta-analysis of cognitive remediation for schizophrenia: methodology and effect sizes. Am J Psychiatry. 2011;168(5):472–485. doi:10.1176/appi.ajp.2010.10060855 [PubMed: 21406461]

90. Cicerone KD, Langenbahn DM, Braden C, et al. Evidence-Based Cognitive Rehabilitation: Updated Review of the Literature From 2003 Through 2008. Arch Phys Med Rehabil. 2011;92(4):519–530. doi:10.1016/j.apmr.2010.11.015 [PubMed: 21440699]

91. Twamley EW, Jak AJ, Delis DC, Bondi MW, Lohr JB. Cognitive Symptom Management and Rehabilitation Therapy (CogSMART) for veterans with traumatic brain injury: pilot randomized controlled trial. J Rehabil Res Dev. 2014;51(1):59–70. doi:10.1682/JRRD.2013.01.0020 [PubMed: 24805894]

92. Twamley EW, Thomas KR, Gregory AM, et al. CogSMART Compensatory Cognitive Training for Traumatic Brain Injury: Effects Over 1 Year. J Head Trauma Rehabil. 2015;30(6):391–401. doi:10.1097/HTR.0000000000000076 [PubMed: 25033034]

93. Rebok GW, Ball K, Guey LT, et al. Ten-Year Effects of the ACTIVE Cognitive Training Trial on Cognition and Everyday Functioning in Older Adults. J Am Geriatr Soc. 2014;62(1):16–24. doi:10.1111/jgs.12607 [PubMed: 24417410]

94. Jones A, Hardman CA, Lawrence N, Field M. Cognitive training as a potential treatment for overweight and obesity: A critical review of the evidence. Appetite. 2018;124:50–67. doi:10.1016/j.appet.2017.05.032 [PubMed: 28546010]

95. Houben K, Jansen A. Training inhibitory control. A recipe for resisting sweet temptations. Appetite. 2011;56(2):345–349. doi:10.1016/j.appet.2010.12.017 [PubMed: 21185896]

96. Lawrence NS, Verbruggen F, Morrison S, Adams RC, Chambers CD. Stopping to food can reduce intake. Effects of stimulus-specificity and individual differences in dietary restraint. Appetite. 2015;85:91–103. doi:10.1016/j.appet.2014.11.006 [PubMed: 25447023]

97. Veling H, Lawrence NS, Chen Z, van Koningsbruggen GM, Holland RW. What Is Trained During Food Go/No-Go Training? A Review Focusing on Mechanisms and a Research Agenda. Curr Addict Rep. 2017;4(1):35–41. doi:10.1007/s40429-017-0131-5 [PubMed: 28357193]

98. Stice E, Lawrence NS, Kemps E, Veling H. Training motor responses to food: A novel treatment for obesity targeting implicit processes. Clin Psychol Rev. 2016;49:16–27. doi:10.1016/j.cpr.2016.06.005 [PubMed: 27498406]

99. Forman EM, Manasse SM, Dallal DH, et al. Computerized neurocognitive training for improving dietary health and facilitating weight loss. J Behav Med. 2019;42(6):1029–1040. doi:10.1007/s10865-019-00024-5 [PubMed: 30891657]

100. Preuss H, Pinnow M, Schnicker K, Legenbauer T. Improving Inhibitory Control Abilities (ImpulsE)—A Promising Approach to Treat Impulsive Eating? Eur Eat Disord Rev. 2017;25(6):533–543. doi:10.1002/erv.2544 [PubMed: 28901678]

101. Boutelle KN, Monreal T, Strong DR, Amir N. An open trial evaluating an attention bias modification program for overweight adults who binge eat. J Behav Ther Exp Psychiatry. 2016;52:138–146. doi:10.1016/j.jbtep.2016.04.005 [PubMed: 27116704]

102. Kemps E, Tiggemann M, Orr J, Grear J. Attentional retraining can reduce chocolate consumption. J Exp Psychol Appl. 2014;20(1):94–102. doi:10.1037/xap0000005 [PubMed: 24079387]

103. Turton R, Bruidegom K, Cardi V, Hirsch CR, Treasure J. Novel methods to help develop healthier eating habits for eating and weight disorders: A systematic review and meta-analysis. Neurosci Biobehav Rev. 2016;61:132–155. doi:10.1016/j.neubiorev.2015.12.008 [PubMed: 26695383]

104. Kakoschke N, Kemps E, Tiggemann M. Approach bias modification training and consumption: A review of the literature. Addict Behav. 2017;64:21–28. doi:10.1016/j.addbeh.2016.08.007 [PubMed: 27538198]

105. Verbeken S, Braet C, Naets T, Houben K, Boendermaker W. Computer training of attention and inhibition for youngsters with obesity: A pilot study. Appetite. 2018;123:439–447. doi:10.1016/j.appet.2017.12.029 [PubMed: 29305890]

106. Carbine KA, Muir AM, Allen WD, et al. Does inhibitory control training reduce weight and caloric intake in adults with overweight and obesity? A pre-registered, randomized controlled event-related potential (ERP) study. Behav Res Ther. 2021;136:103784. doi:10.1016/j.brat.2020.103784 [PubMed: 33316579]

107. Kemps E, Tiggemann M, Martin R, Elliott M. Implicit approach–avoidance associations for craved food cues. J Exp Psychol Appl. 20130218;19(1):30. doi:10.1037/a0031626 [PubMed: 23421423]

108. Fishbach A, Shah JY. Self-control in action: Implicit dispositions toward goals and away from temptations. J Pers Soc Psychol. 20060530;90(5):820. doi:10.1037/0022-3514.90.5.820 [PubMed: 16737375]

109. Becker D, Jostmann NB, Wiers RW, Holland RW. Approach avoidance training in the eating domain: Testing the effectiveness across three single session studies. Appetite. 2015;85:58–65. doi:10.1016/j.appet.2014.11.017 [PubMed: 25447011]

110. Yang Y, Shields GS, Wu Q, Liu Y, Chen H, Guo C. Cognitive training on eating behaviour and weight loss: A meta-analysis and systematic review. Obes Rev. 2019;20(11):1628–1641. doi:10.1111/obr.12916 [PubMed: 31353774]

111. Veling H, Verpaalen IAM, Liu H, Mosannenzadeh F, Becker D, Holland RW. How can food choice best be trained? Approach-avoidance versus go/no-go training. Appetite. Published online March 23, 2021:105226. doi:10.1016/j.appet.2021.105226

112. Houben K, Dassen FCM, Jansen A. Taking control: Working memory training in overweight individuals increases self-regulation of food intake. Appetite. 2016;105:567–574. doi:10.1016/j.appet.2016.06.029 [PubMed: 27349707]

113. Verbeken S, Braet C, Goossens L, van der Oord S. Executive function training with game elements for obese children: a novel treatment to enhance self-regulatory abilities for weight-control. Behav Res Ther. 2013;51(6):290–299. doi:10.1016/j.brat.2013.02.006 [PubMed: 23524063]

114. Dassen FCM, Houben K, Van Breukelen GJP, Jansen A. Gamified working memory training in overweight individuals reduces food intake but not body weight. Appetite. 2018;124:89–98. doi:10.1016/j.appet.2017.05.009 [PubMed: 28479405]

115. Raman J, Hay P, Tchanturia K, Smith E. A randomised controlled trial of manualized cognitive remediation therapy in adult obesity. Appetite. 2018;123:269–279. doi:10.1016/j.appet.2017.12.023 [PubMed: 29278718]

116. Allom V, Mullan B, Smith E, Hay P, Raman J. Breaking bad habits by improving executive function in individuals with obesity. BMC Public Health. 2018;18(1):505. doi:10.1186/s12889-018-5392-y [PubMed: 29661241]

117. Twamley EW, Zurhellen CH, Vella L. Compensatory Cognitive Training. Neurocognition Soc Cogn Schizophr Patients. 2010;177:50–60. doi:10.1159/000284378

118. Twamley EW, Thomas KR, Burton CZ, et al. Compensatory cognitive training for people with severe mental illnesses in supported employment: A randomized controlled trial. Schizophr Res. 2019;203:41–48. doi:10.1016/j.schres.2017.08.005 [PubMed: 28823720]

119. Twamley EW, Vella L, Burton CZ, Heaton RK, Jeste DV. Compensatory cognitive training for psychosis: effects in a randomized controlled trial. J Clin Psychiatry. 2012;73(9):1212–1219. doi:10.4088/JCP.12m07686 [PubMed: 22939029]

120. Kramer JH, Mungas D, Possin KL, et al. NIH EXAMINER: Conceptualization and Development of an Executive Function Battery. J Int Neuropsychol Soc JINS. 2014;20(1):11–19. doi:10.1017/S1355617713001094 [PubMed: 24103232]

121. Delis DC, Kaplan E, Kramer JH. Delis-Kaplan Executive Function System (DKEFS). San Antonio, TX: Psychological Corporation; 2001.

122. Roth RM, Isquith PK, Gioia GA. Behavioral Rating Inventory of Executive Function - Adult Version. Lutz, FL: Psychological Assessment Resources, Inc; 2005.

123. Skender ML, Goodrick GK, Del junco DJ, et al. Comparison of 2-Year Weight Loss Trends in Behavioral Treatments of Obesity: Diet, Exercise, and Combination Interventions. J Am Diet Assoc. 1996;96(4):342–346. doi:10.1016/S0002-8223(96)00096-X [PubMed: 8598434]

124. Rippe JM, Price JM, Hess SA, et al. Improved Psychological Well-Being, Quality of Life, and Health Practices in Moderately Overweight Women Participating in a 12-Week Structured Weight Loss Program. Obes Res. 1998;6(3):208–218. doi:10.1002/j.1550-8528.1998.tb00339.x [PubMed: 9618125]

125. Kramer FM, Jeffery RW, Forster JL, Snell MK. Long-term follow-up of behavioral treatment for obesity: patterns of weight regain among men and women. Int J Obes. 1989;13(2):123–136. [PubMed: 2663745]

126. Sarlio-Lähteenkorva S, Rissanen A, Kaprio J. A descriptive study of weight loss maintenance: 6 and 15 year follow-up of initially overweight adults. Int J Obes Relat Metab Disord J Int Assoc Study Obes. 2000;24(1):116–125. doi:10.1038/sj.ijo.0801094

127. G Wilson KD Brownell. Behavioral treatment for obesity. In: Eating Disorders and Obesity: A Comprehensive Handbook. 3rd ed. The Guilford Press; :524–528.

128. Wadden TA, Sarwer DB. Behavioral Treatment of Obesity. In: Goldstein DJ, ed. The Management of Eating Disorders and Obesity. Nutrition ◊ and ◊ Health. Humana Press; 1999:173–199. doi:10.1007/978-1-59259-694-2_14

129. Leon AC, Davis LL, Kraemer HC. The role and interpretation of pilot studies in clinical research. J Psychiatr Res. 2011;45(5):626–629. doi:10.1016/j.jpsychires.2010.10.008 [PubMed: 21035130]

Highlights

- Executive function (EF) may be associated with lower weight loss
- Compensatory Cognitive Training (CCT) teaches compensatory skills for EF deficits
- We developed Novel Executive Function Training for Obesity (NEXT) from a CCT
- NEXT (CCT + behavioral weight loss) is acceptable and feasible and may improve outcomes
- Incorporating CCT with obesity treatment may improve weight loss.

Table 1.

EF and EF-related constructs and their relation to weight management and BWL skills

Construct	Description	Example of relation to weight management
Core Executive Functions		
Working memory	The ability to hold information in mind and manipulate it[35]	Keeping long term health goals in working memory when selecting foods to eat in the moment (so that you are more likely to make healthier choices)
Inhibition	The ability to control impulses/thoughts/behaviors to override habits or internal dispositions to do what is more appropriate in the given situation[35]	Inhibiting the urge to eat donuts that are in the break room
Cognitive flexibility	The ability to change perspectives and consider alternate solutions to a problem[35] (also known as set-shifting)	Thinking flexibly about solutions for high-risk eating situations
Related Executive Functions		
Reasoning	The ability to think logically and solve novel problems; decision-making[40]	Evaluating and choosing which solution will work best for a given high-risk situation
Problem solving	The ability to describe the parameters of a situation, call upon relevant experience, select a solution, and plan a sequence of behavior[41]	Identifying solutions that will work in future high-risk situations; anticipating and dealing with barriers
Planning	The ability to devise a sequence of behaviors needed to meet a goal[19]	Meal planning; planning PA in advance; planning ahead for future high-risk situations
Prospective Memory	The ability to remember to do things in the future	Remembering to self-monitor, weigh weekly, and schedule in PA
Organization	The ability to maintain order both physically in your surroundings and cognitively to help achieve goal-directed action	Organizing the kitchen to promote eating more fruits and vegetables; system to store meal plans
Attention	The ability of certain stimuli to capture attention[42]	Attending to healthy food choices rather than the high-calorie food cues in the environment
Fluency	The ability to generate a variety of ideas or responses	Generate a variety of ideas to use while planning for high-risk situations

Table 2:

CCT Strategies that Support BWL in NEXT

BWL Tenet	CCT Supportive Strategies and Formalized Didactics	In-Session Practice
Attending Group Treatment	Calendar use starting with tips on how to effectively use and regularly check calendar, alarms, developing routines, prioritization and time management	Writing Sessions in Calendar on Day 1; Identifying barriers and coming up with plans to allow for attendance; time spent in session identifying priorities related to weight loss and plans to limit time wasters
Self-Monitoring	Routines, alarms, calendar use, SMART goals, benefits of daily and weekly planning sessions to evaluate progress	Setting alarms and reminders; scheduling time in calendar to track; setting SMART goals around frequency of tracking
Healthy Eating/ Calorie Restriction	Set calorie goal for each meal, holding a weekly planning session and linking meal planning with weekly planning session, creating lists, calendar use to incorporate grocery shopping & meal prep time, planning ahead and problem solving, using self-talk while problem solving, routine formation around meal planning and preparation	Time to develop personalized goal for calories at each meal and snack each week; practice meal planning in session; calendar exercise to schedule in grocery shopping and meal prep time; in-session activity to create routines around meal prepping and planning
Increasing Physical Activity	Calendar use, the benefits of routines and how to establish them, problem solving barriers, prioritization	Time spent scheduling PA in calendar; scheduling & planning reminders to stick to schedule; problem solving exercise to look at barriers; exercise to develop routines around PA
Maintaining a Healthy Home/ Stimulus Control	Calendar use, creating lists, linking tasks, self-talk, organizing environment to facilitate healthy habits	Time spent in session planning on how to organize environment; scheduling in time to make grocery lists during weekly planning and sticking to list while shopping (using self-talk)

Table 3:

Change in EF Measures following NEXT treatment

Executive Function Outcome	Change in EF outcome	SD of Change Score	Effect Size	Pearson Correlation with BMI Change
NIH EXAMINER				
Executive Composite Score	0.09	0.26	0.34	−0.05; p=0.86
Fluency Factor Score	0.11	0.35	0.33	0.18; p=0.49
Cognitive Control Factor Score	0.18	0.26	0.70	0.11; p=0.70
BRIEF [a]				
Global Executive Composite	−0.94	7.57	−0.12	0.18; p=0.50
Behavioral Regulation Index	0.00	8.18	0.00	0.20; p=0.46
Metacognition Index	−1.50	6.82	−0.22	0.16; p=0.55
Inhibit Scale	−0.13	5.74	−0.02	0.39; p=0.15
Shift Scale	0.13	9.67	0.01	−0.08; p=0.75
Emotional Control Scale	0.94	8.24	0.11	0.13; p=0.62
Self-Monitor Scale	−1.38	7.33	−0.19	0.38; p=0.15
Initiate Scale	−1.63	7.00	−0.23	0.19; p=0.48
Working Memory Scale	−0.63	9.22	−0.07	−0.01; p=0.97
Plan/Organize Scale	−0.13	9.69	−0.01	0.25; p=0.35
Task Monitor Scale	−2.75	9.33	−0.29	−0.11; p=0.68
Organization of Materials Scale	−1.69	5.57	−0.30	0.08; p=0.76
D-KEFS				
Trail Making Test – Condition 4: Number-Letter Switching Scaled Score	−0.27	1.28	−0.21	−0.26; p=0.34
Design Fluency Composite Scaled Score	0.80	2.81	0.28	−0.09; p=0.74
Color Word Interference – Condition 4: Inhibition/Switching	0.53	1.19	0.45	0.39; p=0.15
Tower Test Total Achievement Scaled Score	1.86	2.60	0.71	0.44; p=0.12

Note: BRIEF = Behavior Rating Inventory of Executive Function; D-KEFS = Delis-Kaplan Executive Function System.

[a]Higher scores on the BRIEF represent greater impairment so negative numbers indicate improvement in EF