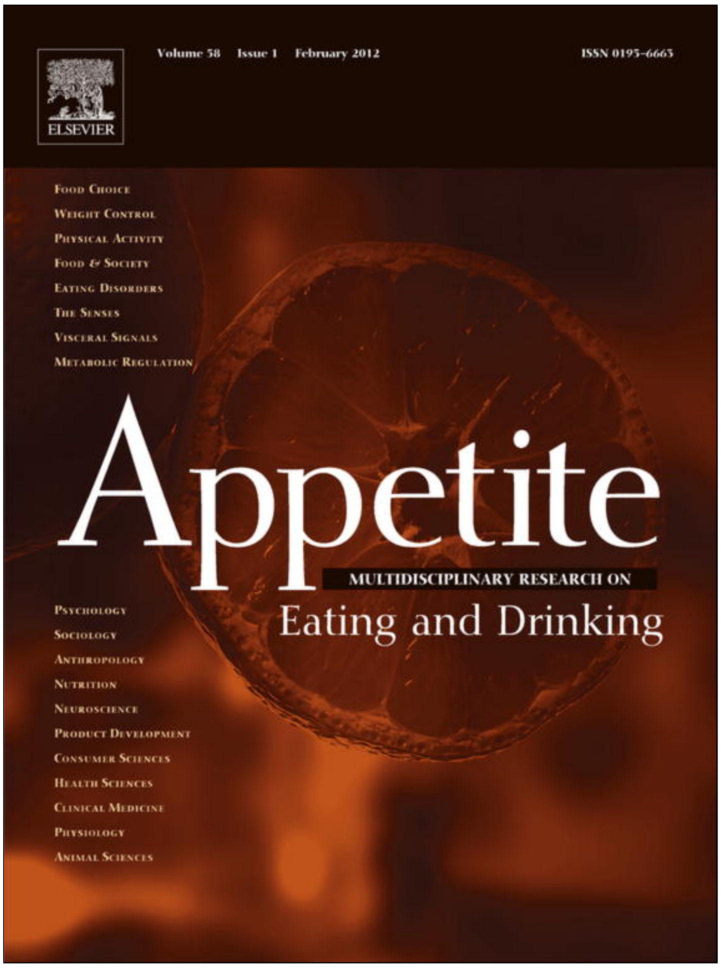
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Research report

Intuitive eating is associated with interoceptive sensitivity. Effects on body mass index ☆

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ABSTRACT

Intuitive eating is relevant for adaptive eating, body weight and well-being and impairments are associated with dieting and eating disorders. It is assumed to depend on the ability to recognize one's signs of hunger and fullness and to eat accordingly. This suggests a link to the individual ability to perceive and processes bodily signals (interoceptive sensitivity, IS) which has been shown to be associated with emotion processing and behavior regulation. This study was designed to clarify the relationships between IS as measured by a heartbeat perception task, intuitive eating and body mass index (BMI) in $N = 111$ healthy young women. Intuitive eating was assessed by the Intuitive Eating Scale (IES) with three facets, reliance on internal hunger and satiety cues (RIH), eating for physical rather than emotional reasons (EPR), and unconditional permission to eat when hungry (UPE). IS was not only positively related to total IES score and RIH and EPR, and negatively predicted BMI, but also proved to fully mediate the negative relationship between RIH, as well as EPR and BMI. Additionally, the subjective appraisal of one's interoceptive signals independently predicted EPR and BMI. IS represents a promising mechanism in research on eating behavior and body weight.

Introduction

Adaptive behaviors play an important role in maintaining overall psychological health (e.g., Seligman & Csikszentmihalyi, 2000). Up to now, research on adaptive eating behaviors is sparse and much remains unknown about positive eating behaviors. Research has predominantly focussed on correlates and predictors of disordered rather than adaptive eating and has been mostly a pathology-focused endeavor (cf., Tylka, 2006). In most studies investigating adaptive eating behaviors both in unrestrained eating (e.g., Kahan, Polivy, & Herman, 2003; Polivy & Herman, 1999) and in eating disorders (e.g., Mintz & Betz, 1998; Tylka & Subich, 2004), adaptive eating has been primarily defined as the absence of eating disorder symptoms (cf., Garner, 2004; Mintz, O'Halloran, Mulholland, & Schneider, 1997). However, adaptive eating represents more than just the absence of symptoms of clinical eating disorders (e.g., Gast & Hawks, 2000; Hawks, Merril, Gast, & Hawks, 2004; Tribole & Resch, 1996; Tylka, 2006; Tylka & Wilcox, 2006).

One adaptive form of eating that has recently gained recognition is "intuitive eating", defined as a strong connection with, and eating in response to, internal physiological hunger and satiety cues (e.g., Gast & Hawks, 2000; Tribole & Resch, 1996; Tylka, 2006; Tylka & Wilcox, 2006).

The concept of intuitive eating developed during the 1980s with the evolving antidieting movement that was based on the assertion that restrained dieting is not sustainable and may contribute to such negative outcomes as weight cycling, dysfunctional relationships with food, and increased risk of eating disorders (e.g., Gast & Hawks, 1998; Hawks & Gast, 2000). Since then, intuitive eating has continued to grow in popularity as an alternative to dieting (Gast & Hawks, 2000; Tribole & Resch, 1996; Tylka, 2006). It has been argued that all individuals have within themselves a natural mechanism that if allowed to function will ensure good nutrition at a healthy weight (e.g., Hawks, Madanat, Hawks, & Harris, 2005). It has been suggested that as individuals get in touch with this "inner guide" they are more in tune with their body's physical needs and eat in a way that supports health, adequate body weight, and nutrition, while at the same time avoiding overeating, obsessive food consumption and harmful dieting (e.g., Schwartz, 1996; Tribole & Resch, 1996). This style of eating is supposed to represent adaptive behavior because it represents trust in and a strong connection

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with and response to internal physiological needs pertaining to hunger and satiety cues, and eating in response to these cues, rather than relying on diet plans, environmental cues and emotional states (Carper, Fisher, & Birch, 2000; Fedoroff, Polivy, & Herman, 1997; Polivy & Herman, 1999; Tribole & Resch, 1996; Tylka, 2006).

Intuitive eating has been measured by using self-report questionnaires that have been developed to assess adaptive eating behavior as an alternative to the typical focus on disordered eating, such as the "Intuitive Eating Scale" (IES; Tylka, 2006). The IES comprises the three central components or facets of intuitive eating: (1) unconditional permission to eat when hungry and what food is desired, (2) eating for physical rather than emotional reasons, and (3) reliance on internal hunger and satiety cues to determine when and how much to eat (cf. Tylka, 2006). Studies using self-report measures of intuitive eating up to now have supported intuitive eating's adaptive properties by demonstrating that intuitive eating scores are positively related to self-reports of increased physical and reduced emotional eating, improved emotional well-being, and less preoccupation with food choice (Cole & Horacek, 2010; Faith, Scanlon, Birch, Francis, & Sherry, 2004). Those who report to eat intuitively have been described to be less likely to overindulge in food in the absence of hunger (Birch, Fisher, & Davison, 2003) and to allow emotional (e.g. stress) or situational (e.g. mere presence of food) cues guide their food intake (Woody, Costanzo, Leifer, & Conger, 1981). Consequently, intuitive eating scores have also been demonstrated to be associated with lower BMI, especially in female college students (Gast, Madanat, & Nielson, 2012; Hawks et al., 2005; Smith & Hawks, 2006) and in early and mid-age women (Augustus-Horvath & Tylka, 2011; Madden, Leong, Gray, & Horwath, 2012; Tylka, 2006) in cross-sectional surveys.

In summary, a crucial key feature of intuitive eating assumes that it is primarily based on one's physiological hunger and satiety signals rather than external and emotional cues as well on the ability to clearly recognize the physical signs of hunger and fullness. This links the concept of intuitive eating with the concept of "interoception" representing the perception and processing of bodily signals on the basis of the afferent feedback of bodily information in the brain (e.g., Cameron, 2002; Craig, 2002; Craig, 2004; Craig, 2008; Critchley, Wiens, Rothstein, Öhlman, & Dolan, 2004).

The conceptualization of interoception comprises sensing the physiological condition of the body as well as the representation of the internal state within the context of ongoing activities (Craig, 2008; Craig, 2009). Anatomical studies demonstrated a class of afferent fibers that monitor the physiological state of all internal organs of the body which converge to "interoceptive centers" in the insular cortex (Craig, 2002; Craig, 2008; Craig, 2009) and give rise to conscious visceral perception, i.e. interoception. Bodily visceral states are mapped in distinct brain areas which are linked within an interoceptive central network that is involved in the representation and re-representation as well as integration of interoceptive bodily signals with higher order cognitive and emotional processes (Craig, 2004; Craig, 2009; Damasio, 1999; Herbert & Pollatos, 2012). Additionally, research on interoception of the cardiovascular (e.g. Critchley et al., 2004; Herbert, Pollatos, & Schandry, 2007; Herbert, Ulbrich, & Schandry, 2007; Herbert et al., 2012; Pollatos et al., 2008; Pollatos, Schandry, Auer, & Kaufmann, 2007) and the gastrointestinal system (Herbert, Muth, Pollatos, & Herbert, 2012; Herbert & Pollatos, 2012; Stephan et al., 2003) has demonstrated that there are substantial and quite stable, trait-like individual differences in the ability to process and perceive one's bodily signals ("interoceptive sensitivity") that have been shown to be reflected in differences in the activity within the central interoceptive network (Critchley et al., 2004; Moisset et al., 2010; Pollatos, Schandry, et al., 2007; Yuan, Tao, Xu, Sun, & Xu, 2003). There is ample evidence showing the relevance of interoceptive sensitivity for feelings (e.g., Barrett, Quigley, Bliss-Moreau, & Aronson, 2004; Herbert, Pollatos, et al., 2007; Herbert, Herbert, et al., 2012; Wiens, 2005), the emotional awareness of one's feelings (Herbert, Herbert, & Pollatos, 2011), emotion processing (Herbert, Pollatos, et al., 2007), and the more finely tuned self-regulation of behavior (Herbert, Ulbrich, 2007) as well as for benefits in decision making (Dunn et al., 2010; Werner, Jung, Duschek, & Schandry, 2009).

Although there is empirical evidence highlighting the relevance of intuitive eating for eating disorder symptomatology, self-rated adaptive eating behaviors, well-being, and body weight, these data are based solely on self report indices of intuitive eating which require subjective ratings on one's eating behavior. Up to now, it has not been investigated whether the subjectively rated degree of intuitive eating – obviously comprising relevant interoceptive abilities that are suggested to determine when and how much to eat, and to accurately perceive and respect one's hunger and satiety cues – is indeed related to individual differences in interoceptive sensitivity.

Particularly well established measures of interoceptive sensitivity are heartbeat perception tasks assessing the ability to accurately perceive one's heartbeats (e.g., Critchley et al., 2004; Dunn et al., 2010; Herbert, Pollatos, et al., 2007; Herbert, Ulbrich, et al., 2007; Wiens, 2005). Experimental data demonstrate that heartbeat perception correlates with the ability to detect changes in other autonomically innervated organs such as the activity and signals of the stomach (Herbert, Muth, et al., 2012; Whitehead & Drescher, 1981). This highlights that this indicator is regarded to reflect a generalized sensitivity for visceral processes in situations evoking interoceptive signals (Herbert & Pollatos, 2012), that has also been shown during food deprivation and feeling hungry (Herbert, Herbert, et al., 2012).

According to these findings we hypothesize a positive relationship between interoceptive sensitivity and especially those facets (=subscales) of intuitive eating based on interoceptive abilities such as eating for physical reasons and the reliance on internal hunger and satiety cues to determine when and how much to eat (cf. Tylka, 2006). Our hypothesis is also underscored by study results showing that intuitive eating (Hawks et al., 2004; Tylka, 2006; Tylka & Wilcox, 2006) as well as subjectively rated interoception related to hunger (Garner, Olmstead, & Polivy, 1983) and interoceptive sensitivity as measured by a heartbeat perception task (Pollatos et al., 2008) are impaired in eating disorders. Thus, the main objective of the present study was to investigate for the first time whether intuitive eating behavior as measured by self-report is indeed associated with a more precise perception accuracy of bodily visceral signals.

Furthermore, intuitive eating has also been demonstrated to be a distinct construct only from low levels of eating disorder symptomatology (Tylka & Wilcox, 2006). Hence, we investigated the relationship between individual interoceptive sensitivity as assessed by a standard heartbeat perception task and the facets of intuitive eating by using the intuitive eating scale (IES; Tylka, 2006) in a large, healthy sample of young women with BMI in the normal range. A second relevant focus of this study centers on the reported association between intuitive eating and BMI: Intuitive eating has been demonstrated to be negatively associated with BMI especially in young women (Augustus-Horvath & Tylka, 2011; Gast et al., 2012; Hawks et al., 2005; Smith & Hawks, 2006; Tylka, 2006). On the basis of these study results we also examined the relationship between interoceptive sensitivity and BMI. Additionally, we investigated the relevance of individual interoceptive sensitivity as a possible mediator of the – in former studies reported – relationship between facets of intuitive eating and BMI.

Finally, recent data (Garfinkel & Critchley, 2013; Herbert, Herbert et al., 2012) strongly suggest that the accuracy of perceiving ones bodily signals and the subjective appraisal of this more or less accurately perceived body information are different components of interoception. Especially, recent studies reported that the appreciation of and trust in one's body's signals is positively associated with intuitive eating and decreased non-adaptive eating behavior such as dieting (Augustus-Horvath & Tylka, 2011; Bacon, Stern, Can Loan, & Keim, 2005; Cole & Horacek, 2010; Gast et al., 2012; Iannantono & Tylka, 2012; Smith & Hawks, 2006), and further is of relevance for the success of intuitive eating programs (Augustus-Horvath & Tylka, 2011; Bacon et al., 2005; Cole & Horacek, 2010; Iannantono & Tylka, 2012). On the contrary, the non-acceptance or aversive experience of affective and bodily signals has been suggested to contribute to symptoms of disordered eating and dietary restraint (e.g., Merwin, Zucker, Lacy, & Camden, 2010; Schmidt & Treasure, 2006). Based on these insights, we were also interested in shedding light on possible associations between the subjective appraisal of interoceptive bodily signals and intuitive eating as well as BMI. Thus, we also examined the association between the individual appraisal of ones heartbeat signals and the different facets of intuitive eating as well as BMI exploratorily,

Summary of the hypotheses:

(1) Interoceptive sensitivity as measured by a standard heartbeat perception task is positively associated with relevant facets of intuitive eating.
(2) Intuitive eating is negatively associated with BMI as has been reported by recent studies AND: Interoceptive sensitivity is negatively associated with BMI.
(3) Interoceptive sensitivity is hypothesized to mediate the relationship between intuitive eating and BMI.
(4) Exploratory examination of the associations between the subjective appraisal of interoceptive heartbeat signals and both facets if intuitive eating, and BMI.

Methods

Participants

A total of 120 female students from the University of Tübingen participated in the study.

After participants arrived at the laboratory, body height and body weight were measured and body mass index (BMI, kg/m^2) was calculated. Then, they completed a screening questionnaire regarding sociodemographic and health information. Items of the screening questionnaire included age, educational status, current and former illnesses (e.g., eating disorders and/or disordered eating behavior, psychiatric diseases, cardiac and cardiovascular disease, diseases of the respiratory system, diabetes, and further internal and metabolic diseases, infections, craniocerebral injuries, accidents, etc.), medication use, and sporting activities. Only healthy female participants without any relevant diseases, without use of medication, without substance abuse and with a normal BMI between 20 and 25 were selected for inclusion in the study reducing the final sample to 111 participants (see Table 1). All participants gave written informed consent and all measurements were conducted in accordance with the Declaration of Helsinki.

Procedure

The study is a cross-sectional descriptive study in which participants were asked to complete the Intuitive Eating Scale (IES; Tylka, 2006), the heartbeat perception test (Schandry, 1981) and fill in ratings of their subjective appraisal of interoceptive signals during the heartbeat perception procedure, the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and had their BMI measured. Each of the methods will be further described below.

Interoceptive sensitivity: the heartbeat perception task

Participants were seated in a comfortable chair in a sound-attenuated chamber connected to the adjacent equipment room by intercom and ECG electrodes were attached for recording of the electrocardiogram. For the heartbeat perception task, ECG measurements were taken using nonpolarizable Ag–AgCl electrodes attached to the right mid-clavicle and lower left rib cage. Signals were recorded at 500 Hz using Biopac amplifyers (MP150, version 2.7.2.) and analyzed with AcqKnowledge (BIOPAC Systems Inc., Santa Barbara, CA). Mean heart rate was recorded for 5 min baseline in each participant, in order to control for potential differences in mean heart rate potentially affecting heartbeat perception accuracy (e.g. Herbert, Pollatos, Flor, Enck, & Schandry, 2010).

Then, the heartbeat perception task was performed according to the Mental Tracking Method by Schandry (1981) using four intervals of 25, 35, 45, and 55 s that were separated by standard resting periods (30 s). During all trials, ECG was recorded and participants were asked to concentrate on their heart activity and silently count their own heartbeats. The beginning and the end of the counting phases were signaled by a soft start and stop tone. During heartbeat counting, participants were not permitted to take their pulse or to attempt any other physical manipulations that could facilitate the detection of heartbeats. Following the stop signal, participants were asked to verbally report the number of counted heartbeats. The participants were not informed about the length of the counting phases nor about the quality of their performance.

Interoceptive sensitivity was measured using a heartbeat perception score, calculated as the mean score across four heartbeat perception intervals according to the following transformation: $\frac{1}{4}\Sigma(1 - (|\text{recorded heartbeats} - \text{counted heartbeats}|)/\text{recorded heartbeats})$. The heartbeat perception score varies between 0 and 1. The maximum score of 1 indicates absolute accuracy of heartbeat perception. This heartbeat detection task is widely used to assess interoceptive sensitivity (Dunn, Dalgleish, Ogilvie, & Lawrence, 2007; Herbert, Pollatos, et al., 2007; Herbert, Herbert et al., 2012; Pollatos et al., 2008), has good test–retest reliability (up to .81) and correlates highly with other heartbeat detection tasks (cf., Knoll & Hodapp, 1992). Heartbeat perception tasks have been shown to be well validated and reliable (Cronbach's α .69–.90) (Dunn et al., 2007; Jones, 1994; Wildmann & Jones, 1982).

After completion of the heartbeat perception task appraisal ratings of interoceptive signals were assessed. Ratings of the subjective appraisal of interoceptive signals during the interoception procedure were assessed by using a Likert-like rating scale ranging from 1 (not aversive/unpleasant at all) to 6 (extremely aversive/unpleasant). The participants were asked to rate how aversive/unpleasant or not aversive/not unpleasant they felt while feeling their cardiac signals.

Intuitive Eating Scale (IES)

Intuitive eating was measured by using the 21-item Intuitive Eating Scale (IES; Tylka, 2006). The IES assesses the three components of intuitive eating which are represented in three subscales: "unconditional permission to eat when hungry and what food is desired" (UPE; e.g., "If I am craving a certain food, I allow myself to have it"; nine items), "eating for physical rather than emotional reasons" (EPR; e.g., "I stop eating when I feel full"; six items), and "reliance on internal hunger and satiety cues to determine when and how much to eat" (RIH; e.g., "I trust my body to tell me when to eat"; six items). The nine-item "UPE" subscale measures the

Table 1
Mean scores for age, BMI, interoceptive sensitivity (heartbeat perception score), appraisal of interoceptive signals, state and trait anxiety (STAI-S, STAI-T), and Intuitive Eating Scores (IES).

	Mean (SD)		Mean (SD)
Age	25.4 (4.8)	IES-total	3.59 (0.53)
BMI (kg/m^2)	22.21 (2.77)	IES-unconditional permission to eat (UPE)	3.42 (0.67)
Interoceptive sensitivity	.65 (0.19)	IES-eating for physical rather than emotional reasons (EPR)	3.56 (0.86)
Appraisal of interoceptive signals	2.85 (1.58)	IES-reliance on internal hunger/satiety cues (RIH)	3.79 (0.56)
STAI-T	38.05 (9.11)	STAI-S	37.24 (7.86)

N = 111; SD in parentheses.

readiness to eat in response to internal physiological hunger signals and what food is desired at the moment. The "RIH" subscale indicates awareness and use of internal hunger cues to guide one's eating behavior, i.e. to determine when and how much to eat. The "EPR" subscale assesses a willingness to eat to satisfy hunger rather than to eat for emotional reasons or distress. The difference between these two subscales is that one focuses on the awareness of hunger, whereas the other focuses on the willingness to eat. Item responses are rated on a scale that ranges from 1 (strongly disagree) to 5 (strongly agree). After appropriate items are reverse-scored, item responses are averaged to arrive at a total score. The IES also allows creating a total intuitive eating score.

Higher total scores correspond with higher levels of intuitive eating and indicate more positive eating habits. Tylka (2006) upheld the factor structure of the IES subscales and the total score. They confirmed its internal consistency reliability (coefficient αs = .85–.89) and 3-week test–retest reliability (r = .90), as well as its convergent validity via its negative relationship to eating disorders symptomatology, and its discriminant validity.

State- and Trait-Anxiety (STAI)

The State–Trait-Anxiety Inventory (STAI) (Spielberger et al., 1983) is a 40 item scale, which assesses both state and trait anxiety. The STAI scales are well-validated and represent a reliable (Cronbach's α = .73–.86) self-report measure of dispositional and state anxiety. State and trait anxiety were measured, as some findings have suggested a positive relationship between interoceptive sensitivity as measured by heartbeat perception sensitivity and state and/or trait anxiety (e.g., Ehlers & Breuer, 1996; Willem Van der Doers, Antony, Ehlers, & Barsky, 2000), though there are also contradictory findings (Herbert et al., 2010; Wells & Papageorgiou, 2001). Anxiety was primarily assessed in order to be able to possibly control for anxiety as a potential confounding variable in this design if there were any relevant associations between the measures of interest.

Data analysis

Bivariate Pearson correlations were computed to explore the relationship between interoceptive sensitivity, the subjective appraisal of interoceptive signals, intuitive eating, and BMI. In order to control for potential associations between mean heart rate and heartbeat perception sensitivity as well as the rest of the relevant variables, correlations were also calculated for mean heart rate.

Multiple linear regression analyses were used to determine whether interoceptive sensitivity and the subjective appraisal of interoceptive signals independently predicted intuitive eating (IES total and IES subscales).

A series of regression analyses were performed, in accordance with the model for mediation delineated by Baron and Kenny (1986) in order to establish whether intuitive eating and IES subscales represent relevant predictors for BMI, and to test if this association is mediated by (a) interoceptive sensitivity and (b) the appraisal of interoceptive signals. A significant mediation effect is present if (1) the predictor variable (IES scores) is significantly associated with or predicts the outcome variable (BMI); (2) the predictor variable is significantly associated with the mediator: (a) interoceptive sensitivity, (b) appraisal of interoceptive signals; (3) the mediator is significantly associated with or predicts the outcome variable (BMI); and (4) the previously significant predictor variable no longer predicts the dependent variable when the mediator is added as a covariate (full mediation), or the association between the independent variable and the dependent variable is significantly attenuated when the mediator is covaried (partial mediation). Possible partial mediation effects were explored with Sobel tests (Sobel, 1982): With Sobel tests regression coefficients of the pathway between the independent variables and the mediating variables are determined, as well as regression coefficients of the pathways between the mediating variables and the dependent variables and tested for differences. The Statistical Package for the Social Sciences (SPSS for Windows, Version 14.0) was used for the statistical analyses.

Results

Sample description

The mean scores of relevant variables describing the whole sample are depicted in Table 1.

Correlation analyses

Results of the bivariate Pearson's correlations between interoceptive sensitivity, subjective appraisal of interoceptive signals, intuitive eating, BMI and state and trait anxiety are shown in Table 2. The results demonstrate significant positive correlations between interoceptive sensitivity and total IES score, the IES subscales "EPR" and "RIH" as well as a significant negative correlation between interoceptive sensitivity and BMI. Interoceptive sensitivity was not significantly associated with the IES subscale "UPE", or with the subjective appraisal of interoceptive signals, or with state and trait anxiety.

In addition, the subjective aversive appraisal of interoceptive signals was negatively correlated with IES total score and IES subscale "EPR", and was positively correlated with BMI. The total IES score and the IES subscales "EPR" and "RIH" were negatively correlated with BMI. The subscale "UPE" failed to reach a significant correlation with BMI (p = .19).

Neither state nor trait anxiety of the STAI was significantly associated with any of the assessed variables or with interoceptive sensitivity (cf., Herbert et al., 2010; Wells & Papageorgiou, 2001). Mean heart rate was neither significantly correlated with interoceptive sensitivity (r = 0.08, p = .22) nor with IES scores (IES total: r = 0.03, p = .36; UPE: r = 0.01, p = .43; EPR: r = .02, r = .40; RIH: r = 0.02; p = .41) or BMI (r = .09, p = .21)

Table 2
Pearson's bivariate correlations (*r*) between interoceptive sensitivity (heartbeat perception score), appraisal of interoceptive feelings, state and trait anxiety (STAI-S, STAI-T), intuitive eating scores and BMI.

	Interoceptive sensitivity	Negative appraisal of interoceptive signals	BMI (kg/m^2)	STAI-S	STAI-T
Negative appraisal of interoceptive signals	−.01	–	.22*	.19	.20
IES-total	.49**	−.32**	−.29**	−.02	−.05
IES-unconditional permission to eat (UPE)	.17	−.09	−.19	−.16	−.18
IES-eating for physical rather than emotional reasons (EPR)	.45**	−.43**	−.30**	.11	.10
IES-reliance on internal hunger/satiety cues (RIH)	.53**	−.15	−.31**	.05	.01
BMI (kg/m^2)	−.60**	–	–	.12	.11
STAI-S	.10	–	–	–	.83**
STAI-T	.12	–	–	–	–

N = 111.
* $p < 0.05$.
** $p < 0.01$.

Regression analyses

When entering subjective appraisal of interoceptive signals in addition to interoceptive sensitivity as predictors of intuitive eating into the simultaneous linear multiple regression equations the results of the full regression analyses showed that for IES subscales "EPR", "RIH" and the IES total score all predictors accounted for a significant portion of the variance: IES total score: $F(2,108) = 29.03$, $p = .001$, $R^2 = .25$, IES–EPR: $F(2,108) = 32.88$, $p = .001$, $R^2 = .38$, IES–RIH: $F(2,108) = 22.99$, $p = .001$, $R^2 = .29$. There was no significant effect for IES scale "UPE": $F(2,108) = 2.09$, $p = .13$, $R^2 = .04$. The results demonstrated that interoceptive sensitivity remained an independent and significant predictor for IES subscales "EPR" and "RIH" and the IES total score (see also Table 3) with subjective interoceptive sensitivity taken into account. The subjective appraisal of interoceptive signals remained a relevant predictor for IES total score and IES subscale "EPR". Significant effects, unstandardized (*B*) and standardized (β) regression coefficients together with R^2 changes in the linear regression analyses for the IES scores are depicted in Table 3.

Correlation analyses demonstrated no relevant associations between interoceptive sensitivity and the subjective appraisal of interoceptive signals. Hence, separate mediation analyses were run for IES totals score and IES subscales as predictors for BMI with (a) interoceptive sensitivity as mediator and (b) the subjective appraisal of interoceptive signals as mediator.

For testing the association of IES scores and BMI and (a) the mediation effect of interoceptive sensitivity, in a first step of separate mediational analyses, BMI was regressed on IES total score and IES subscales. Total IES score and the IES subscales "EPR" as well as "RIH" significantly predicted BMI scores (total IES: $\beta = -.29$, $t = -3.17$, $R^2 = .08$, $p = .02$; UPE: $\beta = -.20$, $t = -3.28$, $R^2 = .04$, $p = .21$; EPR: $\beta = -.30$, $t = -3.28$, $R^2 = .09$, $p = .001$; RIH: $\beta = -.31$, $t = -3.41$, $R^2 = .09$, $p = .001$). Next, interoceptive sensitivity was regressed onto IES scores. IES total score and scores of IES subscales "EPR" and "RIH" were significantly correlated with interoceptive sensitivity (total IES: $\beta = .49$, $t = 6.00$, $R^2 = 25$, $p = .001$; EPR: $\beta = .45$, $t = 5.21$, $R^2 = 20$, $p = .001$; RIH: $\beta = .53$, $t = 6.48$, $R^2 = .28$, $p = .001$; UPE: $\beta = .17$, $t = 1.79$, $R^2 = .03$, $p = .10$). Then BMI was regressed onto interoceptive sensitivity, showing that interoceptive sensitivity significantly predicted BMI ($\beta = -.60$, $t = -7.89$, $R^2 = .36$, $p = .001$).

For the final step of mediational testing, both the source variables (IES scores) and the mediating variable (interoceptive sensitivity) were added to the separate equations, and were regressed simultaneously on BMI. After completing this step, the source variables no longer significantly predicted BMI (IES total score: $\beta = .06$, $t = .15$, $R^2 = .01$, $p = .87$; EPR: $\beta = -.05$, $t = -.44$, $R^2 = .003$, $p = .65$; RIH: $\beta = .02$, $t = .11$, $R^2 = .004$, $p = .91$; UPE: $\beta = .05$, $t = .75$, $R^2 = .03$, $p = .45$), while interoceptive sensitivity continued to significantly predict BMI (IES total score: $\beta = -.60$, $t = -6.88$, $R^2 = .36$, $p = .001$).

In order to test the predictor effects of IES scores on BMI and (b) the mediation effect of the aversive appraisal of interoceptive signals, a second set of mediational analyses was performed. After having BMI regressed on IES total score and IES subscales (see Section 'Results' above), the appraisal of interoceptive signals was regressed onto IES scores. IES total score and scores of the IES subscale "EPR" were significantly associated with the appraisal of interoceptive signals (total IES: $\beta = -.32$, $t = -3.56$, $R^2 = .11$, $p = .001$; EPR: $\beta = -.43$, $t = -4.93$, $R^2 = .18$, $p = .001$; RIH: $\beta = -.15$, $t = -1.56$, $R^2 = .02$, $p = .12$; UPE: $\beta = -.09$, $t = -.99$, $R^2 = .01$, $p = .32$). Then, BMI was regressed onto the appraisal of interoceptive signals. Results demonstrated that the appraisal of interoceptive signals significantly predicted BMI ($\beta = .22$, $t = 2.37$, $R^2 = .05$, $p = .02$).

Finally, both the predicting variables (IES scores) and the mediating variable (appraisal of interoceptive signals) were added to the separate equations, and were regressed simultaneously onto BMI. It was shown that the source variables IES total score ($\beta = -.24$, $t = -2.53$, $R^2 = .10$, $p = .01$) and EPR ($\beta = -.25$, $t = -2.48$, $R^2 = .10$, $p = .02$) continued to significantly predict BMI, however there were smaller associations (β-coefficients). Nevertheless, Sobel tests provided evidence that the association between IES total score and BMI as well as between IES–EPR scale and BMI were

Table 3
Linear multiple regression analyses with intuitive eating scores as criteria (outcome variables) and interoceptive sensitivity and appraisal of interoceptive signals as predictors.

Outcome variables	Predictors							
	Interoceptive sensitivity				Appraisal of interoceptive signals			
	B	SE *B*	β	R^2	*B*	SE *B*	β	R^2
IES-total	1.34	.21	.49**	.25**	−.12	.03	−.32**	.11**
IES-unconditional permission to eat (UPE)	0.58	.32	.17	.03	−.04	.04	−.09	.01
IES-eating for physical rather than emotional reasons (EPR)	1.96	.37	.45**	.20**	−.25	.05	−.43*	.18**
IES-reliance on internal hunger/satiety cues (RIH)	1.50	.23	.53**	.28**	−.06	.03	−.15	.02

R^2 represents R^2 changes (*N* = 111).
* $p < 0.05$.
** $p < 0.01$.

not relevantly diminished and mediated by the negative appraisal of interoception signals (IES total score: $z = -.49$, $p = .61$; EPR: $z = -1.31$, $p = .19$). The negative appraisal of interoceptive signals continued to be a relevant and independent predictor for BMI ($\beta = .22$, $t = 2.33$, $R^2 = .05$, $p = .02$).

Discussion

The present study investigated the association between interoceptive sensitivity as measured by a standardized and well-validated heartbeat perception task assessing the individual sensitivity towards one's cardiac signals, and three facets defining intuitive eating as measured by a reliable and valid self-report questionnaire, the intuitive eating scale (IES) (Tylka, 2006), in a large sample of healthy young women. Furthermore, the relationship between interoceptive sensitivity and BMI, and the mediating contribution of interoceptive sensitivity for the association between intuitive eating and BMI, as well as the meaning of the subjective appraisal of interoceptive signals for intuitive eating and its relatedness to BMI were investigated.

As to the first aim of the study, our results showed that the individual degree of accurately perceiving one's interoceptive signals (interoceptive sensitivity) represents a significant predictor of the total IES score and especially of those facets of adaptive eating that have been suggested to be associated with the awareness of hunger and satiety cues (RIH) and the willingness to eat to satisfy hunger rather than to eat for external and emotional reasons (EPR). In addition, the appraisal of interoceptive signals, i.e. the subjective experience of one's interoceptive signals as aversive or pleasant, proved independent from interoceptive sensitivity and did not influence the association between interoceptive sensitivity and the EPR and RIH subscales or the total IES score. However, the aversive appraisal of interoceptive cues was demonstrated to negatively predict the intuitive eating facet ''EPR'' as well as total IES score. Both, interoceptive sensitivity and the appraisal of interoceptive signals independently predicted the total IES score and ''EPR''. These results underscore that individual interoception accuracy and the evaluation of the more or less accurately registered bodily cues are independent processes, however, both significantly predicting eating according to one's hunger signals and not because of being distracted by the presence of external cues and one's emotional states (EPR).

Interestingly, interoceptive sensitivity as measured by heartbeat perception (Pollatos et al., 2008), perception of interoceptive signals related to hunger and satiety (e.g., Garner et al., 1983), intuitive eating (Hawks et al., 2004; Tylka, 2006; Tylka & Wilcox, 2006), and the appraisal of bodily signals (Kaye, Fudge, & Paulus, 2009; Mauler, Hamm, Weike, & Tuschen-Caffier, 2006) have been reported to be impaired when disordered eating behaviors and eating disorders were identified. Our findings are also in line with suggestions of eating disorders and disordered eating to represent disturbances of embodiment with relevant impairments in interoception (e.g., Herbert & Pollatos, 2012), and with the characterization of eating disorders to constitute a main disturbance of embodiment related to the body image or body awareness (Fuchs & Schlimme, 2009). Recent study results (Tsakiris, Tajadura-Jiménez, & Costantini, 2011) showing that interoceptive sensitivity as assessed by heartbeat perception affects exteroceptive body awareness and modulates the online integration of multi-sensory body percepts and exteroceptive body-awareness, underscore these views.

The relevance of interoceptive sensitivity for the intuitive eating facet ''EPR'' that reflects being less likely to allow emotional (e.g. stress) or situational (e.g. mere presence of food) cues guide one's food intake but rather eating for physical reasons is in accordance with study results demonstrating that interoceptive sensitivity is fundamentally associated with the subjective experience and processing of emotional stimuli (e.g., Herbert, Pollatos, et al., 2007; Wiens, 2005), the awareness of emotional states (Herbert et al., 2011), and that it facilitates the effects of emotion regulation strategies comprising the downregulation of affect and the more pronounced modulation of underlying neural activity (Füstös, Gramann, Herbert, & Pollatos, 2012). Hence, greater interoceptive sensitivity should be associated with a more adequate awareness of one's feelings allowing for more efficient emotion regulation, also affecting eating behavior, such as eating according to physical needs and not in answer to affective stress or external cues. Moreover, there is evidence that interoceptive sensitivity is of importance for decision-making (Werner et al., 2009), and is associated with a more finely tuned self-regulation of behavior according to one's bodily and physical needs (Herbert, Ulbrich, et al., 2007). These associations also support the relevance of interoceptive sensitivity for the regulation of eating behavior according to one's bodily cues, as has been found in this study.

Our data show that the individual appraisal of interoceptive signals is of additional importance for the intuitive eating facet ''EPR''. This could be seen in the light of evidence suggesting the prominence of both, a disturbed perception of interoceptive signals (Kaye et al., 2009; Lilenfeld, Wonderlich, Riso, Crosby, & Mitchell, 2006; Pollatos et al., 2008), and an aversive experience of visceral sensations during exposure to food- or food-related stimuli (Kaye et al., 2009) and own or other's bodily cues (Vocks et al., 2010) in samples with disordered eating behavior. The non-acceptance or aversive experience of affective and bodily signals has also been suggested to contribute to symptoms of disordered eating via individuals failing to engage in healthy behaviors associated with bodily signals because of the discomfort associated with them (e.g., Merwin et al., 2010). For instance, binge eating has been proposed to function as an escape from aversive self-awareness or feelings of dysphoria (Heatherton & Baumeister, 1991) and dietary restraint has been suggested as a way to avoid internal sensations of fullness and/or feelings of guilt and shame (Schmidt & Treasure, 2006). Relief from negative affective states or bodily discomfort by the use of avoidance strategies or manipulations influencing these negative bodily sensations might be highly reinforcing for individuals with eating disorders, thus perpetuating eating disorder symptoms (Kaye et al., 2009; Merwin et al., 2010). Together with recent findings highlighting that the appreciation of one's body is positively associated with intuitive eating and less non-adaptive eating behavior such as dieting (Augustus-Horvath & Tylka, 2011; Bacon et al., 2005; Cole & Horacek, 2010; Gast et al., 2012; Iannantono & Tylka, 2012; Smith & Hawks, 2006), our results demonstrate the relevance of the subjective appraisal of interoceptive signals for intuitive eating according to ones physical cues and the described connections to dieting behavior and disordered eating.

The results of this study demonstrate a relevant contribution of interoceptive sensitivity to the ''RIH'' and ''EPR'' facets, but not to the ''UPE'' aspect of intuitive eating, and just as interoceptive sensitivity, the appraisal of interoceptive signals was also not significantly related to ''UPE'' scores. The ''RIH'' scale assesses the awareness of internal hunger and satiety signals to determine when and how much to eat and the inclination to trust these signals to guide eating behavior, and the ''EPR'' scale reflects using food/eating to satisfy a physical hunger drive and not to cope with emotional fluctuations and/or distress (cf. Tylka, 2006). In contrast, the ''UPE'' scale of the IES primarily focuses on the unconditional permission to eat that reflects a readiness to eat both in response to hunger signals and what food is desired at the moment (cf. Tylka, 2006). Individuals who engage in this eating strategy do not place any restricting conditions on their eating behavior and on their physiological hunger signals and do not try to ignore their hunger signals, nor do they classify food into acceptable and non-acceptable categories and attempt to avoid food in the latter category (Faith et al., 2004; Tribole & Resch, 1996; Tylka, 2006). That this facet of intuitive eating is neither significantly related to the individual extent of interoceptive sensitivity nor to the appraisal of interoceptive cues, suggests that some further factors beyond interoception-related processes should be of relevance in order to predict the individual permission to eat without restrictions according to bodily cues. Relevant factors could comprise external and internal processes that are well known to influence eating behavior and behavior regulation, such as environmental pressure to be thin, others acceptance of body shape, emphasis on body appearance, self-acceptance (e.g. Augustus-Horvath & Tylka, 2011; Galloway, Farrow, & Martz, 2010; Ghaderi, 2001) and especially aspects comprising cognitive control or top down regulation of behavior (e.g., Hollmann et al., 2011; Kaye, 2008; Kaye et al., 2009). Though, a more adequate interoceptive perception of bodily signals might represent a prerequisite of eating intuitively, however, in order to unconditionally permit oneself to eat without restrictions seems to involve further relevant aspects that have not been assessed in this study.

With regard to the mentioned associations between interoception, body appreciation, intuitive eating and disorders of eating behavior, it is finally also consistent that both factors, interoceptive sensitivity and the appraisal of interoceptive signals, were shown to significantly predict BMI that is very much dependent on eating behavior. A very important finding of this study is that interoceptive sensitivity explained 36% of variance of BMI scores while the aversive appraisal of interoceptive signals still accounted for 5% of the variance of normal range BMI in young and healthy women. Furthermore, as expected and largely in support of earlier findings (e.g., Augustus-Horvath & Tylka, 2011; Gast et al., 2012; Hawks et al., 2005; Madden et al., 2012; Smith & Hawks, 2006; Tylka, 2006), IES scores were associated with lower BMI. IES total score and "EPR" and "RIH" scores were significantly and negatively associated with BMI while the association between UPE and BMI failed to reach statistical significance ($p = .19$). These findings are in accordance with the suggestion that listening to body signals in determining when and how much to eat is associated with lower body mass (e.g., Tylka, 2006).

Most interestingly, statistical mediation analyses provided evidence for interoceptive sensitivity mediating the found relationship between intuitive eating and BMI. This suggests that interoceptive sensitivity as measured by heartbeat perception, is fundamentally responsible for intuitive eating, especially the IES facets "RIH" and "EPR" predicting BMI. This is in accordance with our hypotheses that the individual ability of accurately perceiving one's own bodily signals should be especially important for those intuitive eating facets primarily reflecting the adequate perception of and reactivity toward interoceptive feelings (RIH and EPR). This should be related to BMI as eating behavior is of relevance for weight regulation (cf. Tylka, 2006). Accordingly, our results suggest that intuitive eating and its connection to body mass is importantly associated with and to a great extent explained by an inter-individually varying sensitivity for accurately perceiving one's own bodily signals.

This interpretation of your findings is supported by recent findings (Herbert, Muth, et al., 2012; Herbert, Herbert, et al., 2012) demonstrating that there is a significant overlap between the individual sensitivity of recognizing one's own heartbeat and the sensitivity for feeling signs of hunger and satiety in healthy subjects.

Moreover, the analyses showed that the aversive appraisal of one's interoceptive signals that was demonstrated to be positively related to both BMI and the total IES score and "EPR" did not significantly mediate the association between intuitive eating and BMI. These findings highlight that, in contrast to interoceptive sensitivity, and despite its relevant relation to BMI, the appraisal of one's bodily cues is not of significance for the relevant association between intuitive eating and BMI, but independently predicts BMI, with more aversive appraisal of one's interoceptive signals involving higher BMI. The latter is in accord with findings mentioned before, underscoring the positive associations between appreciation of one's body, intuitive eating and less dieting (e.g., Augustus-Horvath & Tylka, 2011; Bacon et al., 2005; Cole & Horacek, 2010; Faith et al., 2004; Gast et al., 2012; Iannantono & Tylka, 2012; Smith & Hawks, 2006).

Intuitive eating is thought to represent an inborn characteristic or inert mechanism that can be disrupted or disturbed by early restrictive and monitoring feeding practices, external eating rules or dietary restraint, pressures that induce a disconnection from internal experience and food intake regulation (e.g., Birch & Fisher, 2000; Birch et al., 2003; Cole & Horacek, 2010; Galloway et al., 2010; Tylka, 2006). The latter again has been shown to be related with the emergence of dieting behavior, weight gain, and eating in the absence of hunger and in response to emotional and situational factors (Birch & Fisher, 2000; Birch et al., 2003). Interoceptive sensitivity as assessed by heartbeat perception has been conceptualized (e.g. Craig, 2002) and demonstrated to be indicative for interoceptive sensitivity for different bodily signals, such as the perception of hunger and gastric activity (Herbert, Muth, et al., 2012; Herbert, Herbert, et al., 2012) and exteroceptive body-awareness (Tsakiris et al., 2011). It represents an inter-individually varying, stable and trait-like ability (e.g., Dunn et al., 2007; Herbert & Pollatos, 2012; Jones, 1994), that is grounded on differences in the activity within the central interoceptive network in the brain (Critchley et al., 2004; Pollatos, Schandry, et al., 2007) and which constitutes a representation of the "material me" or the "physiological condition of the body" (Craig, 2002, 2008, 2009). Our data suggest that individually varying interoceptive sensitivity describing these trait-like differences in the perception of body cues could play a decisive role in the individual vulnerability of intuitive eating behavior being disrupted by external factors with relevant consequences for body weight (BMI). Thus, interoceptive sensitivity could represent an important mechanism explaining how intuitive eating translates into body mass.

Training programs of intuive eating skills in healthy persons and in clinical samples, comprising aspects such as rejecting the diet mentality, honoring one's hunger and feeling one's fullness, respecting one's body, exercising and feeling the difference and several more factor (e.g., Cole & Horacek, 2010), could profit by this evidence that there are fundamental trait-like differences in interoceptive sensitivity potentially affecting the success of these programs. To know which participant needs more training in perceiving his bodily signals should be helpful for treating or changing non-adaptive eating behavior in order to improve the ability to listen to physical hunger/fullness signals and decreasing caloric consumption for physical but not emotional reasons. For the latter, our data indicate that also the appraisal of one's interoceptive signals is of importance. This could be seen in association with found links between body appreciation, intuitive eating and less dieting behavior (e.g., Augustus-Horvath & Tylka, 2011). In addition, there are also findings showing that the perception of interoceptive signals such as heartbeat perception can be trained (Schandry & Weitkunat, 1990) and is potentially modifiable (Herbert, Herbert, et al., 2012). As interoceptive sensitivity has been demonstrated to be strongly associated with the self-regulation of behavior (Herbert, Ulbrich, et al., 2007), these findings may lend support to the consideration that training the self-perception of bodily signals could prove to be an effective method for increasing sensitization and detection of bodily symptoms and behavior regulation, including adaptive eating, in everyday life and ultimately body mass.

Finally, especially the "interoception-related" components "EPR" and "RIH" of intuitive eating have been shown to represent unique predictors of well-being. Well-being has been emphasized to comprise the affirmative presence of strength rather than the mere absence of symptoms or pathology (e.g., Fredrickson & Losada, 2005; Seligman & Csikszentmihalyi, 2000). It is also closely related to adaptive behavior and adaptive personality characteristics (e.g., Lopez et al., 2006) going beyond eating behavior and eating disorder symptomatology (Tylka & Wilcox, 2006). There is evidence for these intuitive eating facets to be associated with general health indicators such as lower triglyceride level, higher levels of high density proteins, improved cardiovascular risk (Hawks et al., 2005) and decreased adiposity (Weigenberg, Shoar, Lane, & Spruijt-Metz, 2009) and to make unique contributions to well-being measures such as positive affect, self-esteem, proactive coping, optimism and social problem solving (Tylka & Wilcox, 2006).

Thus, the results of this study underscoring the relevance of interoceptive sensitivity for intuitive eating and body mass in healthy young women also lend support to the importance of interoceptive sensitivity for related general health factors and might initiate future studies investigating the association between interoceptive sensitivity and intuitive eating and its significance for further health associated behaviors and general indicators of well-being.

The strength of this study is that it demonstrates for the first time the relevant role of interoceptive sensitivity and the appraisal of interoceptive bodily signals for adaptive eating behavior and body weight regulation (BMI) in a large sample of healthy young women with normal BMI. Our findings are of importance for individually adapting programmes on the regulation of body weight and eating behavior by highlighting the importance of the individually varying accuracy of perceiving one's interoceptive signals. However, up to now, no conclusions can be drawn regarding these associations in a comparable sample of healthy young men. Additionally, although our findings lend support to relevant associations for disordered eating behaviors and eating disorders that have been discussed here, no final conclusions can be drawn regarding clinical samples as well as overweight or obese persons. Our data build the starting point for future studies going into this direction.

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