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None for the submitted work.

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Abstract

Background: Negative affect is shown consistently to promote unhealthy food choices and dietary intake in laboratory studies. However, this relationship in naturalistic settings is less clear and previous research is limited by dietary assessment methodology and neglects to account for several important moderating variables. This observational study aimed to examine the association of negative affect and other psychological factors associated with eating behaviour simultaneously with discretionary energy intake and total energy intake, and whether these were moderated by emotional eating predisposition or age, sex and weight status.

Methods: One hundred adults completed a four-day food diary, a concurrent end-of-day questionnaire that assessed daily affect and experience of appetite, and the Three Factor Eating Questionnaire to assess trait eating behaviour. Food diaries provided data on participants' daily intake of total energy and of "discretionary items" (specific energy-dense and nutrient poor foods and beverages as defined by the Australian Guide to Healthy Eating). Stepwise random effects models were used to estimate the association of end-of-day ratings, trait eating behaviour and personal factors, and their interactions, with discretionary and total energy intake.

Results: Daily rated negative affect and appetite were significantly and positively associated with discretionary intake, such that a one unit increase in each scale was associated with eating 139 kJ/d [SE 61] and 194 kJ/d [SE 68] more discretionary energy, respectively. Negative affect and its interaction with emotional eating were consistently, positively associated with discretionary energy intake. This relationship was strongest in younger participants (β = -4.9 [SE 2.2], $p < 0.05$). There was no interaction with sex or weight status. Total energy intake was not associated with negative affect nor its interaction with emotional eating but was consistently associated with appetite.

Conclusion: When personal factors (age, sex, BMI), trait eating behaviours and daily rated negative affect and appetite are considered simultaneously, daily discretionary intake is associated most strongly with negative affect. Individuals, particularly young adults, may be more likely to overeat discretionary energy on days that negative affect is rated more highly, . However, this may not necessarily translate into greater total energy intake which was most consistently associated with daily rated appetite.

Background

Prolonged overeating is a prerequisite for the pathogenesis of obesity [1]. While overeating any food can theoretically cause weight gain, certain food types are especially implicated. Discretionary foods and beverages are described in the Australian Guide to Healthy Eating as being "too high in saturated fat and/or added sugars, added salt or alcohol and low in fibre… [discretionary foods and beverages] can also be too high in kilojoules (energy)" [2]. Depending on national dietary guidelines, they may also be known as 'extra' or as energy dense and nutrient poor (EDNP)[1].These foods and beverages are highly palatable, inexpensive, marketed aggressively and readily available, making them easy to overeat. The World Health Organisation rated evidence for the increased risk of weight gain and obesity due to EDNP foods as 'convincing' [3]. Therefore, identifying and understanding individual-level factors that influence overconsumption of these foods is essential to better assist individuals with weight management.

Experimental research demonstrates reliably that negative affect drives dietary intake [4-6]. This was consolidated in a systematic review and meta-analyses of laboratory studies showing that negative mood induction was consistently associated with greater food intake [7]. Negative mood appears to also influence food choice, with experimental work demonstrating that negative affect promotes greater intake of more sweet, high fat foods [6, 8, 9], greater meal energy density [8] and more urges to eat 'favourite' foods such as cake, chocolate and biscuits [7, 10]. This has been described as the 'comfort food hypothesis' [11] whereby palatable EDNP foods are eaten in order to elicit a hedonic experience and reduce aversive affect [12-15]. There are suggestions that the relationship of negative affect and dietary intake is potentially moderated by dispositional emotional eating. However, the evidence on this is mixed, with confirmatory findings of some studies [4, 5, 8] being contradicted by the null-findings of another [16].

[1] EDNP = energy dense nutrient poor

While experimental studies provide greater control over variables and allow investigation of cause and effect on acute dietary intake, these studies have limited ecological validity. Studying eating behaviour in a naturalistic setting provides greater insight into how the relationships between affect and dietary intake manifest in the real world. Yet, findings from naturalistic field studies are also conflicting. Several studies have observed an association of negative affect with greater overall intake [17] and greater consumption of high fat and high sugar snacks [18-22]. In contrast, others found no relationship between negative affect and intake of EDNP snack foods in adults with obesity [23], who have overweight [24], or of mixed weight [25]. Moderation by trait emotional eating was absent in one study [23], yet present in another [19].

Findings of these existing naturalistic studies are limited by the dietary assessment methodology and often only one component of dietary intake is examined, with most research reporting total snack intake. Snacks contribute around 20-25% energy intake of adults in Western countries [26-28], therefore, studies reporting snack intake only neglect a significant proportion of the diet. There are reports that intake at main meals is also positively associated with negative affect [17, 29], highlighting the need to examine overall intake. Further, in some studies, 'snacks' appear to be conflated with 'junk food' (e.g. chips, chocolate, cakes) [18, 22]. Some individuals eat healthy foods such as fruit as snacks [30], therefore total snack intake may not be a representative marker of 'unhealthy' dietary intake. Also, as there is no unifying definition of snacking [31], the validity of these results may be questioned. To the best of the authors' knowledge, only two naturalistic studies have examined the association of negative affect with overall dietary intake (assessed using quantitative food diaries) [17, 23]. One study found that meals eaten in positive and negative moods had greater energy content than those eaten in a neutral mood [17], while the other found that negative mood was not associated with food intake scores; although the method for calculating these scores was not reported [23].

In addition, the mixed findings of naturalistic studies suggest a need to consider factors that may potentially moderate whether and when negative affect is related to dietary intake. For instance, while

subjective appetite [32-34], stress [6, 8], body weight [19, 24, 25], age [35, 36] and sex [35, 36] are all ostensibly associated with dietary intake, a mood induction experiment that accounted simultaneously for these variables found that intake was associated with stress and sex but weight status and hunger were less relevant [37]. To the best of the authors' knowledge, only one study has examined simultaneously the association of several moderating factors with overall dietary intake [23]. However, this study was conducted in a relatively small sample of participants with obesity, limiting its generalisability. The dietary and affect data were analysed in aggregated form, such that daily data were averaged [23]. Affect and dietary intake are highly variable, therefore aggregating data may dilute meaningful daily fluctuations that would provide insight into their proximal relationship.

This study extends existing research by examining the association of several putative moderators of eating behaviour simultaneously in subjects of a healthy weight and those with obesity using highly detailed, disaggregated dietary intake collected in a real-life setting. The aims were to determine: 1) the association of daily negative affect, and other psychological determinants of eating behaviour, with discretionary energy intake (DEI)[2] and total energy intake (TEI)[3]; 2) whether any such association is moderated by trait emotional eating behaviour; and 3) whether there is any interaction with age, sex or weight status. The hypothesis was that negative affect would be associated with DEI and that this relationship would be moderated by trait emotional eating. Identifying the most important determinants of unhealthy dietary intake is essential for developing targeted and evidence-based strategies that address problematic eating behaviour in susceptible individuals.

Methods

Participants and study procedure

Participants were a convenience sample recruited through advertisements emailed to registrants of the Boden Institute clinical trials database, a post on the University of Sydney research volunteer website,

[2] DEI = discretionary energy intake
[3] TEI = total energy intake

and flyers posted around the University of Sydney campus. Advertising material invited individuals to volunteer for a study investigating a broad range of eating behaviours and their relationship to weight control. The advertisement did not state explicitly the authors' intention to examine discretionary intake to reduce the risk of social desirability bias and subsequent underreporting. The study was approved by the Sydney Local Health District Human Research Ethics Committee (Protocol Number X17-0228). Prior to study enrolment, participants provided informed written consent. Fifty participants with healthy weight (BMI 18.5-24.9 kg/m^2) and 50 with obesity (BMI $\geq$ 30kg/m^2) were recruited based on anthropometric data collected at study visits. To be eligible to participate, participants needed to be able to complete the study materials adequately. Participants were excluded from the study if they: were currently enrolled in a weight management program, were on a restrictive diet, had gained or lost 5% of their body weight in the previous three months, were shift workers, were currently pregnant or breast feeding, had an eating disorder, had previous bariatric surgery, or were currently/previously enrolled in a nutrition degree. At Visit 1, anthropometric measurements were collected, baseline questionnaires were administered, and the Food Diary and end-of-day questionnaire were dispensed. Approximately ten days later at Visit 2, the study materials were returned to the researcher. As compensation for their time, participants were presented with a $30 voucher.

Anthropometry

Anthropometric measures were collected with participants in light clothing and shoes removed. Height was measured to the nearest centimetre using a wall mounted stadiometer. Weight was measured to the nearest 0.1 kg using calibrated, digital scales. BMI was calculated in kg/m^2. Waist circumference was measured at the mid-point between the highest point of the iliac crest and lowest part of the costal margin in the midaxillary line. Measurements were record to the nearest 0.5 cm.

Background questionnaires

Participants completed a questionnaire at Visit 1 that collected demographic information including age, sex, education level, and postcode. The latter was used to determine participants' socioeconomic

indexes for areas (SIEFA) decile which provided a broad measure of socio-economic status [38]. Participants also reported whether they had an affective disorder. The Three Factor Eating Questionnaire-R18 (TFEQ-R18) [39] was administered to assess their trait eating behaviour. The TFEQ-R18 provides measures of emotional eating (three items), dietary restraint (six items) and disinhibited eating (nine items). This questionnaire has shown good internal consistency (Cronbach's alpha ≥ 0.77) for all subscales in samples from previous studies [39]. In this study, all scales had reasonably strong alpha coefficients, indicating good internal consistency within each. The scale reliability coefficient (Cronbach's alpha) was 0.78 for disinhibited eating items, 0.75 for dietary restraint items and 0.79 for emotional eating items. Raw subscale scores were transformed to a 0-100 scale using the equation: [(Raw score – lowest raw score)/possible raw score range] x 100 [40].

Dietary intake

Participants completed a four-day estimated food diary comprising three weekdays and one weekend day. Participants were instructed to record all food and beverages consumed except for water. At Visit 1, the researcher provided detailed verbal and written instructions on how to complete the diary. Participants were encouraged to maintain their habitual dietary habits while completing the food diary. The study dietitian assessed the food diary for completeness and prompted participants for clarification or additional information where required at Visit 2.

Nutrient analysis and coding

Dietary data were analysed using Xyris Foodworks Nutrition Analysis software [41]. The study dietitian identified discretionary foods and beverages in the participants' diets. The main principle used to classify foods and beverages as discretionary is that they were specified or inferred in the 2013 the Australian Dietary Guidelines [2, 42]. This included most sweet biscuits, cakes, desserts and pastries; processed meats and sausages; ice cream and other ice confections; confectionary and chocolate; savoury pastries and pies; commercial 'fast foods'; potato chips, crisps and other fatty and/or salty snack foods; cream, butter and spreads which are high in saturated fats; sugar sweetened soft drinks, milk-based drinks and cordials, sports and energy drinks and alcoholic drinks. Where

ambiguous, the following additional nutrition criteria were used to classify items as discretionary [43]: breakfast cereals >30 g sugar per 100g or for breakfast cereals with added fruit >35 g sugar/100g, mixed dishes with cereal content (e.g. sandwiches, burgers, wraps, sushi, pizzas) >5 g sat fat per 100 g Total energy intake (TEI) and discretionary energy intake (DEI) were extracted from food diary analyses.

Validity of dietary intake

Reported energy intake was assessed for validity using the Goldberg method [44], which involves calculating the ratio between reported TEI and BMR based on the Harris Benedict equation [45]. A ratio of less than 0.9 indicates that reported TEI is not consistent with energy intake required for a normal (non-bedbound) lifestyle. Participants whose reported energy intake yielded TEI: BMR < 0.9 were considered under reporters and their data excluded from analyses.

End-of-day questionnaire

At the end of each day that participants recorded their dietary intake, they also rated their daily subjective experience of mood and appetite on a Visual Analogue Scale (VAS) consisting of a numbered line anchored from 0 (not at all) to 10 (extremely). Participants were asked to rate the following: how anxious have you felt today, how easy have you found it to control your eating, how hungry have you felt today, how tense have you felt today, how irritable have you felt today, how strong was your desire to eat today, and how often have you had food cravings today. This instrument provides measures of negative affect, specifically tense arousal, and subjective experience of appetite and eating, and various adaptations have been used in previous studies [46, 47]. VAS assessment has a long history, good participant compliance and is a highly reliable and valid method to measure subjective experiences of affect [48] and appetite [49].

Data analysis

Factor analysis was performed to confirm the categorisation of the end-of-day questionnaire items using iterated principal factor method [50]. A varimax orthogonal rotation technique was applied to

maximise the variance of the squared loadings within each factor and to produce uncorrelated factors [51]. As there are reports that previous days' affect can affect the current day's dietary intake [52] and vice versa, a lagged effect analysis was performed to investigate whether this association existed in our sample. Random effects models tested the association of current day's dietary intake with the previous one- (L1) and two-day's (L2) end-of-day ratings and vice versa, to determine whether these associations existed in our sample. Pearson's correlation coefficients were calculated for end-of-day ratings, trait eating behaviours and weight status. To examine the associations of DEI and TEI with explanatory variables, stepwise random effects models were estimated using disaggregated daily dietary and end-of-day data. Random effects models have the advantage of estimating the variation of individual heterogeneity under the panel data structure and are statistically more efficient than pooled cross-sectional models [53]. In the current study, the primary variable of interest was daily negative affect and other daily ratings. Therefore, Model 1 included only the end-of-day ratings, which was used to estimate the association of negative affect, appetite and ease of control with TEI and DEI. As there is evidence indicates that the association between negative affect and dietary intake may depend on trait emotional eating, we included trait eating behaviours in Model 2. In the third step, the interaction terms of emotional eating and end-of-day ratings were included (Model 3). This specification evaluated whether the associations between negative affect, appetite and ease of control and TEI or DEI were moderated by emotional eating. Lastly, we were interested in the variation of these effects across broad demographic variables, Therefore, the fourth step included three-way interactions between emotional eating, end-of-day ratings and weight status (Model 4a), sex (Model 4b) and age (Model 4c). These interaction terms were used to test if the moderating role of emotional eating on the relationship between negative affect, appetite and ease of control, and, TEI or DEI varied across sex, age, and weight status groups. The interaction terms coefficients were presented in marginal effects plots to assist with interpretation. All models were adjusted for sex (male or female), age (< 35 years, 35-64 years, ≥ 65 years), education (completed post high school education or not), presence of self-reported affective disorder (yes or no), weight category (healthy weight or with obesity), day of the week energy intake was reported (weekend or weekday) and socioeconomic status (SEIFA top quintile or below). Standard errors were clustered at the individual level to control for the correlation of observations

within an individual over the study period. All tests of significance of the explanatory variables were conducted at alpha significance level of 0.05 or 0.01. All analyses were performed using Stata software version 14.0 [54].

Results

Participant characteristics

The reported daily energy intake of seven participants (four with healthy weight and three with obesity) yielded a Goldberg ratio of < 0.9. These participants were excluded, leaving 93 participants' data included in the analyses. Between valid and non-valid reporters, there was no difference in age, sex or socioeconomic status, although a greater proportion of valid reporters had completed post high school education (data not shown). Characteristics of participants with valid data are shown in **Table 1**. Age ranged from 18.5-82.4 years. Participants were mostly female (84.9%) and mean BMI was 28.6 kg/m^2, ranging from 18.5-46.6 kg/m^2.

Table 1. Characteristics of participants.

	All participants (n = 93)
Age (years)	45.7 (21.0; 18.5-82.4)
Number and % female participants	79 (84.9%)
BMI (kg/m^2)	28.6 (7.6; 18.5-46.6)
Waist circumference (cm)	94.6 (23.2; 66.0-143.0)
Proportion of sample in top SEIFA quintile	67 (72%)
Number of participants who completed post high school education	65 (70.0%)
DEI (kJ/day)	3406 (1703; 430-8128)
TEI (kJ/day)	8477 (1893; 4887-14585)
Goldberg ratio	1.42
Disinhibited eating	66.4 (14.0; 7-96)
Emotional eating	53.1 (26.1; 0-100)
Dietary restraint	55.0 (9.8; 5-86)

DEI = discretionary energy intake; TEI = total energy intake; TFEQ = Three Factor Eating Questionnaire. Goldberg ratio = TEI:BMR. Results are presented as mean (SD; range) where range is applicable.

Factor analysis and end-of-day ratings

Table 2 presents the underlying structure of the end-of-day questionnaire items. Three main factors were identified from the seven questionnaire items. Anxious, tense, and irritable were highly correlated with factor one which constituted a general negative affect measure; hunger, desire to eat, and food craving frequency were highly correlated with factor two, constituting an appetite measure; and ease of control over eating represented another single factor. The low uniqueness values for anxious, tense, irritable, hungry, desire to eat, and food craving frequency indicate that these variables were well explained by the negative affect factor and appetite factor, respectively. The mean end-of-day ratings for negative affect, appetite and ease in control over eating were 3.3 (2.4), 4.2 (2.1) and

5.5 (2.8), respectively. **Table 3** presents the correlations between these end-of-day ratings, trait eating behaviour and weight.

Table 2. Factor analysis of the end-of-day questionnaire.

Variable	Factor1 (Negative affect)	Factor2 (Appetite)	Factor3 (Ease in eating control)	Uniqueness
Anxious	0.7545			0.3615
Hungry		0.6988		0.5093
Tense	0.9869			-0.0105
Irritable	0.7180			0.4479
Desire to eat		0.9508		0.0860
Food craving frequency		0.6521		0.4006
Ease in eating control			-0.4630	0.7798

Iterated principal factor method is used to analyse the correlation matrix. The factor loading for the varimax orthogonal rotation to maximise the squared loadings of the columns. Factor loadings greater than 0.4 are displayed.

Lagged effect analysis

Results from estimating the main equation allowing for the lagged effect of end-of-day ratings on DEI are presented in **Supplementary Table 1**. The coefficient estimates indicate that end-of-day ratings of the current day was more relevant to the same day's DEI than the end-of-day ratings one day or two days prior. Negative affect (120.8 [SE 60.0]), appetite (157.4 [SE 69.8]) and ease of control over eating (-114.4 [SE 53.4]) had significant associations with same day's DEI. In contrast, there was no statistical association between the previous one- (L1) or two-day's (L2) negative affect (L1: 39.2 [SE 73.5] and L2: -46.2 [SE 102.6]), appetite (L1: 36.5 [SE 86.5] and L2: -11.5 [SE 120.2]) or ease of control over eating (L1: 54.7 [SE 56.0] and L2: 123.3 [SE 76.8]) on the current day's DEI. Similarly, the association between the previous one- (L1) and two- (L2) day's dietary intake with the current day's end-of-day ratings was small and insignificant (data not shown). Therefore, the previous days' end-of-day ratings and dietary intake were not included in subsequent random effects models.

Table 3. Pearson's correlation coefficients (r) for end-of-day ratings, trait eating behaviours and weight status.

	1	2	3	4	5	6	7
1. Negative affect	1						
2. Appetite	0.23*	1					
3. Ease of control	-0.11*	-0.11*	1				
4. Disinhibition	0.26*	0.24*	-0.16*	1			
5. Emotional eating	0.26*	0.18*	-0.16*	0.58*	1		
6. Dietary restraint	-0.03	-0.10	-0.06	-0.13*	-0.02	1	
7. Obesity	0.06	-0.10	-0.12*	0.14*	0.26*	-0.06	1

*p < .05.

End-of-day ratings and dietary intake

Table 4 Model 1 presents the associations of end-of-day ratings with DEI. Scatterplots representing these relationships are shown in the **Supplementary Figure 1**. Negative affect and appetite were positively and significantly associated with DEI, while ease of control over eating was negatively associated with DEI. A one unit increase in end-of-day ratings of negative affect and appetite was associated with eating 139 kJ/d [SE 61] and 194 kJ/d [SE 68] more DEI, respectively. A one unit increase in end-of-day ease of eating control was associated with eating 112 kJ less DEI. There was no significant association between TEI and negative affect (**Table 5 Model 1**). TEI had a direct, significant positive association with appetite ratings, with a one unit increase in appetite rating associated with eating 224 kJ more per day.

End-of-day ratings, trait eating behaviour and dietary intake

When trait eating behaviour was included in estimates for DEI (**Table 4 Model 2**), the effect size of negative affect and appetite decreased, suggesting a positive relationship between trait eating behaviour and these variables. Dietary restraint was negatively associated with DEI (β= -24 [SE 8], p < 0.01). Trait eating behaviour was not significantly associated with TEI at the 5% significance level (**Table 5 Model 2**).

360 **Table 4.** Associations between end-of-day ratings and discretionary energy intake, accounting for trait eating behaviour in a regression analysis.

	Model 1	Model 2	Model 3 (Figure 1a)	Model 4a (Figure 1b)	Model 4b (Figure 1c)	Model 4c (Figure 1d)
Negative affect	**138.7***	**120.8***	**-280.7***	**-283.7***	**-285.8***	**-279.8***
	(61.1)	(60.0)	(142.4)	(141.6)	(143.2)	(134.1)
Appetite	**193.5***	**157.4***	53.5	71.9	60.8	81.9
	(68.2)	(69.8)	(146.0)	(148.0)	(146.7)	(144.9)
Control	**-111.9***	**-114.4***	-188.0	-171.0	-189.4	-172.3
	(53.6)	(53.4)	(105.8)	(107.8)	(107.7)	(107.4)
Disinhibition		12.4	13.4	14.1	12.3	12.6
		(12.4)	(12.0)	(12.4)	(12.3)	(12.1)
Emotional eating		4.6	-34.0	-32.4	-33.9	-31.2
		(7.6)	(20.5)	(20.7)	(20.8)	(20.3)
Dietary restraint		**-23.9***	**-26.0***	**-27.2***	**-26.3***	**-27.3***
		(7.9)	(8.0)	(8.2)	(8.0)	(8.1)
Negative affect x Emotional eating			**7.8***	**9.7***	**8.0***	**10.4***
			(2.2)	(2.8)	(2.2)	(2.7)
Appetite x Emotional eating			1.6	1.3	1.6	1.4
			(2.6)	(3.0)	(2.6)	(3.0)
Control x Emotional eating			1.3	0.3	1.1	-0.7
			(2.0)	(2.8)	(2.1)	(2.8)
Weight status						
Negative affect x Emotional eating x Obesity				-2.7		
				(2.2)		
Appetite x Emotional eating x Obesity				-0.5		
				(2.0)		
Control x Emotional eating x Obesity				1.1		
				(2.1)		

Sex		
Male x Negative affect x Emotional eating	-0.5	
	(4.3)	
Male x Appetite x Emotional eating	-2.0	
	(2.5)	
Male x Control x Emotional eating	2.4	
	(2.2)	
Age		
35≤Age<65 x Negative affect x Emotional eating		**-4.9***
		(2.2)
Age≥65 Negative affect x Emotional eating		-1.8
		(2.4)
35≤Age<65 x Appetite x Emotional eating		0.8
		(2.0)
Age≥65 x Appetite x Emotional eating		-3.6
		(2.5)
35≤Age<65 x Control x Emotional eating		3.9
		(2.3)
Age≥65 x Control x Emotional eating		1.5
		(2.3)

Regressions are estimated using random effects models and control for sex, age, education, affective disorders, weight status, day of the week and socioeconomic status. Results are presented as β coefficient (standard error). Standard errors are clustered at the individual level. * = $p < 0.05$. Control = ease of control over eating. The estimates in Model 3 are graphed in Figure 1a, and the estimates in Model 4a, 4b and 4c are graphed in Figure 1b, 1c and 1d, respectively. To control for individual specific eating habits and preference, fixed effects models were performed for Model 1 in Table 3. Fixed effects models remove the effect of time-invariant characteristics to further control for confounding such as eating habits and personality traits. The size of the coefficients for negative affect (96 kJ/d), appetite (153 kJ/d) and control (-154 kJ/d) in the fixed effects model was similar to that of the random effects model.

Table 5. Associations between end-of-day ratings and total energy intake, accounting for trait eating behaviour in a regression analysis.

	Model 1	Model 2	Model 3 (Figure 2a)	Model 4a (Figure 2b)	Model 4b (Figure 2c)	Model 4c (Figure 2d)
Negative affect	53.1	52.4	-121.0	-130.7	-97.1	-114.2
	(48.3)	(48.7)	(107.7)	(109.5)	(103.8)	(111.1)
Appetite	**223.5***	**215.8***	73.4	103.6	48.4	103.8
	(63.4)	(66.6)	(133.1)	(133.0)	(137.3)	(129.7)
Control	-92.0	-92.7	**-182.5***	**-177.3***	**-185.3***	**-168.4***
	(47.3)	(48.4)	(77.4)	(78.8)	(76.1)	(78.8)
Disinhibition		17.6	18.8	21.2	19.3	20.1
		(11.4)	(11.4)	(11.7)	(11.2)	(10.6)
Emotional eating		-9.0	**-40.3***	-35.0	-38.6	-32.7
		(7.9)	(20.0)	(20.3)	(20.3)	(19.3)
Dietary restraint		-3.9	-5.3	-4.8	-7.1	-6.3
		(11.2)	(11.8)	(11.7)	(11.3)	(11.2)
Negative effect x Emotional eating			3.2	**4.7***	2.9	4.8
			(1.7)	(2.3)	(1.6)	(2.5)
Appetite x Emotional eating			2.7	0.3	3.1	0.2
			(2.7)	(3.0)	(2.8)	(2.9)
Control x Emotional eating			1.8	1.3	2.2	0.6
			(1.7)	(2.2)	(1.8)	(2.2)
Weight status						
Negative affect x Emotional eating x Obesity				-2.2		
				(2.0)		
Appetite x Emotional eating x Obesity				2.0		
				(2.1)		
Control x Emotional eating x Obesity				0.5		
				(1.8)		
Sex						

Male x Negative affect x Emotional eating	-2.9	
	(5.6)	
Male x Appetite x Emotional eating	0.6	
	(2.7)	
Male x Control x Emotional eating	-3.8	
	(3.3)	
Age		
35≤Age<65 x Negative affect x Emotional eating		-2.4
		(2.1)
Age≥65 x Negative affect x Emotional eating		-2.2
		(2.4)
35≤Age<65 x Appetite x Emotional eating		**5.6***
		(2.3)
Age≥65 x Appetite x Emotional eating		-0.05
		(2.0)
35≤Age<65 x Control x Emotional eating		2.1
		(2.1)
Age≥65 x Control x Emotional eating		0.6
		(2.0)

Regressions are estimated using random effects models and control for sex, age, education, mood disorders, weight status, day of the week and socioeconomic status. Results are presented as β coefficient (standard error). Standard errors are clustered at the individual level. * = $p < 0.05$. Control = ease of control over eating. The estimates in Model 3 are graphed in Figure 2a, and the estimates in Model 4a, 4b and 4c are graphed in Figure 2b, 2c and 2d, respectively.

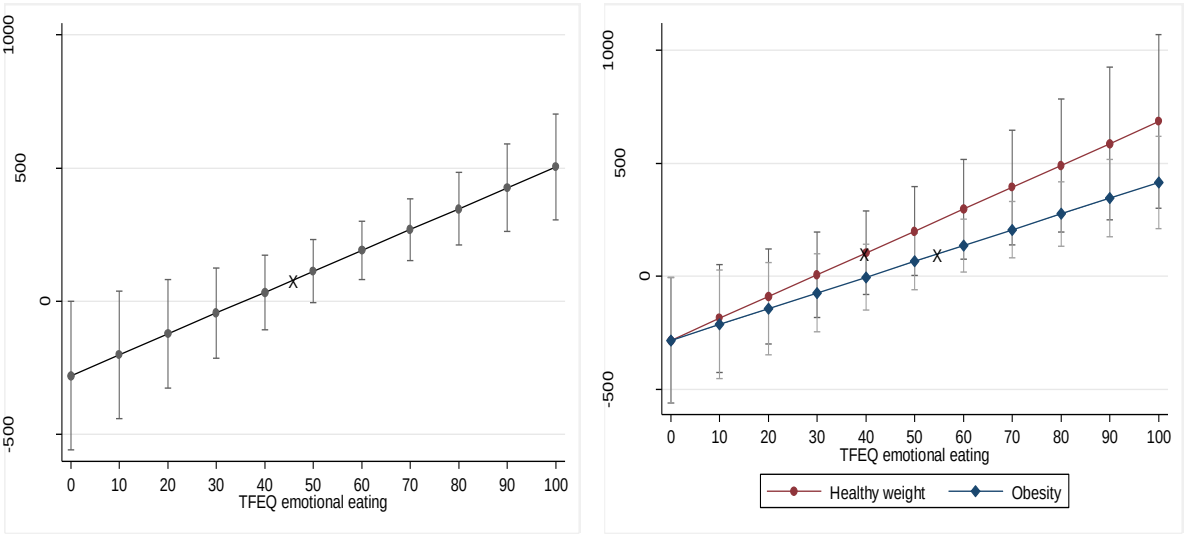
End-of-day ratings (x emotional eating), trait eating behaviour and dietary intake

Table 4 Model 3 and **Figure 1a**) show the results including two-way interactions between end-of day measures and emotional eating and their association with DEI. The interaction between negative affect and emotional eating was statistically significant. As emotional eating scores increased, the association of negative affect with DEI became stronger. For participants with emotional eating scores < 35, the association of negative affect with DEI was negative. For participants with scores ≥ 35 the higher the emotional eating scores the greater (more positive) the association of negative affect with DEI (**Figure 1a**). Emotional eating did not modify the relationship of appetite or ease of control over eating with DEI (**Table 4 Model 3**). The interaction of negative affect and emotional eating was not related to TEI. The effect size of appetite decreased when interaction terms were included in the model (**Table 5 Model 3** and **Figure 2a**).

End-of-day ratings (x emotional eating x personal variables), trait eating behaviour and dietary intake

The association of three-way interactions between end-of-day ratings, trait eating behaviour and biological variables with DEI are reported in **Table 4** and **Table 5 Models 4a-c** and **Figures 1b-1d** and **2b-d**. The two-way interaction between negative affect and emotional eating remained positively and significantly associated with DEI across all Model 4 specifications. Neither the three-way interaction with weight status (**Table 4 Model 4a and Figure 1b**) nor sex were statistically significant (**Table 4 Model 4b** and **Figure 1c**). This was also observed for TEI (**Table 5 Models 4a-b** and **Figure 2b-c**). The association between DEI and the interaction between emotional eating and negative affect was highest among young adults aged < 35 years, followed by those ≥ 65 years (**Table 4 Model 4c** and **Figure 1d)**. Regarding TEI, participants aged 35-64 years with higher emotional eating scores were more likely to experience appetite-induced increases in TEI than those aged < 34 or ≥ 65 years (β= 5.6 [SE 2.3], $p < 0.05$) (**Table 5 Model 4c and Figure 2d)**.

(a) **(b)**



(c) **(d)**

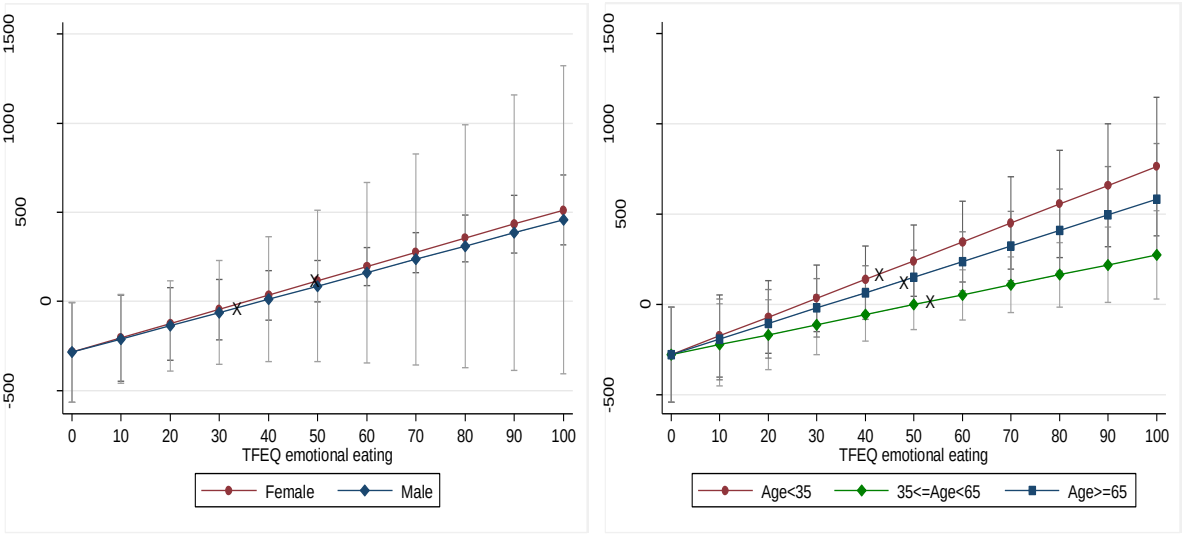
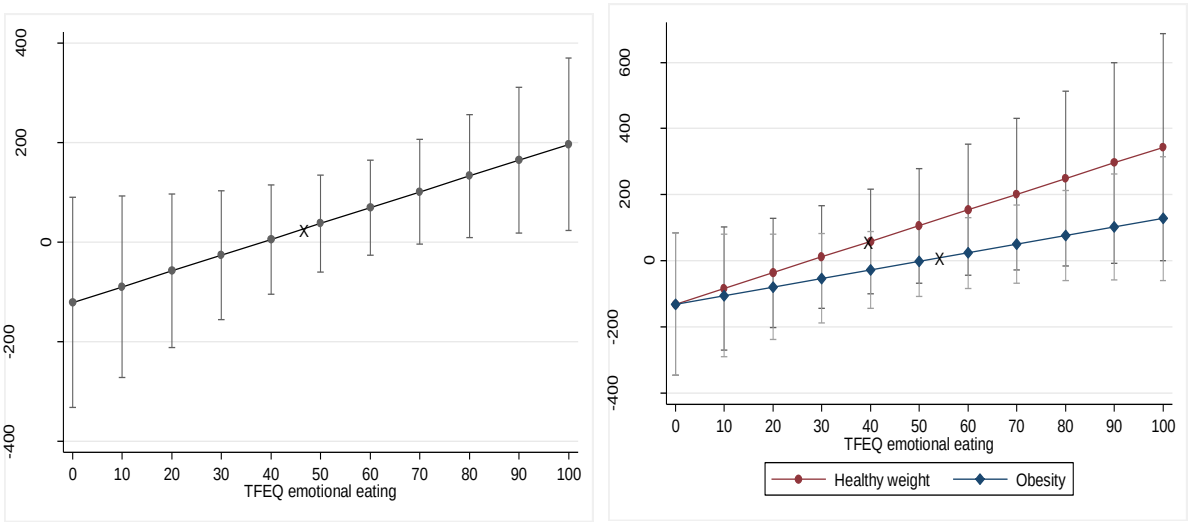


Figure 1. Marginal effects plots show **t**he relationship between DEI and the interaction of **(a)** negative affect and emotional eating, **(b)** negative affect, emotional eating and weight status, **(c)** negative affect, emotional eating and sex, and **(d)** negative affect, emotional eating and age. The y-axis scale is the marginal effect of negative affect from the random effects models as presented in Table 4, with 95% confidence intervals, and the x-axis is emotional eating score. The 'x' on the regression lines indicates the mean emotional eating score.

(a) **(b)**



(c) **(d)**

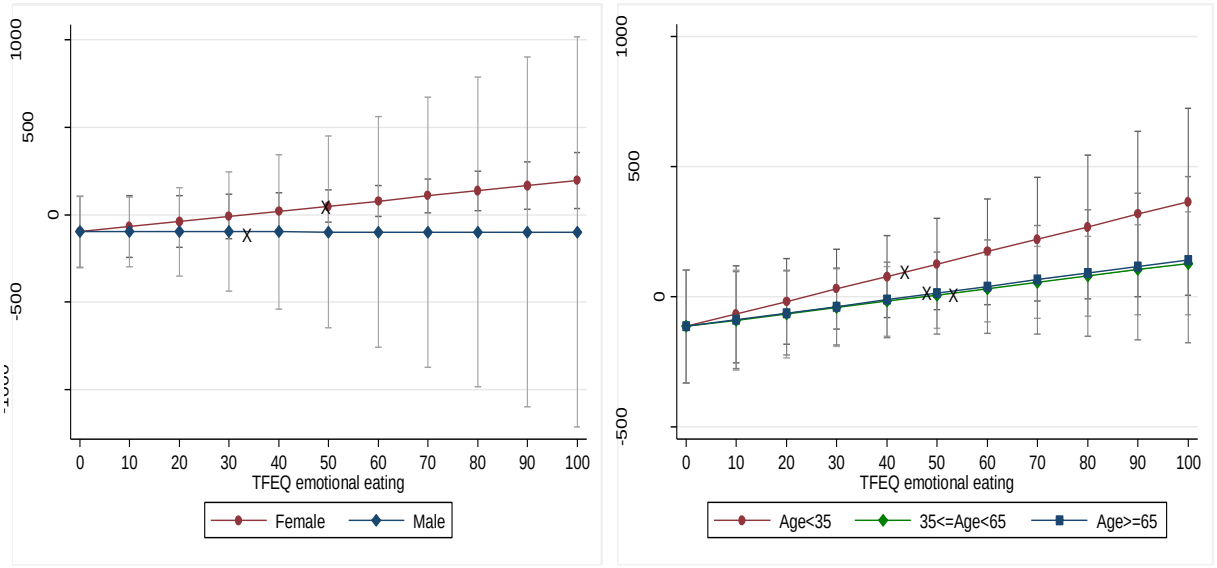


Figure 2. Marginal effects plots show **t**he relationship between TEI and the interaction of **(a)** negative affect and emotional eating, **(b)** negative affect, emotional eating and weight status, **(c)** negative affect, emotional eating and sex, and **(d)** negative affect, emotional eating and age. The y-axis scale is the marginal effect of negative affect from the random effects models as presented in Table 5, with 95% confidence intervals, and the x-axis is emotional eating score. The 'x' on the regression lines indicates the mean emotional eating score.

Discussion

The distinctive features of this naturalistic study were the highly detailed assessment of overall dietary intake, the simultaneous examination of several moderators of eating behaviour and the inclusion of participants of healthy weight and with obesity. As suggested by previous laboratory studies [4-6] and consistent with findings of a systematic review and meta-analysis [7], negative affect and its interaction with emotional eating were positively associated with DEI. Along with dietary restraint, these variables remained significant across all model specifications for DEI. There was no interaction by sex or weight status, however, there was an interaction by age such that the interaction of negative affect and emotional eating was stronger in younger participants. Neither negative affect nor its interaction with emotional eating were related to TEI, which was significantly and positively associated with appetite.

Our study found that negative affect alone and its interaction with emotional eating, along with dietary restraint alone were consistently associated with DEI when all other variables were considered. Our results support those of an experimental study by Mantau et al. [37] who induced negative mood in subjects and examined the effect of several situational, psychological and personal determinants on food choice (choosing an heathy or unhealthy granola bar).. When all variables were accounted for, stress and restrained eating remained significant positive and negative predictors of unhealthy food choice, respectively, while there was no association with hunger. Using an ecological momentary assessment (EMA) protocol, Tomiyama and colleagues [55] determined that hunger and negative affect were unique predictors of the odds of eating at the time of assessment and one hour after, however food type was not assessed. In a field study by Cleobury and colleagues [30] participants with overweight or obesity recorded all food consumed in five days and contemporaneously recorded the extent to which they would ascribe their motivations to initiate eating to particular triggers. The most frequently endorsed trigger for eating unhealthy snacks was because the food ‘looked or smelled tempting’, followed by hunger. Eating in response to negative affect was endorsed in up to 19% of occasions. Given the dearth and heterogeneity of studies that have investigated several moderators in

453 a naturalistic setting, it is difficult to identify the most important determinants of DEI with certainty,
454 however, negative affect appears to be a salient factor.
455
456 Trait emotional eating was not independently associated with DEI but appeared to be contingent on
457 negative affect. While our findings are supported by studies that have observed an interactive
458 relationship between trait emotional eating and affect [19, 56, 57], they are in conflict with the null
459 findings of others [23, 58]. Evers and colleagues [16] argued that scales assessing emotional eating
460 are susceptible to 'triple recall bias' i.e. participants must recall their negative affect, their dietary
461 intake and the relationship between them, and that this may underlie inconsistencies in the literature.
462 It should be noted that higher levels of emotional eating are reported more often by women than men
463 [59, 60] and this may have impacted our results.
464
465 Our observation that appetite was associated with TEI is supported by a wealth of evidence showing
466 that appetite is a consistent predictor of actual dietary intake [32-34, 61]. However, our finding that
467 TEI was not associated with negative affect was somewhat counterintuitive. As DEI comprises a
468 proportion of TEI, one would expect a positive association between negative affect and DEI to
469 correspond to positive association between TEI and negative affect. Our finding suggests that
470 increased DEI associated with greater negative affect may displace intake of non-discretionary foods
471 and beverages, thereby maintaining TEI. This may have implications for dietary quality, given that
472 non-discretionary foods are typically high in nutrients that are essential for health [2]. While there is
473 considerable empirical evidence to show that negative affect is associated with increased intake of
474 energy dense, palatable foods [12-15], research on the association of non-discretionary food is smaller
475 and less compelling. A cross-sectional study in mixed weight women showed that stress correlated
476 positively with intake of palatable non-nutritious food but not nutritious foods [62]. Similarly,
477 European cross-sectional studies with large study samples have found that perceived stress and/or
478 depressive symptoms were associated positively with intake of sweets/fast foods [21] and negatively
479 with intake of fruits, vegetables and meat [21, 24]. It is possible that increased DEI may displace the
480 intake of nutritious non-discretionary foods, meaning that TEI remains relatively stable.

The observation that the interaction between emotional eating and negative affect was strongest in younger participants may allude to age-related trends in affective disorders and regulation. Epidemiological data show that the prevalence of affective disorders tends to decline in older age groups for females and appears to peak in males aged 35-44 years [63]. Research has also shown that older adults have a diminished stress response [64-66] and more effective affective regulation than younger adults [64-66]. Underdeveloped emotional regulation skills and greater rates of affective disorders may potentially make young adults more susceptible to emotional eating.

These findings have clinical relevance. Currently, appetite control is central to the weight management dogma, with dieters being encouraged to eat nutritious 'filling foods' to preemptively reduce wanting for, and intake of, discretionary foods. However, based on the results of the current study, negative affect appears to be more strongly associated with DEI than does appetite. Therefore, weight management interventions that combine appetite control with the strategies to develop emotional regulation and stress management skills may be more effective.

Our study addressed the limitations of previous naturalistic studies that have typically only reported single dietary components (e.g. between meal snacks) by collecting detailed dietary data. Collecting fully quantitative dietary data and reporting in units of energy provided greater clinical applicability and translatability. Analysing data in a disaggregated form allowed the association between daily ratings and daily dietary intake to be investigated. Considering simultaneously several moderators known to effect dietary intake facilitated a more integrative and real-world investigation of eating behaviour. This approach allowed us to determine the relative importance of these moderators. The study sample included a similar number of participants of healthy weight and with obesity which had not been done in the literature previously. Also, a lagged effect analysis was conducted before generating estimation models to determine if there was any association of the previous days' end-of-day ratings with the current day's dietary intake in our sample and vice versa.

Regarding study limitations, our sample had more female than male participants which may have impacted the analyses of interactions by sex. There are suggestions in the literature that the relationship of affect and dietary intake is bi-directional [25, 52, 67]. This was not explored in our study due to the lack of exogenous instruments, and thus may be a focus for future studies. Unplanned and unwanted consumption of these foods may drive negative affect. In addition, the end-of-day questionnaire only captured ratings of tense arousal and did not measure other types of affect such as hedonic tone or energetic arousal. Further, under-reporting of dietary intake, especially of discretionary foods [68], is an inherent bias associated with dietary assessment. While the Goldberg method was used to identify and exclude potential under-reporters, valid reporters may still have misreported or changed their dietary intake to lessen the burden of recording or increase the social acceptability of their responses [69]. A Goldberg cut-off of 0.9 was used in the current study, however, there are suggestions that higher ratios e.g. 1.28 are more appropriate [70]. The inadvertent inclusion of under-reporters may have impacted the validity of the current study's findings.

The results presented here provide impetus for future research. Larger studies that are conducted over a longer time period and collect information more proximal to eating occasions (e.g. EMA-based studies) would provide insight into the direction of the association between negative affect and dietary intake. Assessing other determinants of eating behaviour such as cue reactivity, impulsiveness and habit which are often cited as predictors of dietary intake [37] would be valuable to assess their relative association with eating behaviour. Examining the association of dietary intake with a more diverse range of affective states would be valuable in light of suggestions that different types of negative affect [71] and even positive affect [72] are associated with eating behaviors. Future research should focus on young adults who appear to be more susceptible to emotional eating.

Conclusions

When personal factors (age, sex, BMI), trait eating behaviours and daily rated negative affect and appetite are considered simultaneously, daily discretionary intake is most strongly associated with negative affect. Individuals, especially young adults, may overeat discretionary energy on days that

negative affect is rated more highly. However, this may not necessarily translate to greater total energy intake which is most consistently associated with daily rated appetite. Further studies are needed to determine causality and the direction of these associations in other populations.

Author contributions

MF: conceptualised the study, collected the data, formed data analysis design, interpreted the data, wrote the initial draft manuscript and had responsibility for the final manuscript. AJH: assisted with study design and data interpretation and critically reviewed and revised the manuscript. AL, MC: generated and ran data analysis models, assisted with data interpretation and critically reviewed and revised the manuscript. MRS, CDM and IDC: critically reviewed and revised the manuscript.

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