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*Published in:*  
Appetite

*DOI:*  
[10.1016/j.appet.2021.105746](https://doi.org/10.1016/j.appet.2021.105746)

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*  
Publisher's PDF, also known as Version of record

*Publication date:*  
2022

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Ackermans, M. A., Jonker, N. C., Bennik, E. C., & de Jong, P. J. (2022). Hunger increases negative and decreases positive emotions in women with a healthy weight. *Appetite*, 168(1), Article 105746. <https://doi.org/10.1016/j.appet.2021.105746>

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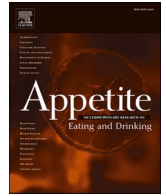
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## Hunger increases negative and decreases positive emotions in women with a healthy weight

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### ARTICLE INFO

#### Keywords:

Hunger  
Negative emotions  
Positive emotions  
Emotion regulation  
Eating disorders  
Restriction  
Healthy weight

### ABSTRACT

The term 'hangry' is colloquially used to describe being "bad tempered or irritable as a result of hunger," but remarkably few studies have examined the effect of hunger on emotions. Yet, women attempting to restrict their food intake may be at risk of becoming entangled in a vicious cycle of hunger and negative emotions. That is, hunger may lead to negative emotions, which can lead to overeating and overeating can, in turn, provoke subsequent restriction leading to more hunger. Therefore the aim of this study was to examine the effect of hunger on positive and negative emotions in women with a healthy BMI, and the role of subclinical eating disorder symptoms in this effect. We randomly assigned women to a hunger condition (fasting for 14 h,  $n = 53$ ) or satiated condition (eat breakfast before the study,  $n = 55$ ), and they completed the Eating Disorder Examination Questionnaire and the Profile of Mood States in the lab. Hungry women reported overall higher negative emotions (higher tension, anger, fatigue, and confusion) and lower positive emotions (lower vigour and marginally lower esteem-related affect) than satiated women. Moreover, for satiated but not for hungry women, higher eating disorder symptoms were associated with lower esteem-related affect. These findings show that food restriction leads to negative emotions, and practitioners and individuals should be aware of these implications of food restriction on mental health. Second, clinicians and individuals should be wary of relatively low esteem-related affect when satiated in individuals with eating disorder symptoms, as it could serve as a maintaining factor in eating pathology.

Hunger is an inherently unpleasant feeling, and most people seem to be aware of the fact that hunger can negatively affect their mood (MacCormack and Lindquist, 2018). This is colloquially referred to as being 'hangry,' which Oxford Dictionary defines as being "bad tempered or irritable as a result of hunger" (Hangry, 2015). Despite this colloquial term, anger is not the only expected negative emotion resulting from hunger. That is, hunger may also elicit several other negative emotions, given that situations that are perceived as negative typically elicit several unpleasant emotions and individuals are likely to endorse multiple emotion-related adjectives when asked to report their emotion (MacCormack & Lindquist, 2016). The effect of such negative emotions on hunger and overeating has been well-studied (e.g. Agras & Telch, 1998; Ferrer et al., 2020), and eating after the experience of negative emotions has been recognized as a crucial factor in overeating, unsuccessful dieting attempts, and weight gain, particularly in women (Koenders & van Strien, 2008; Macht, 1999; Mantau et al., 2018). However, remarkably few studies have examined the reversed effect, i.e. the effect of hunger on negative emotions. This is unfortunate, as a better

understanding of this effect is necessary given that women attempting to restrict their food intake may be at risk of becoming entangled in a vicious cycle of hunger and negative emotions. That is, hunger may lead to negative emotions, which can lead to overeating, and overeating can, in turn, provoke subsequent restriction leading to more hunger. Moreover, such food restriction can be taken too far and result in disordered eating.

Several theories exist regarding the effect of hunger on emotions. The regulatory depletion hypothesis suggests that hunger depletes self-regulation. According to this hypothesis, high-arousal negative emotions such as anger become more difficult to regulate in a state of hunger because biological resources such as glucose are depleted (MacCormack & Lindquist, 2018). However, this theory cannot explain the presence of more low-arousal emotions, such as sadness, when hungry. A more plausible theory posits that feeling 'hangry' is psychologically constructed. This theory also departs from the physiology of hunger: low blood glucose causes the release of the hunger-signaling hormone ghrelin, which increases cortisol, thereby inducing an arousing, unpleasant change in the body which can be interpreted as negative

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<https://doi.org/10.1016/j.appet.2021.105746>

Received 26 February 2021; Received in revised form 4 October 2021; Accepted 8 October 2021

Available online 9 October 2021

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emotion (MacCormack & Lindquist, 2018). However, it builds on this physiological aspect of hunger and suggests that emotions emerge from a combination of 1) representations of the body's internal state, 2) knowledge about emotions from prior experiences, and 3) external representations from the context. In that case, the unpleasant, high-arousal changes induced by hunger may be interpreted as anger or other negative emotions in a negative context (MacCormack & Lindquist, 2016). However, this theory requires the presence of a negative context for hunger to be interpreted as a negative emotion, and would not explain the presence of 'hunger' in a positive or neutral context. A third possible explanation for the effect of hunger on negative emotions is the sustained abstinence of the highly incentive stimulus of food, resulting in a diminished sense of control (Drobles et al., 2001) and associated negative emotions, like frustration (Mauler et al., 2006). If this theory is correct, individuals should experience both high- and low-arousal negative emotions, in response to hunger in a neutral context. Thus, several theories exist and there is no consensus on exactly why hunger negatively affects emotions. Moreover, none of these theories addresses the effect of hunger on positive emotions, which is important given that positive and negative emotions are two separate dimensions, rather than opposite ends of a single continuum (Watson & Tellegen, 1985).

## 1. Empirical evidence for the effect of hunger on emotions

Some empirical evidence corroborates the idea that hunger negatively affects emotions. Women fasting for one or two days every eight days for 48 days reported feeling more nervous and tired and less happy and strong on fasting days than on normal eating days ( $N = 22$ ; Wojciak, 2014). Additionally, low blood glucose has been linked to a state of 'tense tiredness' ( $N = 27$ ; Hepburn et al., 1995) and greater aggression ( $N = 107$ ; Bushman et al., 2014). Moreover, in the Affect Misattribution Procedure, hungry individuals rated an ambiguous Chinese pictograph more negatively than satiated individuals in the presence of a negative context (a prior image with a negative valence) and in a negative interpersonal situation (a frustrated researcher). Although this study had a relatively large sample size, it did not measure the actual experience of negative emotions independently of the pictograph ( $N = 236$ ; MacCormack & Lindquist, 2018).

Many studies, however, showed mixed results for the effect of hunger on negative emotions. One study with a within-subjects design on smoking women who fasted for 18 h found that food deprivation led to reduced positive emotions (specifically vigour-activity), but had no effect on negative emotions ( $N = 15$ ; Kendzor et al., 2008). In contrast, another study found that women with a healthy weight showed an increase in negative emotions, but no change in positive emotions after a 20-h fasting period ( $N = 41$ ; Moreno-Dominguez et al., 2012). Similarly, a group of female college students with a healthy weight showed increased negative emotions after a 24-h fasting period, but no change in positive emotions ( $N = 22$ ; Herbert et al., 2012). Notably, neither of these two studies reported on *specific* negative emotions, but only on negative emotions in general (Herbert et al., 2012; Moreno-Dominguez et al., 2012). Yet another study found no effect of 24-h food deprivation on any of 16 mood scales in non-dieting women (except on 'jitteriness';  $N = 21$ ; Green et al., 1995), and surprisingly, a group of women fasting for Ramadan showed better mood during the fasting period compared to before the fasting period, though this was an observational study ( $N = 40$ ; Molavi et al., 2016). Thus, previous research in participants with a healthy weight showed mixed results, possibly due to relatively small sample sizes and therefore a lack of sufficient power to detect relevant effects. Moreover, earlier studies did not take important moderators of the relationship between hunger and mood into account such as eating pathology or disordered eating behaviors. The current study addressed these shortcomings by including a larger sample size than previous studies and including a measure of eating pathology.

### 1.1. The role of eating disorders in the effect of hunger on emotions

Previous studies have found that eating disorders moderate the relationship between hunger and mood. Individuals with eating disorders such as anorexia nervosa (AN) and bulimia nervosa (BN) not only face elevated negative emotions in general and co-occurring anxiety and depressive disorders (Lavender et al., 2015), they also experience a weaker, or even reversed, effect of hunger on emotions. For instance, in contrast to women without an eating disorder, women with BN showed a reduction in negative affect across a 20-h fasting period (Moreno-Dominguez et al., 2012). Fullness, on the other hand, increased negative emotions in women with BN given that, after eating without being allowed to purge, they reported negative affect, anxiety, and irritation ( $N = 32$ ; Mauler et al., 2006). Moreover, women with BN likely also use restriction as a means of reducing the negative affect associated with food exposure and a fear of gaining weight (Mauler et al., 2006).

Similarly, for women with AN, the sensation of hunger can elicit positive emotions, as it is taken as evidence of achieving their goal of being thin (Blackburn et al., 2012). For individuals with AN, "physiological cravings for food are experienced positively, because of a more salient psychological desire to avoid gaining weight" (Blackburn et al., 2012). Food and eating, in contrast, are associated with negative emotions because they signify a loss of control (Blackburn et al., 2012). However, one study found no effect of hunger on affect in women with AN, such that restriction on a given day did not predict negative or positive emotions on the following day (Engel et al., 2013). Thus, although findings are equivocal, women with both AN and BN generally show less negative emotions or more positive emotions when hungry than when satiated.

### 1.2. The role of subclinical eating pathology in the effect of hunger on emotions

In addition to women with clinical eating disorders, women with subclinical eating disorder symptoms may also exhibit a different relationship between hunger and emotions than women without these symptoms. This relationship is important to investigate in women with disordered eating behavior given that dieting, weight control attempts, and shape and weight concerns are common in the general population, particularly in women (Blokstra et al., 1999). One study assessed emotions in women who frequently experienced strong cravings (Hill et al., 1991). Women who typically gave into their cravings felt better after eating, whereas those who only occasionally gave into their cravings (i.e. also restricted sometimes) felt a positive mood after resisting the craving, but a continuing negative mood after eating (Hill et al., 1991). However, this study only looked at the role of one specific behavior (i.e. giving in to cravings), rather than assessing eating disorder symptoms more broadly. Moreover, it had a small sample size ( $N = 20$ ) and did not experimentally induce hunger.

### 1.3. The current study

The aim of the current study was to examine the effect of fasting on positive and negative emotions in a well-powered sample of women with a healthy BMI. We only included women because they report more dieting and food restriction than men (De Ridder et al., 2014; Wardle et al., 2006) and are more likely to have eating disorders (National Eating Disorders Association, 2020). We tested the hypothesis that women deprived of food would show higher scores on negative emotions and lower scores on positive emotions compared to a control group that was not deprived of food. We also investigated whether the effect of hunger on emotions differed according to the extent of subclinical eating disorder symptoms, and expected the effect of hunger to be different in women with relatively high levels of eating disorder symptoms in comparison to women with low levels of eating disorder symptoms.

## 2. Method

### 2.1. Sample size and participants

Individuals eligible for the study were women with a healthy weight (BMI between 18.5 and 25) who identified themselves as following a routine in which they normally eat breakfast. Participants were recruited through social media advertisements and flyers placed at several university locations around Groningen. A total of 168 women signed up for the study, of which 129 (77%) actually participated. Participants were on average 22.4 years of age ( $SD = 3.2$ ), and had an average BMI of 21.4 ( $SD = 1.8$ ). Participants were recruited as part of a three-part study on hunger (findings for the second part regarding hunger and attentional engagement can be found in [Jonker et al., 2020](#); findings for the third part on approach-avoidance have yet to be published). Given that the required sample size was established by the analyses for the attentional engagement part of the study ([Jonker et al., 2020](#)), we report a sensitivity analysis for the current study. With 129 participants, an alpha level of 0.05 and power of .80 we could reliably detect an effect size of  $> 0.10$  for negative emotions and  $> 0.08$  for positive emotions. This is in line with effect sizes of the findings about the effect of hunger on emotions in previous studies, which ranged from 0.06 to 0.22 ([Herbert et al., 2012](#); [Kendzor et al., 2008](#); [Moreno-Dominguez et al., 2012](#)).

### 3. Materials

**Manipulation check.** To check whether participants complied with the instructions, time since eating was assessed with the question “How long has it been since you last ate?” from the Hunger Scale ([Grand, 1968](#)). Scores reflect the number of hours that have passed since the participants last ate, rounded off to quarters of an hour. They were also asked “How hungry are you right now?” from the Hunger Scale, which was answered on a 7-point scale from *not hungry at all* (1) to *extremely hungry* (7).

**Positive and negative emotions.** Positive and negative emotions were measured with the Profile of Mood States (POMS; [Grove & Prapavessis, 1992](#)). The POMS consists of 40 emotions of which participants have to identify how much it currently applies to them from 0 (“*Not at all*”) to 4 (“*Extremely*”). The POMS consists of 7 subscales of which internal consistency in the current study ranged from acceptable to good: Tension (6 items, e.g. ‘tense’ and ‘uneasy’; Cronbach’s alpha = .85), Anger (6 items, e.g. ‘angry’ and ‘annoyed’; Cronbach’s alpha = .85), Fatigue (5 items, e.g. ‘fatigued’ and ‘worn out’; Cronbach’s alpha = .83), Depression (7 items, e.g. ‘hopeless’ and ‘miserable’; Cronbach’s alpha = .90), Esteem-related affect (6 items, e.g. ‘proud’ and ‘competent’; Cronbach’s alpha = .70), Vigour (5 items, e.g. ‘lively’ and ‘energetic’; Cronbach’s alpha = .81) and Confusion (5 items, e.g. ‘confused’ and ‘unable to concentrate’; Cronbach’s alpha = .76).

There were 5 participants who missed one item on a subscale. For these participants the missing item was replaced with the mean score of the other items of the same subscale.

**Eating disorder symptoms.** The Eating Disorder Examination Questionnaire (EDE-Q; [Fairburn & Beglin, 2008](#)) consists of 22 items assessing eating disorder pathology in the past 28 days. It contains questions regarding restraint, shape concerns, weight concerns, and eating concerns. Items indexed the frequency or severity of symptoms and were answered on a scale ranging from 0 (“*never/not at all*”) to 6 (“*every day/markedly*”). In their psychometric study, [Aardoom et al. \(2012\)](#) found no support for the theorized four subscales. They found that the theorized four subscales tap one general underlying dimension, rather than separable sub dimensions. Therefore the average of the 22 items was used as a measure of global eating pathology severity ([Aardoom et al., 2012](#)). Internal consistency of this global score in the current sample was excellent (Cronbach’s alpha = .94).

### 3.1. Procedure

The current study was approved by the ethical committee of the psychology department of the University of Groningen (17374). After signing up for the study participants received an online prescreen questionnaire. At the start of this questionnaire participants signed informed consent for the study, after which they were randomly assigned to a fasting or satiated condition. Instructions to the corresponding condition were then emailed to the participant. To ensure compliance, participants were called 1–5 days prior to their scheduled lab session to go through the instructions. Lab sessions were scheduled at 9 a.m. or 10.30 a.m. Sixty-four participants were assigned to the fasting group and were instructed to abstain from food and sugar-containing drinks for 14 h prior to the study. Thus, they could eat the latest at either 7 p.m. or 8.30 p.m. Sixty-five participants were assigned to the satiated group and were instructed to have breakfast before coming to the lab. Both groups were instructed not to drink alcohol 14 h prior to the lab session. Lab sessions were the same for both groups; participants first answered the EDE-Q, the POMS, and the Hunger Scale, and then performed an Attentional Response to Distal vs. Proximal Emotional Information (ARDPEI) task and an Approach-Avoidance Task (AAT), which are not of interest for this study (findings of the ARDPEI have been reported in [Jonker et al., 2020](#)). At the end of the study, they were asked whether they complied with the instructions of the study, and their height and weight were measured. Participants received course credits ( $n = 14$ ), or financial compensation (12 euros) for their participation ( $n = 115$ ).

### 3.2. Analysis plan

Compliance was examined by checking the answer to the open question on compliance, and the number of hours that had passed since the participant had eaten. Individuals who did not comply with the instructions were excluded from the analyses. A manipulation check was performed by examining group differences on time since last eaten.

To examine whether hunger resulted in an increase in the experience of negative emotions, a multivariate analysis of variance (MANOVA) was performed with group (fasting vs. satiated) as the independent variable and the five negative emotion subscales of the POMS (Tension, Anger, Fatigue, Depression, and Confusion) as dependent variables. Significant results were followed up with one-way ANOVAs.

To examine whether hunger also resulted in a decrease in the experience of positive emotions, a MANOVA was performed with group (fasting vs. satiated) as the independent variable and the two positive emotion subscales of the POMS (Esteem-Related Affect and Vigour) as dependent variables. Significant results were followed up with one-way ANOVAs. All MANOVA assumptions were checked and reported if they were *not met*.

To assess whether the effect of hunger on negative emotions depended on eating disorder symptoms, a centered EDE-Q score was added as a continuous predictor variable to the aforementioned analyses. Significant results of univariate analyses were followed up with a simple linear regression analysis for each Fasting Group with EDE-Q as predictor variable and the specific emotion as dependent variable.

## 4. Results

### 4.1. Compliance and manipulation check

Seven participants in the fasting condition reported having eaten shortly before their appointment in the lab (0.25–1.5 h before), and were therefore excluded from the analyses. Additionally, one participant in the satiated condition reported not having eaten before the experiment in the morning (12.25 h since eaten), and was therefore also excluded from the analyses. Moreover, for 13 participants who had a healthy self-reported BMI (18.5–25), lab measurements showed their

BMI was outside the healthy range, so they were also excluded. Excluding these participants left 53 participants in the fasting condition and 55 participants in the satiated condition. With 108 participants, we could reliably detect an effect size of > 0.13 for negative emotions and > 0.09 for positive emotions. The two groups showed a large difference in the time that they had last eaten,  $t(106) = -46.00, p < .001, 95\% \text{ CI} [-13.75; 12.61]$ , and their reported hunger,  $t(106) = -11.19, p < .001, 95\% \text{ CI} [-3.27; 2.28]$ .

4.1.1. Assumptions

For the MANOVA on negative emotions the assumption of equal covariance matrices was violated,  $\text{Box's } M = 39.82, p < .001$ . Pillai's trace was therefore used, as it is most robust against this violation (Kaymaz et al., 2019).

Descriptive statistics

Descriptive statistics for each group are shown in Table 1. EDE-Q scores are slightly higher than in women from the general population, for whom the mean score is 0.93 ( $SD = 0.86$ ; Aardoom et al., 2012).

Do fasting women report more negative emotions?

The fasting group scored higher on negative emotions in general than the satiated group and this effect was large (Pillai's Trace = .153,  $F(5,102) = 3.68, p = .004, \eta_p^2 = 0.153$ ). Specifically, the fasting group scored higher than the satiated group on Tension,  $F(1,106) = 6.46, p = .012, \eta_p^2 = 0.057$ , Anger,  $F(1,106) = 11.17, p = .001, \eta_p^2 = 0.095$ , Fatigue,  $F(1,106) = 6.03, p = .016, \eta_p^2 = 0.054$  and Confusion,  $F(1,106) = 6.92, p = .010, \eta_p^2 = 0.061$ , but not on Depression,  $F(1,106) = 1.63, p = .205, \eta_p^2 = 0.015$ . POMS scores for negative emotions per group are depicted in Fig. 1 and raw scores are shown in the Appendix.

Do fasting women report less positive emotions?

The fasting group scored lower on positive emotions in general than the satiated group and this effect was large (Pillai's Trace = .133,  $F(2,105) = 8.04, p = .001, \eta_p^2 = 0.133$ ). Specifically, the fasting group scored lower than the satiated group on Vigour,  $F(1,106) = 16.22, p < .001, \eta_p^2 = 0.133$  and marginally on Esteem-Related Affect,  $F(1,106) = 3.95, p = .050, \eta_p^2 = 0.036$ . POMS scores for positive emotions per group are depicted in Fig. 2.

Is there an interaction with eating disorder symptoms?

Higher EDE-Q scores were associated with higher scores on negative emotions in general, Pillai's Trace = 0.116,  $F(5,100) = 2.64, p = .028, \eta_p^2 = 0.116$ . This difference was independent of fasting state as evidenced by the absence of a significant interaction of Fasting Group \* EDE-Q, Pillai's Trace = 0.092,  $F(5,100) = 2.02, p = .082, \eta_p^2 = 0.092$ . Regardless of group, higher EDE-Q scores were associated with higher scores on Tension,  $F(1,104) = 6.59, p = .012, \eta_p^2 = 0.060$ , Anger,  $F(1,104) = 6.41, p = .013, \eta_p^2 = 0.058$ , and Depression,  $F(1,104) = 10.41, p = .002, \eta_p^2 = 0.091$ , but not Fatigue,  $F(1,104) = 1.40, p = .239, \eta_p^2 = 0.013$ , or Confusion,  $F(1,104) = 3.39, p = .068, \eta_p^2 = 0.032$ .

Table 1  
Descriptive statistics per group.

	Fasting (n = 53)			Satiated (n = 55)		
	Mean	SD	Range	Mean	SD	Range
Age	23.0	3.4	18.0–35.0	21.6	2.3	18.0–30.0
BMI	21.4	1.5	18.6–24.8	21.7	1.7	18.7–24.9
EDE-Q	1.6	1.0	0.3–3.9	1.7	1.1	0.23–5.1
Hunger	4.8	1.4	2.0–7.0	2.0	1.2	1.0–6.0
Time since eaten	14.1	2.0	8.3–18.3	0.9	0.6	0.3–2.8

Note. Post-hoc t-tests indicated that mean age ( $t = 2.51, p = .01$ ) differed between the two conditions (medium effect, Cohen's  $d = 0.48$ ), whereas BMI ( $t = 1.03, p = .30$ ) and EDE-Q ( $t = 0.32, p = .75$ ) did not.

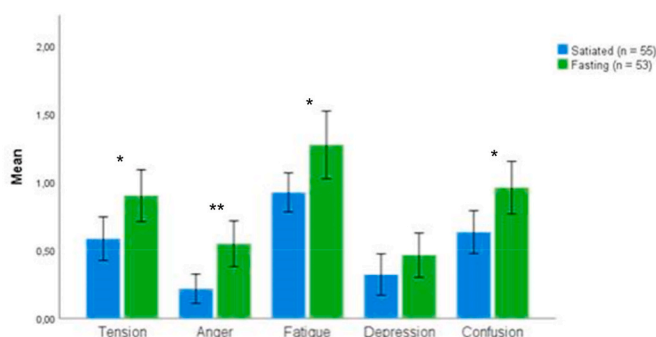


Fig. 1. Average scores on POMS negative emotions per group. Note. \* $p < .05$ , \*\* $p < .01$ . Error bars represent standard error.

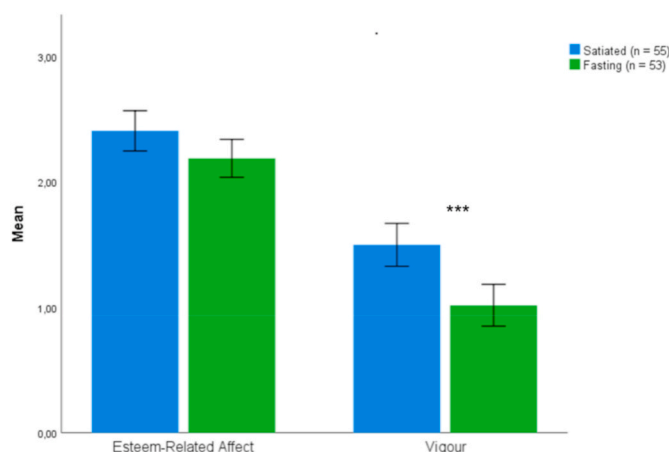


Fig. 2. Average scores on POMS positive emotions per group. Note. \*\*\* $p < .001$ . Error bars represent standard error.

The main effect of EDE-Q on overall positive emotions was not significant,  $F(2,103) = 0.662, p = .518$ , Pillai's Trace = 0.013,  $\eta_p^2 = 0.013$ . However, the interaction of Fasting Group \* EDE-Q did reach significance,  $F(2,103) = 3.62, p = .030$ , Pillai's Trace = 0.066,  $\eta_p^2 = 0.066$ . The interaction effect was significant for Esteem-Related Affect,  $F(1,104) = 7.29, p = .008, \eta_p^2 = 0.065$ , but not for Vigour,  $F(1,104) = 2.22, p = .139, \eta_p^2 = 0.021$ . In the satiated group, EDE-Q was negatively related to Esteem-Related Affect,  $\beta = -.98, F(1,53) = 4.79, p = .033$ . In the fasting group, EDE-Q showed a non-significant positive relationship with Esteem-Related Affect,  $\beta = .70, F(1,51) = 2.64, p = .11$ . The interaction effect is shown in Fig. 3.

5. Discussion

This study investigated the effect of hunger induced by a 14-h fasting period on positive and negative emotions in women with a healthy weight. Moreover, we examined whether this effect depended on the level of eating disorder symptoms. As expected, hungry women reported overall higher negative emotions (higher tension, anger, fatigue, and confusion) and lower positive emotions (lower vigour and and marginally lower esteem-related affect) than satiated women. Moreover, eating pathology was related to the effect of hunger on positive emotions such that for satiated women, more eating disorder symptoms were associated with lower esteem-related affect. For hungry women, however, eating disorder symptoms were not significantly associated with higher esteem-related affect.

The finding that hunger has a negative effect on emotions is in line with previous research (MacCormack & Lindquist, 2018;

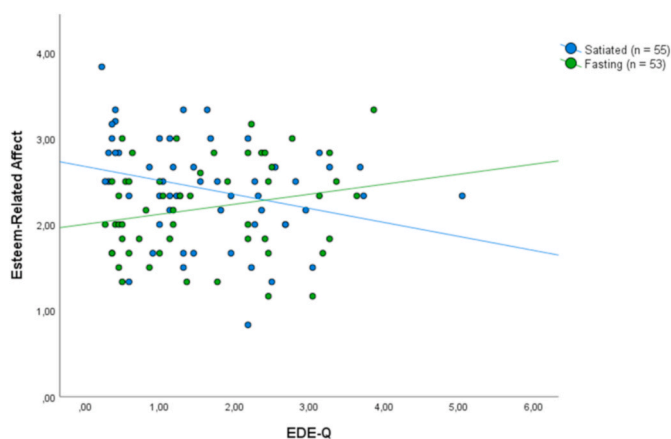


Fig. 3. Relationship between EDE-Q score and esteem-related affect per group. Note. Fasting group  $R^2 = 0.05$ . Satiated group  $R^2 = 0.08$ .

Moreno-Dominguez et al., 2012). Some previous studies had found an effect of hunger on either positive or negative emotions, possibly because they did not have sufficient power to detect small or even medium sized effects. Our study, on the other hand, found an effect on both positive and negative emotions. The only subscale on which hunger had no effect was depression, possibly because the POMS questions related to depression contained more intense, long-term emotions such as worthlessness, sadness, unhappiness, hopelessness, and helplessness, as opposed to other subscales which contained more momentary emotions such as annoyance, nervousness, bitterness, or uncertainty. It is possible that a longer fasting period would be necessary to elicit such intense emotions, as seen in a previous study in which women who fasted for two days every eight days for 48 days showed significantly higher scores on the Beck Depression Inventory after the study compared to before the study, whereas women fasting for one day every eight days showed no difference (Wojciak, 2014).

The effect of hunger on high-arousal negative emotions (i.e. anger and tension), and the absence of an effect on the low-arousal emotion depression in our study are in line with the regulatory depletion hypothesis, which posits that (only) high-arousal emotions are difficult to regulate in a hungry state (MacCormack & Lindquist, 2018). This hypothesis does not explain the effect on fatigue and confusion in our study, which may be better explained by the psychological constructionist theory. The psychological constructionist theory requires the presence of a negative context for hunger to be interpreted as a negative emotion, i.e. the effect of hunger would only be present if the participants experienced the lab setting as a negative context (MacCormack & Lindquist, 2016). It remains unclear whether this was indeed the case because the subjective experience of the lab setting was not assessed in our study. Future research could include a question on personal experience of the experiment to assess the role of the context on hunger-induced emotions. Finally, our findings partially support the theory of the abstinence of an incentive stimulus (i.e. food) resulting in negative emotions (Mauler et al., 2006), as this theory explains the presence of both high- and low-arousal emotions in response to hunger. The support is only partial because with regards to low-arousal emotions, hunger did have an effect on fatigue, but not on depression. Regarding the effect of hunger on positive emotions, we are not aware of any theories on this relationship. Overall, our findings are in line with existing theories on the effect of hunger on negative emotions.

With regards to eating disorder symptoms, we found that higher eating pathology was associated with greater tension, anger, and depression regardless of hunger, which is in line with the literature indicating that eating disorders are associated with elevated negative mood and with mood disorders (DeSocio, 2019; Lavender et al., 2015). Although we expected the effect of hunger on negative emotion to

depend on the level of eating disorder symptoms such that those with greater eating pathology would show less negative emotion when hungry, we did not find this effect. However, higher levels of eating disorder symptoms were related to lower esteem-related affect for the satiated women. This subscale included emotions such as pride, confidence, competence, and embarrassment (reverse scored). This is an important finding, particularly in light of previous research indicating low self-esteem as a risk factor for disturbed eating and eating disorders (Ghaderi, 2001). If satiation leads to a decrease in self-esteem in women with eating disorder symptoms, we may expect restriction to increase self-esteem in these women. However, despite previous research showing that women in the early stages of anorexia nervosa (i.e. upholding some restrictive eating habits) feel pride when they successfully restrict (Faija et al., 2017), our results did not indicate that individuals with high eating disorder symptoms have relatively high esteem-related affect when restricting food.

Strengths of this study include the experimental manipulation of hunger, the relatively large sample size compared to previous studies, the inclusion of a measure on positive emotions in addition to negative emotions, the reporting of *specific* emotions, and the inclusion of a measure of eating disorder symptoms. This study also had several limitations. First, we relied on self-report to ascertain whether individuals in the fasting group had indeed fasted, and it is possible not all participants answered this question truthfully. Second, the experiment was conducted in the morning, and although the fasting group had not eaten after 7 p.m. or 8.30 p.m. the evening before, some individuals are naturally less hungry in the morning. Indeed, hunger follows a circadian rhythm, with a circadian hunger trough around 8 a.m. and only a slight increase by 9 a.m.–10 a.m. (Scheer et al., 2013). However, the fact that we screened participants for ‘usually eating breakfast’ (indicating they are at least somewhat hungry in the morning) and the significant difference in subjective hunger between the groups largely mitigates this limitation. Future research could still consider asking participants to fast during the day and carry out the experiment in the afternoon/evening to increase hunger in all fasting participants and thereby increase power. However, our study still found medium to large effects (except one: the effect of group on esteem-related affect), which would likely be even larger with increased hunger. A third limitation of this study is the relatively higher rate of non-compliance of the fasting group than the satiated group (seven and one, respectively). It is possible that those in the fasting group did not comply (i.e. ate before the study) precisely because they experienced negative emotions because they were hungry and these individuals would have been particularly interesting to include. Furthermore, our study did not specifically recruit women with an eating disorder diagnosis, thus it remains to be examined whether the findings related to eating disorder symptoms also generalize to women with clinical eating disorder diagnoses. Finally, our study was restricted to a homogenous group of female participants; it thus remains to be seen if the current findings also apply to men.

Findings from this study have practical relevance in two ways. First, they show that food restriction leads to negative emotions, which is not desirable in and of itself. What is more, these findings, in combination with findings of negative emotions leading to overeating, show that food restriction is not recommendable for weight loss or management. Practitioners and individuals should be aware of these implications of food restriction on mental and physical health. Second, our study suggests that clinicians and individuals should be wary of relatively low esteem-related affect when satiated in individuals with subclinical eating disorder symptoms, as it could serve as a maintaining factor in eating pathology (e.g. provoking food restriction).

To conclude, this is the first study to investigate the effect of hunger in women on overall positive and negative emotions with a sufficient sample size while also considering eating disorder symptoms. We found that hunger was associated with higher negative emotions and lower positive emotions. We also found that women with relatively high subclinical eating pathology showed lower esteem-related affect when

satiated. These findings add to the literature on emotions and hunger and can help inform treatments for weight loss and disordered eating.

### Ethical statement

The study protocol was approved by the ethical committee of the psychology department of the University of Groningen (17374).

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.appet.2021.105746>.

### Appendix

Average scores on the POMS subscales per group				
	Fasting (n = 53)		Satiated (n = 55)	
	Mean	SD	Mean	SD
Tension	0.90	0.69	0.58	0.59
Anger	0.55	0.61	0.22	0.40
Fatigue	1.27	0.90	0.92	0.53
Depression	0.46	0.59	0.32	0.56
Confusion	0.96	0.70	0.63	0.58
Esteem-Related Affect	2.19	0.55	2.41	0.60
Vigour	1.02	0.61	1.50	0.63

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