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Executive functioning in overweight individuals with and without loss-of-control eating

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Abstract

Objective—The current study sought to examine executive functioning (EF) in overweight individuals with and without loss-of-control (LOC) eating.

Method—Eighty overweight and obese individuals entering a behavioral weight loss trial with (n=18) and without (n=62) LOC eating were administered a clinical interview and neuropsychological battery designed to assess self-regulatory control, planning, delayed discounting, and working memory.

Results—After controlling for age, IQ, and depression, individuals with LOC eating performed worse on tasks of planning and self-regulatory control and did not differ in performance on other tasks.

Discussion—Results indicate that overweight individuals with LOC eating display relative deficits in EF compared to overweight individuals without LOC eating. Planning and self-regulatory control deficits in particular may contribute to dysregulated eating patterns, increasing susceptibility to LOC episodes. Future research should examine how EF deficits relate to treatment outcome.

Keywords

Binge eating; neuropsychology; loss-of-control-eating; obesity; executive function

INTRODUCTION AND AIMS

Binge eating (BE) is characterized by the consumption of an objectively large amount of food within a discrete amount of time, accompanied by a sense of loss of control (LOC) over eating. LOC eating is the subjective experience of being unable to control how much one is eating, regardless of amount consumed (Tanofsky-Kraff et al., 2009). Converging evidence suggests that the experience of LOC eating, rather than objective size or frequency of

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Disclosure of Conflicts

The authors have no conflicts of interest to disclose.

amount consumed, is the characteristic of BE most associated with distress and poor outcomes (Latner, Hildebrandt, Rosewall, Chisholm, & Hayashi, 2007; Mond, Latner, Hay, Owen, & Rodgers, 2010). A growing body of literature suggests that implicit neurocognitive processes, such as executive function (EF), may underlie the regulation of eating behavior and food intake (Cohen, 2008). EF deficits have been detected across a wide spectrum of eating and weight-related disorders (Fagundo et al., 2012); however, the neurocognitive characterization of individuals with LOC eating in the absence of compensatory behavior (e.g., self-induced vomiting) remains understudied and poorly understood (Van den Eynde et al., 2011). Further understanding of the specific control processes underlying LOC eating in overweight and obese individuals is sorely needed to discover new treatment targets and provide direction for understanding neural mechanisms that drive and maintain BE.

Executive Function and Binge Eating

EF encompasses a diverse, overlapping group of higher-level control processes that enable an individual to perform self-organized and goal-directed behavior. Deficits in EF may contribute to the development and maintenance of BE. More specifically, EF deficits may lead to an inability to balance a desire for immediate relief of tension with future consequences, or to deliberately plan and execute an adaptive strategy in the context of BE cues (e.g., negative affect, highly-palatable food, interpersonal conflict). There are several specific EF deficits that, if present, could theoretically influence the development and maintenance of LOC eating: 1) Cognitive inflexibility, which might contribute to an over-focus on eating as a learned coping strategy in the presence of BE cues and difficulty generating and enacting other behavioral patterns; 2) Poor self-regulatory control, which may contribute to the automatic response to eat when faced with a cue, and the marked drive to continue eating until uncomfortably full; 3) Planning deficits, which could contribute to an inability to develop, organize, and execute a structured and regularized plan of eating, increasing susceptibility to BE; 4) Overvaluation of immediate versus delayed reward; and 5) Working memory difficulties, which may lead to weaknesses remembering and updating goals (e.g., to only eat at pre-planned times or avoid binge trigger foods), and assessing their match with behavior.

A small number of studies have found preliminary evidence for EF weaknesses in adults with threshold BED (Danner, Ouwehand, van Haastert, Hornsveld, & de Ridder, 2012; Duchesne et al., 2010; Mobbs, Iglesias, Golay, & Van der Linden, 2011; Svaldi et al., 2013). However, investigations in the extant literature have utilized differing methodologies (e.g., self-report measures to assess BE, a single cognitive task to assess multiple aspects of EF), and results are mixed, with several studies finding no differences in EF between BED and overweight control groups (Davis, Patte, Curtis, & Reid, 2010; Galioto et al., 2012). More research is needed to parse specific EF deficits that are hypothesized be present in those with LOC eating (Van den Eynde et al., 2011).

As such, the current study aimed to examine whether several aspects of EF differ between weight-loss treatment-seeking overweight individuals with and without LOC eating using well-validated measures that examine various facets of EF. We hypothesized that overweight individuals with LOC eating would perform worse on tasks measuring self-regulatory control, planning, delayed discounting, working memory, and set-shifting compared to weight-matched controls.

METHODS

Participants and Procedures

Participants (n=80) were overweight and obese females (BMI 27.0−45.0 kg/m^2; ages 18–70) seeking entry into a behavioral weight loss trial conducted from November 2012 - September 2013 at Drexel University. Recruitment took place in two four-month waves. Participants from both groups were recruited concurrently from the community, using methods such as radio ads, and flyers. Exclusion criteria included greater than 5% body weight loss in the past six months or having undergone bariatric surgery. Trained doctoral students and post-doctoral fellows supervised by a licensed clinical psychologist conducted clinical interviews and neuropsychological assessments. Participants who endorsed any LOC episodes in the past three months were included in the LOC group (n=18) and all other participants were included in the overweight control group (OWC; n=62). No individuals endorsed currently engaging in compensatory behaviors (e.g., vomiting). Neuropsychological assessment order was counterbalanced across participants. Participants gave informed consent and the Drexel University Institutional Review Board approved the study.

Measures

The Eating Disorders Examination (EDE) version 16 is the gold-standard semi-structured interview for assessing for BE pathology (Grilo, Masheb, Lozano-Blanco, & Barry, 2004; Wilfley, Schwartz, Spurrell, & Fairburn, 1997). The Overeating section (“Questions for Identifying Bulimic Episodes and Other Episodes of Overeating”) was administered to all participants to examine for presence of LOC eating. The EDE has high inter-rater reliability and test-retest reliability (Rizvi, Peterson, Crow, & Agras, 2000) and good internal consistency. (Cooper, Cooper, & Fairburn, 1989).

Wechsler Test of Adult Reading (Wechsler, 2001) is an oral single-word reading test used to estimate verbal intelligence; scores were converted to Full Scale IQ estimates. The WTAR has strong correlations (.70–.80) with WAIS-III FSIQ scores for a wide age range (Wechsler, 2001).

Beck Depression Inventory-II (BDI-II(Beck, Steer, & Brown, 1996)) is a self-report measure of depression symptomatology in the previous two weeks. The BDI-II has adequate test-retest reliability, high internal consistency, and convergent validity has been established. (Dozois, Dobson, & Ahnberg, 1998; Steer, Ball, Ranieri, & Beck, 1997).

The Delis Kaplan Executive Functioning System (D-KEFS) (Delis, Kaplan, & Kramer, 2001) was developed to assess several domains of EF through well-established tests from the literature; the normative national sample is consistent across tests (1750 children and adults). The Color-Word Interference and Tower Tasks were administered. The Color-Word Interference Task is a modified Stroop task assessing response inhibition in the presence of distractors (self-regulatory control); raw number of errors made was used in analyses. The

Tower Task requires participants to build towers using a three-pronged apparatus and wooden disks using the fewest numbers of moves possible. Achievement score (derived from number of moves to complete each trial) was used as a measure of planning.

The Letter N-Back Task (Ragland et al., 2002) is a widely-used computerized task of working memory capacity. In the one-back condition, participants are asked to indicate if the letter that appears on the screen is the same as the one that came before it. In the two-back condition, participants are asked to indicate if the letter that appears is the same as the letter that came two before it. An "efficiency score" that incorporates accuracy and reaction times on one- and two-back trials was used in analyses.

Penn Conditional Exclusion Task (Kurtz, Ragland, Moberg, & Gur, 2004) is a computerized task measuring set-shifting. Participants are asked to identify one of four objects on the screen that does not match the others based on a rule (e.g., size or shape) that participants figure out based on feedback as to whether the object they chose was correct. The criteria changes without warning and the participant must switch which criteria they are using to choose the object. Number of perseverative errors (using an old rule to govern choices) was used in analyses. The PCET has been shown to have good construct validity (Kurtz et al., 2004).

The Delayed Discounting Task (Robles & Vargas, 2007) is a widely-used computerized monetary delayed discounting task. Participants are asked to choose between a smaller amount of money that they would receive sooner and a larger amount of money they would receive later. The "indifference point" is the point at which the participant chooses the sooner, smaller amount over the later, larger amount. Area-under-the-curve (AUC) was calculated from indifference points across trials (Myerson, Green, & Warusawitharana, 2001).

Statistical Analyses

Independent samples t-tests were used to compare demographic and clinical characteristics between groups. Primary outcome analyses utilized ANCOVAs for each dependent variable. The small size of the LOC group that could be recruited in this pilot study (n=18) resulted in low power to detect between-group differences in the neurocognitive variables, as calculated a priori (β=.35–.65, assuming effect sizes of f=.25–.40). As such, effect sizes obtained in the current study were examined in conjunction with statistical significance, with the intention of identifying directions for further investigation and replication.

Because of known associations of age and IQ with neurocognitive performance (Bugg, DeLosh, Davalos, & Davis, 2007; Salthouse, Fristoe, & Rhee, 1996), these variables were entered as covariates. Because of high comorbidity of depression with BED, analyses were repeated with BDI-II score added as a covariate to examine the influence of depression on EF in the sample. False-discovery rate (Benjamini & Hochberg, 1995) was used to correct for multiple comparisons. Alpha level was set at .05 for interpreting statistical significance, and statistical analyses were performed using SPSS Version 20 (IBM, 2013).

RESULTS

Clinical Characteristics of Participants

Sample demographic and clinical characteristics are presented in Table 1. BMI was not significantly associated with LOC status (*r* = .124, *p* = .27); of the sample, 82.8% of participants were in the obese range (BMI 30.0–l45.0 kg/m^2) and the remainder were overweight (BMI 27.0–29.99 kg/m^2). Consistent with previous literature (Smith, Hay, Campbell, & Trollor, 2011), working memory capacity was associated with BMI (*r* = −.26, *p* = .02), but no other dependent variables were associated with BMI. The LOC group was younger, more depressed, and had a lower IQ (at the trend level) than the OWC group; as such, we controlled for IQ and age in analyses. We repeated analyses controlling for BDI-II score in order to parse out effects of depression on EF.

EF differences between groups

The LOC group performed significantly worse on the N-back, Tower Task, and made more inhibition errors on the Color-Word Interference Task (See Table 2). The distribution of inhibition errors was positively skewed, thus the ANCOVA was repeated on this variable after normalization of the data via a log transformation. Results were unchanged, thus statistics using the non-transformed variable are reported. Unequal sample sizes can affect the assumption of homogeneity of variance (HOV) in ANOVA; however, Levene's Tests for HOV were not significant in all analyses (*ps* > .05), indicating no large departures from this assumption. The performance of the two groups did not significantly differ on the Delayed Discounting Task or in number of perseverative errors on the Exclusion Task. When BDI-II score was entered as a covariate, differences in Tower Task performance ($F(1, 79) = 4.05$, $p = .048$, 95%CI [−1.378, −3.384]) and number of inhibition errors ($F(1, 79) = 6.40$, $p = .01$, 95%CI [1.81, 3.64]) remained significant; however, the difference in N-back performance was no longer statistically significant ($F(1, 79) = .782$, $p = .38$, 95%CI [−.23, −.01).

DISCUSSION

Results of the current study represent novel findings that, in overweight individuals, LOC eating (regardless of frequency and size of episodes) is associated with several EF weaknesses. These findings are generally consistent with those of prior studies that documented impairments in EF in populations with eating pathology (Lopez, Tchanturia, Stahl, & Treasure, 2008a; Roberts, Tchanturia, Stahl, Southgate, & Treasure, 2007) but represent that first evidence that the underlying construct of LOC itself is associated with EF deficits. Specifically, our results indicate that overweight individuals with LOC eating perform worse on tasks of self-regulatory control, planning, and working memory compared to overweight individuals without LOC eating. The pattern of deficits observed may help to explain the development and maintenance of LOC eating within overweight and obese samples. For example, poor planning may contribute to irregular eating patterns (e.g., going long periods of time without eating) that lead to extreme hunger, thus increasing susceptibility to LOC eating. Deficits in self-regulatory control may further increase susceptibility to LOC episodes in food environments where palatable food, or food associated with past binge episodes, is available. Working memory may also play a role in inability to keep goal-relevant information online; however, the causal factor for this deficit may heightened depressive symptoms rather than LOC (Harvey et al., 2004). Only two other studies have examined self-regulatory control, planning or working memory in those with BED (Duchesne et al., 2010; Svaldi et al., 2013), both of which reported similar deficits.

The current study featured a number of strengths. The examination of the presence of LOC eating as a correlate of neurocognitive deficits, without regard to specific frequency or size of binge episodes, adding to a growing body of research suggesting that LOC may be a central construct of BE. Additionally, our study used well-validated neuropsychological tasks that tapped into multiple constructs within EF, matched groups on BMI, and investigated age, IQ, and depression as potential alternative explanatory variables. Despite these strengths, it is important to note some limitations in the current study, including the small sample of LOC participants, and use of a weight-loss treatment-seeking sample that could potentially differ from typical BED or overweight populations. For example, while the LOC group scored significantly lower than OWCs in several EF domains, both groups scored above test norm averages on the Tower Task, and above the population mean of IQ, indicating that EF deficits may be relative in nature, rather than objectively low, and/or that a treatment-seeking sample may have unique characteristics. Lack of data regarding number of LOC episodes and how many, if any, participants met full criteria for BED made us unable to examine if EF performance on any tasks differed by BE frequency. Additionally, because of the cross-sectional design, temporal relations cannot be inferred; it is possible that deficits may represent neurocognitive “scars” rather than preceding factors. Lastly, our sample only included females, limiting the ability to generalize interpretations to males.

Although the current study provides support for the role of EF deficits in LOC eating, additional work is needed to compare sub-threshold and full-threshold BED and examine the relation between LOC eating frequency and severity and EF deficits. Future studies should examine additional explanatory variables that could impact neurocognitive performance (e.g., trait anxiety, fatigue). Other neurocognitive variables that have been associated with BE, including central coherence (a bias towards local over global processing) and food-specific inhibitory control (Lopez, Tchanturia, Stahl, & Treasure, 2008b; Svaldi, Naumann, Trentowska, & Schmitz, 2014), should be examined. The role of EF deficits in treatment outcome in weight loss trials and interventions for BE remains unknown. Future research should examine whether EF performance is associated with outcome, or is associated with treatment dropout or poor adherence to treatment recommendations. Replication of results could imply that improving EF directly (e.g., computerized inhibitory control training paradigms) may be a potential method through which to improve outcomes. Continued study of the specific neurocognitive processes underlying LOC eating is needed to provide direction for treatment development and for uncovering the neurocognitive mechanisms that drive BE within overweight populations.

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Table 1

Demographic and Clinical characteristics by group

	LOC Group* **(n=18)**	**OWC Group*** **(n=62)**	***t***	***p***	**Effect size[a]**
Age (yrs)	47.77 (14.70)	53.31 (9.46)	4.58	.04	.45
Body Mass Index (Kg/m^2)	35.93 (6.51)	36.15 (5.50)	.02	.89	.04
IQ	110.23 (14.11)	114.12 (10.81)	2.19	.14	.31
BDI-II[b]	13.05 (6.48)	6.94 (6.00)	16.67	< .01	.99

*Data are shown as mean (SD)

[a]Cohen's *d*

[b]Beck Depression Inventory – II; 0–9 indicates minimal depression, 10–18 indicates mild depression

Table 2

Differences in executive function by group, controlling for age and IQ

	LOC Group* **(n=18)**	**OWC Group*** **(n=62)**	***F***	***p***	**Effect size**[a]
Perseverative errors	16.00 (2.34)	16.43 (1.22)	.03	.85	<.01
N-back efficiency score	4.40 (.10)	4.62 (.05)	4.06	.047	.04
Color-Word Interference Errors	5.82 (.76)	3.4 (.39)	7.92	< .01[b]	.08
Tower Task Achievement Score	15.12 (.89)	17.43 (.46)	5.25	.02 [b]	.05
Delay Discounting	.65 (.04)	.72 (.02)	2.60	.11	.03

*Data are shown as adjusted means (standard error)

[a]Partial eta squared

[b]Remained statistically significant (p < .05) after correction for multiple comparisons using Remained statistically significant (p < .05) after correction for multiple comparisons using