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Characterising binge eating over the course of a feasibility trial among individuals with binge eating disorder and bulimia nervosa

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ABSTRACT

Binge eating disorder and bulimia nervosa are eating disorders that are characterized by recurrent binge eating episodes. The highly contextualized nature of binge eating makes naturalistic research a particularly suitable means of understanding the context within which binge eating occurs. The present study aimed to characterise binge eating days with regards to the frequency and probability of negative affect, food craving, meal skipping, and dietary restriction. In addition, it aimed to examine whether a combined intervention that targets the experience of 'loss of control' over eating can decrease these potential maintenance factors that often precede binge eating episodes. Seventy-eight participants with bulimia nervosa (N = 40) or binge eating disorder (n = 38), who were randomly allocated to a food-specific or general intervention combining inhibitory control training and implementation intentions, completed mood and food diaries over four weeks. Results suggest that negative affect and food craving were elevated on binge eating days, but that dietary restraint and meal skipping did not characterise binge eating days. Moreover, meal skipping, binge eating, restriction, and compensation decreased throughout the intervention period, while negative affect and food craving did not. This suggests that some interventions may successfully reduce binge eating frequency without necessarily decreasing negative affect or food craving, thus pointing to the different routes to targeting binge eating and providing implications for future interventions.

1. Introduction

Binge-eating disorder (BED) and bulimia nervosa (BN) are eating disorders that are characterized by recurrent binge-eating episodes. During such episodes, these individuals experience loss of control over eating and consume objectively large amounts of food. In BN, compensatory behaviours, such as laxative use or self-induced purging, are used to prevent weight gain (DSM 5; American Psychiatric Association, 2013). A substantial body of literature has emphasised the importance of momentary cognitive and emotional processes that maintain eating disorder psychopathology (Haedt-Matt & Keel, 2011). Indeed, the highly contextualized nature of binge eating, involving multiple internal (e.g. negative emotions; food craving) and external triggers (e.g. meal skipping) makes naturalistic research particularly suited.

The tendency to consume food in response to negative emotions is termed 'emotional eating' (Bruch, 1974; Crockett, Myhre, & Rokke, 2015; Kaplan & Kaplan, 1957). The affect regulation model of binge eating, which posits that negative affect serves as a trigger for binge eating and that binge eating, in turn functions to mitigate it (Heatherton & Baumeister, 1991), provides one explanation for the maintenance of binge eating. In line with this theory, experimental and naturalistic paradigms suggest that negative mood may act as an antecedent to binge eating among individuals with BED (Cardi, Leppanen, & Treasure, 2015; Chua, Touyz, & Hill, 2004; Evers, Dingemans, Junghans, & Boevé, 2018; Munsch, Meyer, Quartier, & Wilhelm, 2012; Stein et al., 2007; Svaldi, Werle, Naumann, Eichler, & Berking, 2019) and BN (Lavender et al., 2016). Nonetheless, findings from EMA research on the second part of

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the theory (i.e. binge eating mitigating negative affect) remain inconsistent (Berg et al., 2017), with some evidence suggesting that negative affect decreases for several hours following a binge eating episode (Munsch et al., 2012; Smyth et al., 2007) and other evidence suggesting that negative affect increases after a binge eating episode (Berg et al., 2017; Haedt-Matt & Keel, 2011, 2015; Stein et al., 2007). In either case, this strategy of coping with negative emotions may lead to a downward spiral, as overeating often only temporarily alleviates distress (Haedt--Matt & Keel, 2011), and the most likely outcomes of binge eating are either no change in negative affect (Svaldi et al., 2019; Wegner et al., 2002), a short-term reduction in negative affect (Munsch et al., 2012; Smyth et al., 2007), or a worsening of negative affect (Berg et al., 2017).

In addition, food craving, characterized as the intense desire or urge to eat a particular type of food (Pelchat, 2002), has been reported as one of the most important contributors to the binge-purge cycle (Moreno, Warren, Rodríguez, Fernández, & Cepeda-Benito, 2009). The conditioning model of binge eating proposes that individuals who binge eat, compared to those who do not binge eat, exhibit a higher reactivity to food cues (Jansen, 1998; Meule et al., 2018). Indeed, this is reflected in both higher self-reported trait food craving (i.e. more frequent food cravings in general) and state food craving (i.e. more intense food craving during food exposure; Innamorati et al., 2014), which significantly distinguishes them from weight-matched controls (Leslie, Turton, Burgess, Nazar, & Treasure, 2018).

Furthermore, dietary restraint, characterized by cognitive attempts to restrict the overall amount, frequency, or type of food consumed with the intention to regulate body weight (e.g. meal skipping; dietary restriction), has also been regarded as a risk and maintenance factor for binge eating (Fairburn, Cooper, & Shafran, 2003). According to the restraint theory, binge eating occurs to compensate for the excessive deprivation that results from unrealistic dietary restraint (Wilfley, Pike, & Striegel-Moore, 1997). In line with this theory, EMA research exploring dietary restraint as a maintenance factor has indicated that cognitive restraint predicted binge eating the following day (Zunker et al., 2011).

The sections above highlight the relationship between independent risk/maintenance factors and binge eating. Nevertheless, when conceptualised holistically, researchers have theorised that negative affect among individuals with binge eating behaviour (Volkow, Wise, & Baler, 2017) may contribute to heightened food craving, as it increases the likelihood of compensatory reward seeking particularly through palatable food consumption (Treasure, Leslie, Chami, & Fernández-Aranda, 2018). In addition, there is evidence to suggest that inducing negative affect only triggers overeating behaviour among individuals who restrict their food intake (Cools, Schotte, & McNally, 1992; Polivy, Herman, & McFarlane, 1994) and that individuals who report high restraint and high negative affect engage in the highest levels of binge eating (Stice, Akutagawa, Gaggar, & Agras, 2000). These additive effects reflect the importance of understanding the collective impact of several risk factors.

Despite the value of exploring the associations between negative affect, food craving, meal skipping, dietary restriction, and binge eating, several gaps can be found and addressed in the literature. For instance, the present study will explore how the relationship between the aforementioned maintenance factors and binge eating evolve on a day-to-day level and across an intervention period. Moreover, little is known about which specific forms of dietary restraint (e.g. meal skipping; dietary restriction) contribute to binge eating (Elran-Barak et al., 2015), about how food craving correlates with binge eating, or about potential differences in these relationships between individuals with BN and BED. Together, these findings will contribute to our understanding of process measures that contribute to intervention success/failure. In light of this, the present study will explore these relationships in the context of a recently published feasibility trial conducted by our team (Chami et al., 2020; clinicaltrials.gov ID: NCT03126526). Within the trial, we compared two forms of combined inhibitory control trainings that aim to reduce binge eating among individuals with BN and BED-namely, food-specific and general inhibitory control training (ICT) and food-specific and general implementation intentions (If-then planning). Adherence to ICT met the pre-set cut-off, with 84.6% of participants completing at least four sessions of the training, while adherence to if-then planning was sub-optimal, with only 53.4% of participants engaging with the intervention. Nevertheless, evidence of symptomatic benefit was found (i.e. reductions in binge eating frequency), with stronger effect size changes among participants receiving a food-specific intervention (Chami et al., 2020). These findings were in line with previous research in pre-clinical samples, which indicated significant reductions in high energy-dense food intake after ICT (Allom & Mullan, 2015; Jones et al., 2016) and if-then planning (Adriaanse, Vinkers, De Ridder, Hox, & De Wit, 2011; Vila, Carrero, & Redondo, 2017). The present study will thus extend the preliminary findings from our feasibility study by characterising binge eating behaviour among treatment-seeking individuals with binge eating and exploring the day-to-day relationships between negative affect, food craving, meal skipping, dietary restriction, and binge eating over the course of the feasibility trial.

By analysing the daily diaries of participants who took part in the feasibility trial, the present study aims to:

1) Characterise binge eating days with regards to the frequency and probability of particular affects, food craving, meal skipping, and dietary restriction. We hypothesised that the likelihood of these conditions would be significantly greater on binge eating days compared to non-binge days.

2) Explore within-individual changes in these relationships over the course of an intervention aimed at reducing binge-eating frequency, while considering intervention arms (i.e. food-specific vs. general) and patient groups (i.e. BN vs. BED). We hypothesised that, over the course of the trial, the likelihood of experiencing negative affect, food craving, meal skipping, and dietary restriction on binge eating days would decrease, and that these effects would be greater among individuals allocated to the food-specific, versus the general intervention. Analysis of patient group differences in these relationships will remain exploratory.

2. Methods

2.1. Participants

The sample consisted of individuals with BN (N = 40) or BED (N = 38), aged between 18 and 60 years (BN: M = 30.6; SD = 10.7; BED: M = 36.6, SD = 13.7). Thirty-eight participants (BN: N = 22; BED: N = 16) were allocated to a general inhibitory control training condition and 40 participants (BN: N = 18; BED: N = 22) were allocated to a food-specific inhibitory control training condition.

Eligibility required that participants, at the time of testing, met criteria for BN or BED according to the Structured Clinical Interview for DSM-5 (First, 2016), had a Body Mass Index (BMI) of at least 18.5 kg/m^2, were between the ages of 18 and 60, did not have a visual impairment that could not be repaired with eyewear, a neurological impairment, an alcohol or drug dependence, or psychosis.

2.2. Interventions

As part of the **inhibitory control training** (go/no-go; adopted from Lawrence et al., 2015), participants were asked to complete a 10-min computerised, web-based version of the go/no-go task daily over 4 weeks. Participants allocated to the food-specific intervention group completed a food-specific go/no-go task, while participants allocated to the general intervention group completed a general go/no-go task, where food stimuli (i.e. pictures) were replaced with tools and stationery.

As part of the **implementation intentions (if-then planning)**,

participants were encouraged to identify an unhelpful habit, reflect on situations and motivations that are likely to precede the unhelpful habit, and design an if-then plan that integrated an alternative behaviour. They were encouraged to share their plan and discuss success/failure in completing it with their mentor weekly. This was done online through email exchanges, and participants were sent a template of table to fill in weekly. Participants allocated to the food-specific intervention group were asked to select a food-specific unhelpful habit (e.g. *If I am home alone and feeling anxious, then I will listen to a self-compassion meditation for 10 min*), while those in the general intervention group were encouraged to select a non-food-related unhelpful habit (e.g. *If I argue with a friend and feel upset, then I will ask them to meet to discuss what has upset me*).

For more details of the intervention, please refer to Chami et al. (2020).

2.3. Measures

Eating Disorder Diagnosis. The Structured Clinical Interview for DSM-5 (SCID-5, First, Williams, Karg, & Spitzer, 2016), a semi-structured interview for making a DSM-5 diagnosis, was used during the initial phone screening with participants to confirm a diagnosis of BN or BED.

Demographics. The demographic questionnaire included questions relating to age, gender, subjectively reported weight, height, ethnicity, marital status, years spent in education, employment status, current/previous mental health support received, and use of psychiatric medication.

Eating Disorder Psychopathology. The Eating Disorder Examination Questionnaire (EDE-Q; Fairburn et al., 2008) is a 28-item self-report measure of eating disorder psychopathology. It assessed eating disorder behaviour within the past 28 days and comprises 4 subscales: dietary restraint (DR), eating concern (EC), weight concern (WC), and shape concern (SC). In this study, the reliability of the EDE-Q global score ($\alpha = 0.88$) and EDE-Q sub-scales (Restraint $\alpha = 0.83$; Weight Concern $\alpha = 0.69$; Eating Concern $\alpha = 0.76$; Shape Concern $\alpha = 0.81$) was good.

Mood and Food Diary. Participants were encouraged to complete the diary daily at the end of the day. It included questions relating to general mood (multiple choice options including happy, sad, angry, tired, excited, content, relaxed, and afraid), meal skipping (y/n), food restriction (y/n), food craving (y/n), binge eating (y/n), nature of binge (i.e. planned or impulsive), subjective binge motivation and situation (multiple choice options), and compensatory behaviours (y/n). For the purpose of this paper, mood responses were characterized into four groups: negative mood (including 'sad', 'angry', and 'afraid'), positive mood (including 'happy', 'content', and 'excited'), physiologically relaxed (including 'relaxed'), and physiologically tired (including 'tired').

Depressive Symptoms. The Patient Health Questionnaire (PHQ-9 Kroenke, Spitzer, & Williams, 2001) is a 9-item measure used to assess depressive symptoms over the two weeks prior to completion. Responses were given on a 4-point Likert scale ranging from 'not at all' to 'nearly every day'. In this study, the reliability of the PHQ-9 was high ($\alpha = 0.91$).

Anxiety Symptoms. The Generalized Anxiety Disorder questionnaire (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006) is a 7-item measure used to assess anxiety symptoms over the two weeks prior to completion. Responses were given on a 4-point Likert scale ranging from 'not at all' to 'nearly every day'. In this study, the reliability of the GAD-7 was high ($\alpha = 0.88$).

2.4. Study design

This mixed model study includes between subject comparisons (i.e. intervention arm and patient group), within subject comparisons (i.e. factors associated with binge eating), and a time component (i.e. time course of trial). Diary data in the present study was collected as one of the measures of change within our feasibility trial combining inhibitory control training and implementation intentions among individuals with BN and BED (Chami et al., 2020).

2.5. Procedure

After expressing interest in learning about the study procedures, potential participants received an information sheet. Next, interested participants were contacted by phone for a 15-min eligibility screening. Those who met criteria were sent a consent form indicating their rights as participants. After completing the consent form, participants were sent a battery of questionnaires via Qualtrics (i.e. an online platform; Provo, UT). They were encouraged to complete the Mood and Food Diary every day for the four weeks via Qualtrics, while completing the intervention in parallel (please refer to Chami et al., 2020 for more details). Participants were prompted via email if they did not complete the Mood and Food Diary for three consecutive days.

The London Westminster Research Ethics Committee and the Health Research Authority approved all the procedures involved in this study (IRAS Project ID: 209609).

2.6. Statistical methods

Descriptive and frequency data was extracted using SPSS Version 25. Hierarchical linear models were applied due to the nested, longitudinal structure of the data using the software HLM7 (Raudenbush, Bryk, Cheong, Congdon, & Du Toit, 2011). Days (Level 1) were nested within participants (Level 2). To characterise binge days, we modelled mood, meal skipping, dietary restriction, and food craving on Level 1 separately as predictors of binge eating while using patient group status (BN = 0; BED = 1) on Level 2 as a predictor of the intercept as well as a moderator of Level 1 slopes. For 'post-binge' analyses, binge eating was used as a predictor of compensatory behaviours in the same vein.

In auxiliary analyses, we also explored the effects of intervention arm (i.e. food-specific coded 0 vs. general coded 1) on Level 2 as a predictor of the intercept and a moderator of Level 1 slopes in the analyses mentioned above (without accounting for patient status). Additionally, to capture potential linear changes across the intervention period, we modelled time (i.e. days) on Level 1 as a predictor and a moderator in the analyses mentioned above. However, preliminary analysis revealed that time did not interact with intervention arm or patient group in the prediction of binge eating episodes, meal skipping, restriction, food craving, compensation, or affect (2-way interaction). Similarly, time did not moderate any of the relationships between intervention arm, the predictors mentioned above, and the respective dependent variables (3-way interaction). Thus, when analysing time effects, intervention and patient group were not included.

Intercepts and slopes were allowed to vary randomly. Level 1 predictors were person-mean centred for continuous variables or uncentered in case of dichotomous variables. Level 2 predictors were uncentered as both variables were dichotomous. Due to the dichotomous outcome variables (i.e. binge eating and compensation: no = 0, yes = 1), Bernoulli distribution was used and population-average models with robust standard errors were reported. Please refer to Fig. 1 below.

3. Results

3.1. Patient group differences: demographic and psychological characteristics

Table 1 below describes demographic and psychological differences between participants with BN and BED. Participants with BN, compared to BED, showed greater self-reported eating disorder psychopathology, depression, and anxiety. On average, they were also younger than participants with BED, and had lower BMI. No significant differences were

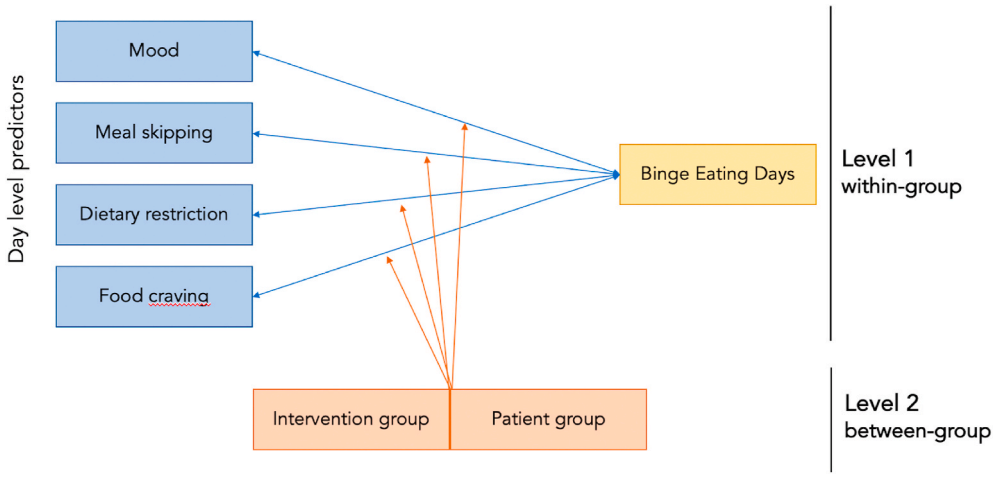

Fig. 1. Visual representation of the applied hierarchal linear model.

Table 1
Differences in demographic and psychological characteristics between individuals with BN and BED.

		Bulimia Nervosa (N = 39) M (SD) or N (%)	Binge Eating Disorder (N = 38) M (SD) or N (%)	*p*-value
Age		30.59 (10.73)	36.59 (13.66)	.037*
Gender	Female	36 (92.3%)	35 (92.1%)	.974
	Male	3 (7.7%)	3 (7.9%)	
BMI		25.52 (6.33)	33.43 (9.29)	.000*
Ethnicity	White	30 (76.9%)	29 (76.3%)	.333
	Black	2 (5.1%)	3 (7.9%)	
	Mixed (Black/White)	NA	2 (5.3%)	
	Asian	2 (5.1%)	3 (7.9%)	
	Middle Eastern	2 (5.1%)	1 (2.6%)	
	Latin American	3 (7.7%)	NA	
Comorbid Disorder	Yes	32 (91.4%)	24 (75%)	.070
	No	3 (8.6%)	8 (25%)	
Duration of Illness		14.94 (11.05)	16.43 (12.47)	.633
EDEQ	Restraint	3.47 (1.52)	2.03 (1.33)	.000*
	Eating Concern	3.81 (1.14)	3.07 (1.38)	.013*
	Shape Concern	4.92 (1.01)	4.13 (1.17)	.002*
	Weight Concern	4.55 (1.07)	3.89 (1.24)	.014*
Depression (PHQ)		14.28 (5.50)	9.63 (6.33)	.001*
Anxiety (GAD)		11.85 (5.29)	7.32 (6.02)	.001*

Note: *p*-values for continuous variables were derived using independent sample t-tests, and *p*-values for categorical variables were derived using Pearson Chi-Square tests.

found in gender, ethnicity, the presence of a comorbidity, or duration of illness. A significant proportion of participants had a severe and enduring form of the illness, with 63.8% having had the disorder for over 10 years, and 12.1% for over 30 years.

3.2. Patient group differences: mood & food diary data

Mean compliance was high, with an average completion frequency of 20, out of 28, diaries per participant (M = 20.24; SD = 6.65). Of 1573 diary entries, 36.4% (N = 573) were completed on binge eating days. Individuals with BN represented 51.3% of the binge days, while those with BED represented 48.7% of the binge days, representing a relatively high symptom severity.

In line with their diagnoses, individuals with BN, compared to BED, exhibited a higher likelihood of meal skipping ($\beta_{01} = -0.837$, $SE = 0.267$, $t\,(73) = -3.14$, $p = .002$), restriction ($\beta_{01} = -1.61$, $SE = 0.293$, $t\,(73) = -5.49$, $p < .001$), and compensation ($\beta_{01} = -3.35$, $SE = 0.313$, t $(73) = -10.7$, $p < .001$). Negative affect was higher among individuals with BN ($\beta_{01} = -0.669$, $SE = 0.248$, $t\,(73) = -2.70$, $p = .009$). Binge eating was only marginally more frequent in the BN, compared to the BED group ($\beta_{01} = -0.374$, $SE = 0.216$, $t\,(73) = -1.73$, $p = .088$). Food craving was not associated with patient group status ($\beta_{01} = 0.218$, $SE = 0.412$, $t\,(55) = 0.53$, $p = .600$). For descriptive data, please see Table S1 in Supplementary Materials.

3.3. Factors associated with the frequency and probability of binge eating

3.3.1. General mood

Participants selected one mood to characterise their day. Negative mood was reported on 38.4% of binge days and 19.2% of non-binge days, positive mood was reported on 24.2% of binge days and 45.7% of non-binge days, physiologically tired was reported on 28.2% of binge days and 22.2% of non-binge days, physiologically relaxed was reported on 4.7% of binge days and 9.9% of non-binge days, and 'neutral' was reported on 1.6% of binge days and 0.4% of non-binge days. Days characterized by negative mood compared to positive mood were those with increased likelihood of a binge eating episode, while patient group did not influence results (see Table 2).

3.3.2. Meal skipping and restriction

Meal skipping and restriction occurred on 30.0% and 20.7% of the binge days, and on 24.1% and 22.5% of non-binge days, respectively. Despite their descriptive differences, neither meal skipping nor restriction of food intake were significantly associated with the likelihood of binge eating. Individuals with BN and BED did not differ with regard to this relationship.

3.3.3. Food craving

Food craving was reported on 73.9% of the binge days and 49.3% of non-binge days. Days with high food craving had higher likelihood of binge eating. BN and BED groups did not differ with regard to this relationship.

Combining both significant predictors (i.e., general mood and food craving) in a single model revealed independent and significant contributions of both predictors while controlling for patient group (see Table 2).

A comprehensive summary of statistical findings can be found in Table 2 above.

Table 2
Summary of statistical findings.

Model	Coefficient β (SE)	*t*(df)	*p*
Binge Eating - Mood			
Level 1			
General Mood (β_{10})	1.33 (.188)	$t(73) = 7.06$	<.001
Level 2			
Patient Group (β_{01})	-.158(.240)	$t(73) = -0.66$	.512
Cross-level interactions			
General Mood * Patient Group (β_{11})	-.286(.294)	$t(73) = -0.987$	.333
Binge Eating – Meal Skipping			
Level 1			
Meal Skipping (β_{10})	.379 (.221)	$t(73) = 1.72$	.090
Level 2			
Patient Group (β_{01})	-.208(.230)	$t(73) = -0.903$	.369
Cross-level interactions			
Meal Skipping * Patient Group (β_{11})	-.497(.315)	$t(73) = 1.58$	.119
Binge Eating – Restriction			
Level 1			
Restriction (β_{10})	.225 (.268)	$t(73) = -0.838$	.405
Level 2			
Patient Group (β_{01})	-.452(.231)	$t(73) = -1.96$	.054
Cross-level interactions			
Restriction * Patient Group (β_{11})	-.244(.383)	$t(73) = -0.64$	.525
Binge Eating – Food Craving			
Level 1			
Food Craving (β_{10})	1.20 (.353)	$t(55) = 3.39$	.001
Level 2			
Patient Group (β_{01})	-.609(.469)	$t(55) = -1.30$	.200
Cross-level interactions			
Food Craving * Patient Group (β_{11})	−130(.495)	$t(55) = -0.26$	.793
Binge Eating - Mood			
Level 1			
General Mood (β_{10})	.943 (.258)	$t(49) = 3.65$	<.001
Food Craving (β_{20})	1.33 (.317)	$t(49) = 4.21$	<.001
Level 2			
Patient Group (β_{01})	-.502(.393)	$t(48) = -1.28$	.208

3.4. Changes across intervention

When adding treatment day to capture time course across the intervention, binge eating ($\beta_{10} = -0.013$, $SE = 0.006$, $t\,(74) = -2.32$, $p = .023$), meal skipping ($\beta_{10} = -0.015$, $SE = 0.006$, $t\,(74) = -2.29$, $p = .025$), restriction ($\beta_{10} = -0.021$, $SE = 0.006$, $t\,(74) = -3.30$, $p = .002$) and compensation ($\beta_{10} = -0.011$, $SE = 0.004$, $t\,(74) = -2.63$, $p = .010$) decreased throughout the course of the intervention period, while negative affect ($\beta_{10} = 0.006$, $SE = 0.006$, $t\,(74) = 0.981$, $p = .330$) and food craving ($\beta_{10} = -0.022$, $SE = 0.011$, $t\,(56) = -2.00$, $p = .051$) did not decrease significantly (or only at trend level).

3.5. Effects of intervention arm

Contrary to our hypotheses (i.e. that the likelihood of experiencing negative affect, food craving, and dietary restriction on binge eating would decrease to a greater extent among individuals allocated to the food-specific, versus the general intervention), intervention arm did not interact with affect ($\beta_{11} = 0.082$, $SE = 0.295$, $t\,(73) = 0.28$, $p = .782$), food craving ($\beta_{11} = 0.218$, $SE = 0.561$, $t\,(55) = 0.39$, $p = .699$), meal skipping ($\beta_{11} = -0.319$, $SE = 0.312$, $t\,(73) = -1.02$, $p = .311$) or restriction ($\beta_{11} = -0.364$, $SE = 0.376$, $t\,(73) = -0.97$, $p = .337$) in their associations with binge eating, indicating that those associations were similar in both intervention arms. Moreover, the intervention arms did not significantly differ in their main effect on the probability of binge eating (β_{01}s ≤ -0.716, $ps \geq .176$). Similarly, intervention arm did not exhibit a main effect ($\beta_{01} = -0.504$, $SE = 0.292$, $t\,(73) = -1.73$, $p = .088$) nor an interaction effect ($\beta_{11} = -0.275$, $SE = 0.302$, $t\,(73) = -0.91$, $p = .365$) on the probability of compensating after a binge eating episode.

4. Discussion

The primary aim of the present study was to characterise binge eating days with regards to the frequency and probability of negative affect, food craving, meal skipping, and dietary restriction. Therefore, we followed two well-sized groups of carefully diagnosed BN and BED patients over the course of their inhibitory control training with daily mood and food diaries. A total of 573 binge days were compared with 1000 non binge days using multi-level modelling.

Findings revealed that negative mood and binge eating co-occurred, and that negative mood on binge eating days did not significantly differ between patient groups. Despite our inability to assert whether negative mood acted as an antecedent to binge eating, this finding is in line with our hypotheses and previous research suggesting that negative mood may act as an important antecedent to binge eating within both diagnostic groups (Cardi et al., 2015; Chua et al., 2004; Haedt-Matt & Keel, 2011, 2015; Lavender et al., 2016; Munsch et al., 2012; Stein et al., 2007). Such findings accentuate that binge eating may be used as a means of down-regulating negative mood (Heatherton & Baumeister, 1991) or that mood may interfere with cognitive control (Ruderman, 1985; Svaldi et al., 2019). Moreover, as expected, food craving was higher on binge days, compared to non-binge days, with no difference between the two patient groups. This fits with research indicating increased state food craving among individuals who binge eat (Innamorati et al., 2014) and individuals who use rigid strategies to control their eating (Meule, Lutz, Vögele, & Kübler, 2012). Although our day level reporting did not track the temporal order of food craving relative to binge eating, it is unlikely that craving was higher after, as opposed to before, a binge episode, as food cravings are known to be proximal antecedents of binge eating (McManus & Waller, 1995). Together, these suggest that binge eating emerges in the background of preceding food craving, marking it as a valuable factor to intervene on. Contrary to expectations, however, meal skipping and restriction were not associated with the likelihood of binge eating in either of the patient groups. This contradicts previous research indicating that cognitive restraint (Zunker et al., 2011) and having fewer meals per day (Elran-Barak et al., 2015) increase the risk of having a binge-eating episode (Fairburn et al., 2003). Nevertheless, given that participants in the present study were encouraged to complete their food diaries at the end of the day, it is likely that their reporting of dietary restriction may have been influenced by the experience of a binge episode that day. This methodological limitation emphasizes the importance of discriminating between the desire to restrict and behavioural restriction within models of eating behaviour (Reichenberger, Smyth, Kuppens, & Blechert, 2019).

The secondary aim of the present study was to explore within-individual changes to these potential maintenance factors over the course of an intervention aimed at reducing binge-eating frequency, while considering intervention arms (i.e. food-specific vs. general) and patient groups (i.e. BN vs. BED). Meal skipping, binge eating, restriction, and compensation decreased throughout the intervention period, while negative affect and food craving only decreased at a trend level (i.e. not significantly). It may be safe to suggest that the present interventions had a specific behavioural impact on reducing consumption of high energy-dense foods, without significantly impacting negative affect or food craving that often precede binge eating episodes. Given that the interventions we adopted led to a reduction in binge eating frequency without significantly modulating negative affect or food craving, our results point to the several mechanisms that can maintain binge eating and could be targeted in treatment. In light of the weight allocated to these binge eating antecedents within current psychotherapeutic treatments (e.g. cognitive behavioural therapy, Fairburn et al., 2003; dialectical behaviour therapy; Palmer et al., 2003), it would be of interest to further explore the different routes of targeting binge eating, particularly within alternative, novel interventions (e.g. go/no-go training;

if-then planning; attention bias modification).

Furthermore, our preliminary findings suggest that the affect regulation model of binge eating (Heatherton & Baumeister, 1991) may not fully explain the variance in binge eating. Instead, our findings point to the addictive appetite model (Treasure, Leslie, Chami, & Fernandez-Aranda, 2018), which postulates that overeating behaviours may begin as reward-driven impulses, which then become habits over time. Once they become habits, the behaviour (i.e. binge eating) can occur in the absence of a particular internal cue (e.g. negative affect). Given the severe-and-enduring status of a large proportion of our participants (63.8% experienced the eating disorder for > 10 years) and the reduction in binge eating frequency despite null effects on negative affect, it is likely that habit-driven binge eating had been present and targeted. The clinical efficacy of the interventions adopted may be explained by ICT's focus on motor response inhibition, which is hypothesised to target stimulus-response learning (Lawrence et al., 2015).

Intervention arm allocation did not interact with affect, food craving, meal skipping, or restriction to influence the likelihood of binge eating, indicating that the two intervention arms did not differ in these relationships. While this was unexpected, it shows that general (i.e. non-food-specific) go/no-go training may have also potentially targeted executive functions (e.g. inhibitory control), which then had an impact on eating-related cognitions and behaviours. Alternatively, the completion of mood and food diaries in both arms might have served as motivational reminders to "stick to" the attempt to reduce binge eating. This unanticipated finding further emphasizes the need for mechanistic models of treatment efficacy. Additional intervention arms with less active engagement (e.g. treatment as usual) may be warranted.

Interestingly, while post-binge compensation confirmed diagnostic classifications, most relationships with bingeing found here did not differ between patient groups. This generally lends support to trans-diagnostic models of eating disorders (Fairburn et al., 2003), which emphasise common underlying factors across the eating disorder spectrum. These models are complemented by dimensional models, including the research domain criteria initiative (Cuthbert & Kozak, 2013), stating that etiological dimensions are similar across disorders, while the intensity or direction of such dimensions might differ by group. Such a dimension has recently been evidenced for emotional eating, which linearly differed in direction and intensity, yet was present across all eating disorders (Reichenberger et al., 2021).

4.1. Strengths, limitations, and future directions

The present study has several strengths that must be acknowledged. A primary strength is the good sample size (BN = 40; BED = 38) of individuals with a long duration of illness, which is often lacking among studies recruiting clinical groups. Furthermore, the present study had a relatively long observation period of 28 days, with a good compliance rate (average of 20 of 28 diaries completed). Together, these offer a high degree of sensitivity.

Nevertheless, our findings must be interpreted in light of several limitations. Due to the format of the mood and food diary, we were unable to assess the temporal nature of these relationships. For instance, it was unclear whether restriction or negative affect preceded the binge or vice versa. This would have been of interest, given that previous research had highlighted the way negative affect can precede a binge, but also further increases after a binge-eating episode (Haedt-Matt & Keel, 2011). Moreover, whilst food diary data indicated no significant reduction in negative affect over the course of the training, it is likely that participants' mood ratings were influenced by the experience of a binge eating episode that day. In addition, a small proportion of food diaries had been 'backfilled', or completed the next morning (10.5%), leaving room for biases in memory. Furthermore, the present study did not measure the extent to which different forms of negative affect (e.g. sadness, anger, anxiety) impact binge eating differently. Previous research had indicated the value of this, by showing that both non-clinical (Meule, Reichenberger, & Blechert, 2018 b) and clinical (Meule et al., 2019) samples reported eating more when sad, but less when angry or anxious. In addition, due to the categorical way of assessing affect in the present study (i.e. negative and positive mood were treated as dichotomous variables), we were unable to run analyses assessing the influence of positive mood on binge eating. This would have been of interest, as positive mood has been found to increase food pleasantness and consumption of healthy foods (Macht, 2008). Additionally, while several theoretical models for emotional eating and binge eating have received support (e.g. conditioning model; escape theory; Paxton & Diggens, 1997; reviewed in Reichenberger, Schnepper, Arend, & Blechert, 2020), our data did not allow for a distinction in their applicability to our findings. Finally, the current study relied on self-report data, which precludes drawing definite conclusions about the causal direction of the relationship between restriction, meal skipping, affect, and binge eating. Thus, further studies with naturalistic designs, or replications with other methodologies (e.g. lab food intake) are needed (Sysko, Steinglass, Schebendach, Mayer, & Walsh, 2018).

5. Conclusion

The present study provides preliminary evidence to suggest that negative affect *and* food craving are associated with the occurrence of a binge-eating episode, while restriction and meal skipping are not. Moreover, it points to the different routes to targeting binge eating by lending evidence that it may be possible to target binge eating without decreasing negative affect or food craving. It would be valuable for future studies to explore and update models of behavioural change within the context of interventional trials to disentangle mechanisms of change. Finally, an integration of inhibitory control training and goal planning with interventions targeting food craving and emotional eating (e.g. mental imagery,;Hamilton et al., 2019 mindfulness-based interventions; Schnepper, Richard, Wilhelm, & Blechert, 2019), may allow us to fully map the various pathways to binge eating reduction.

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Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The London Westminster Research Ethics Committee and the Health Research Authority approved all the procedures involved in this study (IRAS Project ID: 209609). The present study adheres to open science principles. It was pre-registered on ClinicalTrials.gov (ID: NCT03126526). The data were analysed in line with pre-registered aims, and both null and significant findings are reported.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105248.

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