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# INTEROCEPTIVE PROCESSING ACROSS MODALITIES IN DISORDERED EATING BEHAVIOR

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"The game of science is, in principle, without end. He who decides one day that scientific statements do not call for any further test, and that they can be regarded as finally verified, retires from the game."

Karl R. Popper, *The Logic of Scientific Discovery*, p. 32

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## Abstract

Disordered eating behaviors are prevalent in both clinical and non-clinical populations. Early intervention is crucial to prevent their progression into more severe conditions, such as eating disorders (EDs). Altered interoceptive processes, especially the awareness of emotional states and the perception of hunger and satiety, represent a key transdiagnostic feature of EDs and constitute important targets for intervention. This thesis investigated interoceptive processes as underlying mechanisms of disordered eating and EDs using psychophysiological, behavioral, and self-report measures. The main objectives were to (1) develop and validate a self-report measure to assess ED-specific interoceptive perception (EDIP) and (2) provide a comprehensive assessment of interoceptive processes in two organ systems relevant to eating behavior, i.e. the cardiovascular and gastrointestinal systems.

**Studies 1-3** focused on the development and validation of the EDIP Questionnaire (EDIP-Q), a 25-item questionnaire comprising four subscales (i.e., Emotions, Hunger, Satiety, and Discrimination) to assess the ability to perceive and differentiate between emotions, hunger, and satiety. The EDIP-Q, available in German, English, and French, demonstrated sound psychometric properties across all language versions. Using the EDIP-Q, descriptive profiles of EDIP were established for anorexia nervosa (AN), bulimia nervosa (BN), and binge-eating disorder (BED). While individuals with self-reported EDs reported similar difficulties in perceiving emotions, those with AN reported lower sensibility to hunger, higher sensibility to satiety, and fewer difficulties in discriminating between emotional states and hunger compared to individuals with BN and BED. In contrast, the profiles of BN and BED were opposite to that of AN.

**Studies 4 and 5** examined interoceptive processes in individuals with recurrent binge eating episodes (BEEs) across the cardiovascular system (Study 4) and the gastrointestinal system

(Study 5). The findings revealed profiles of interoceptive alterations in individuals with recurrent BEEs. These alterations were, however, not consistent across modalities.

In conclusion, the evidence highlights the differential contribution of interoceptive processes to ED symptoms. Future research is encouraged to assess interoceptive processes across multiple levels and organ systems, investigate how these alterations contribute to the etiology and maintenance of disordered eating behaviors, and develop targeted interventions aimed at improving treatment outcomes.

## Abbreviations

| | |
|---|---|
| µV | Microvolt |
| AN | Anorexia Nervosa |
| ANOVA | Analysis of Variance |
| BCQ | Body Consciousness Questionnaire |
| BE | Binge Eating |
| BED | Binge-Eating Disorder |
| BEE(s) | Binge Eating Episode(s) |
| BMI | Body Mass Index |
| BN | Bulimia Nervosa |
| CBT | Cognitive Behavioral Therapy |
| CFA | Cardiac Field Artifact |
| CFA | Confirmatory Factor Analayis |
| CFI | Comparative Fit Index |
| CNS | Central Nervous System |
| DEBQ | Dutch Eating Behavior Questionnaire |
| DERS | Difficulties in Emotion Regulation Scale |
| DSM-5 | Diagnostic and Statistical Manual of Mental Disorders, fifth edition |
| ECG | Electrocardiogram |
| ED(s) | Eating Disorder(s) |
| EDE | Eating Disorder Examination |
| EDI | Eating Disorder Inventory |
| EDIP | Eating Disorder-specific Interoceptive Perception |
| EDIP-Q | Eating Disorder-specific Interoceptive Perception Questionnaire |
| EDNOS | Eating Disorder Not Otherwise Specified |
| EEG | Electroencephalogram |
| EFA | Exploratory Factor Analysis |
| EGG | Electrogastrogram |
| FFT | Fast Fourier Transformation |
| fMRI | functional Magnetic Resonance Imaging |
| GAD | Generalized Anxiety Disorder |
| HC(s) | Healthy Control(s) |
| HCT | Heartbeat Counting Task |
| HEP | Heartbeat-Evoked Potential |
| HF n.u. | High Frequency Normalized Units |
| HR | Heart Rate |
| HRV | Heart Rate Variability |
| IAcc | Interoceptive Accuracy |
| IAw | Interoceptive Awareness |
| ICA | Independent Component Analysis |
| IES | Intuitive Eating Scale |
| IIn | Interoceptive Insight |
| IRI | Interpersonal Reactivity Index |
| ISCED | International Standard Classification of Education |
| ISe | Interoceptive Sensibility |

| | |
|---|---|
| MAIA | Multidimensional Assessment of Interoceptive Awareness |
| MANOVA | Multivariate Analysis of Variance |
| MB-BEAT | Mindfulness-Based Eating Awareness Training |
| MEG | Magnetoencephalogram |
| MGCFA | Multi group Confirmatory Factor Analysis |
| MIIC | Mean Interitem Correlation |
| MRI | Magnetic Resonance Imaging |
| NA | Negative Affect |
| OSFED | Other Specified Feeding or Eating Disorder |
| PA | Positive Affect |
| PAC | Phase-amplitude coupling |
| PANAS | Positive and Negative Affect Schedule |
| PHQ | Patient Health Questionnaire |
| SRMR | Standardized Root Mean Square Residual |
| SWLS | Satisfaction With Life Scale |
| TLI | Tucker-Lewis Index |
| VNS | Vagus Nerve Stimulation |
| WLT | Water Load Test |

# Table of Contents

# 1. General Introduction

Eating disorders (EDs) constitute a global mental health concern (Silén & Keski-Rahkonen, 2022). Individuals with EDs experience severe disturbances in eating and eating-related behaviors and maintain an unhealthy relationship with food, which affect their physical health, psychosocial functioning, and overall quality of life (American Psychiatric Association [APA], 2013). Most individuals who seek treatment for EDs suffer from their disordered eating behavior but do not meet the criteria for full syndrome diagnoses (Fisher et al., 2001). Disordered eating is a strong predictor of continued problematic eating patterns, which are linked to substantial health risks, including weight gain, obesity, and the development of EDs later in life (Herle et al., 2020; Neumark-Sztainer et al., 2006, 2011; Romano et al., 2020; Tanofsky-Kraff et al., 2011). Thus, early intervention and prevention of disordered eating behaviors are crucial to prevent their progression into more severe conditions. Given the prevalence of disordered eating behaviors in both clinical and non-clinical populations (Ortega-Luyando et al., 2015), as well as the high relapse and mortality rates among patients (Fichter et al., 2008; Fichter et al., 2017; Fichter & Quadflieg, 2016; Quadflieg & Fichter, 2019), it is essential to deepen our understanding of the underlying mechanisms of disordered eating to improve current treatment approaches.

A promising avenue for more targeted interventions involves addressing interoceptive deficits, which pertain to the impaired perception, interpretation, and integration of information about the internal state of the body (Khalsa et al., 2018). Deficits in the processing of emotions and perceiving hunger and satiety have been described in particular in patients with eating and weight disorders (Bruch, 1962, 1964). Alterations in interoceptive processes have, however, not been consistently observed in different organ systems (Martin et al., 2019). These inconsistencies may arise from methodological limitations. For instance, most studies focus on diagnostic categories rather than transdiagnostic characteristics, assess interoceptive processes in isolation, or use self-report measures that either conflate interoceptive sensations or lack specificity to EDs. Addressing these methodological issues is essential for advancing our understanding of the role interoceptive processes play in the development and maintenance of disordered eating and EDs.

The present research project has two main objectives: First, to develop and validate a new self-report measure for assessing ED-specific interoceptive perception (EDIP) in terms of the ability to perceive and discriminate between emotions, hunger, and satiety **(Studies 1-3)**. Second, to provide a more comprehensive assessment of interoceptive processes in two organ systems of relevance for eating behavior, i.e. the cardiovascular **(Study 4)** and gastrointestinal systems **(Study 5)**. **Studies 1-3** will follow a categorical approach to examine differences in EDIP across ED types (e.g., anorexia nervosa, bulimia nervosa, binge-eating disorder), while **Studies 4 and 5** will adopt a multidimensional approach to assess interoceptive processing related to binge eating as a proxy for disordered eating behavior.

## 1.1. Spectrum of Eating Behaviors

Eating behaviors span a broad spectrum, ranging from what is considered 'normal' or 'healthy' to the more extreme forms of 'eating disorders'. In between the two ends of the spectrum are individuals whose eating habits, while not meeting the criteria for a full syndrome eating disorder, still reflect disordered patterns that can cause significant psychological distress. This chapter explores this spectrum and emphasizes the importance of examining individuals who fall between these two extremes. This is illustrated by the example of binge eating, which, while a core symptom of EDs, is also prevalent in the general population.

### 1.1.1. Disordered Eating Behavior

Disordered eating behaviors encompass a range of practices related to abnormal eating and weight control, such as binge eating, fasting, skipping meals, self-induced vomiting, and misuse of medications to control body shape and weight. A systematic review by Ortega-Luyando et al. (2015) highlights the alarming prevalence and significant variability of these behaviors: dieting (0.6-51.7%), fasting (2.1-18.5%), binge eating (1.2-17.3%), and purging behaviors (0-11%). These behaviors are widespread, affecting people of all genders, ethnicities, and ages (Neumark-Sztainer et al., 2011; Parker & Harriger, 2020; Reba-Harrelson et al., 2009), even if those individuals do not meet the full diagnostic criteria for a specific eating disorder.

Disordered eating often develops in childhood and adolescence, influenced by developmental, psychological, and social factors typical of these stages (Fisher et al., 1995, 2001; Rohde et al., 2016). However, these behaviors can persist into adulthood. Longitudinal studies show that the prevalence of dieting and disordered eating behaviors remains high and may either persist or increase from early life through adolescence (Herle et al., 2020) into adulthood (Neumark-Sztainer et al., 2011). This persistence highlights the ongoing nature of these behaviors and their long-term impact. Disordered eating is a strong predictor of continued problematic eating patterns, which are associated with significant health risks, including weight gain, obesity, and the development of EDs later in life (Herle et al., 2020; Neumark-Sztainer et al., 2006, 2011; Romano et al., 2020; Tanofsky-Kraff et al., 2011). Additionally, disordered eating behaviors and EDs are associated with mental health issues such as anxiety, depression, and poor quality of life (e.g., Hambleton et al., 2022; Keski-Rahkonen & Mustelin, 2016; Wade et al., 2012).

Early intervention and prevention of disordered eating behavior are crucial to prevent their progression into more severe conditions, such as EDs, along with their associated health risks and mental comorbidities.

### 1.1.2. Eating Disorders

EDs are complex mental disorders and characterized by severe disturbances in eating and eating-related behaviors, as well as an unhealthy relationship with food. These disturbances result in impaired physical health, psychosocial functioning, and overall quality of life (APA, 2013). Although prevalence rates vary among different population groups, epidemiological findings consistently highlight that EDs constitute a global mental health concern (Silén & Keski-Rahkonen, 2022). The following provides an overview of the most common types of EDs and their core symptoms, as described in the latest edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR; APA, 2022). Information on lifetime prevalence rates derives from the work of Silén & Keski-Rahkonen (2022).

*Anorexia nervosa (AN):* Affecting 0.8–6.3% of women and 0.1–0.3% of men, AN is marked by severe restriction of food intake to prevent weight gain or promote weight loss, an intense fear of gaining weight, and a distorted perception of body weight and shape. There are two subtypes: the restricting type (AN-R), involving extreme underweight maintained through dieting, fasting, or excessive exercise, and the binge-eating/purging type (AN-BP), involving intermittent binge eating and/or purging behaviors.

*Bulimia nervosa (BN):* Affecting 0.8–2.6% of women and 0.1–0.2% of men, BN is characterized by recurrent episodes of binge eating, where individuals consume large amounts of food in a short period, accompanied by a subjective feeling of losing control over eating. These episodes are followed by inappropriate compensatory behaviors aimed at preventing weight gain, such as self-induced vomiting, misuse of laxatives or diuretics, or excessive exercise. Self-evaluation is influenced by body weight and shape.

*Binge-Eating Disorder (BED):* Affecting 0.6–6.1% of women and 0.3–0.7% of men, BED is also characterized by recurrent binge eating episodes, but without compensatory behaviors. BED can occur in individuals of any weight status and is distinct from obesity, as most people with obesity do not experience recurrent binge eating episodes.

*Other Specified Feeding or Eating Disorder (OSFED):* Affecting 0.2–4.7% of women and 0–1.6% of men, OSFED is diagnosed when an individual exhibits symptoms that meet some but not all criteria for a specific feeding or ED. Symptoms cause, however, significant clinical distress and functional impairment. For example, an individual with symptoms of BN but who does not meet the frequency criterion for binge eating episodes (occurring at least once a week) may be diagnosed with OSFED, with the specifier "BN of low frequency."

Research has challenged the validity of categorical diagnoses for several reasons. Significant diagnostic crossover is evident, showing that symptoms and diagnoses can shift over the course of the disorder (Eddy et al., 2008). Additionally, individuals with subthreshold BN or BED experience similar levels of ED psychopathology and impaired mental health as those with full-syndrome BN or BED (Chapa et al., 2018; Johnson et al., 2021; Striegel-Moore et al., 2000). Type of binge eating episodes, which will be discussed in more detail in the next section (see 1.1.3. Binge Eating), are related to both general and ED psychopathology (Mond et al., 2010). Moreover, binge eating behavior is not confined to clinical populations; many individuals from non-clinical populations report recurrent binge eating episodes (e.g., Duarte et al., 2015; Goldschmidt et al., 2015; Sonneville et al., 2013), which are linked to adverse health outcomes, such as obesity, and depressive and anxiety symptoms.

This background highlights the necessity of expanding our understanding of disordered eating beyond traditional diagnostic categories through a transdiagnostic approach. Such an approach will facilitate the identification of new intervention targets and provide support for individuals across the entire spectrum of disordered eating behaviors.

### 1.1.3. Binge Eating

Binge Eating (BE) refers to the consumption of large amounts of food in a discrete period of time, accompanied by the subjective feeling of loss of control over eating. The quantity of food consumed during these episodes significantly exceeds what is typical for most people under similar circumstances (APA, 2022). BE is a transdiagnostic core symptom, occurring across multiple EDs rather than being confined to a single diagnosis.

In clinical practice and research, various psychometrically validated assessments of ED psychopathology are employed, including self-report questionnaires and semi-structured interviews (Schaefer et al., 2021). The Eating Disorder Examination (EDE; Fairburn & Cooper, 1993) is regarded widely as the preferred method for assessing ED psychopathology. It distinguishes between different types of BE episodes (BEEs), which share the common feature of loss of control over eating but differ in the quantity of food consumed. Objective BE (OBE) refers to episodes involving large amounts of food, while subjective BE (SBE) involves normal quantities that are perceived as excessive by the individual. Although SBE is not a formal diagnostic criterion, its assessment is clinically relevant for a comprehensive understanding of the patient's condition. Several lines of research provide evidence that SBE contributes equally to, or even more significantly than, OBE to ED psychopathology, depression, poor quality of life, and psychological distress (Brownstone et al., 2013; Brownstone & Bardone-Cone, 2021; Mond et al., 2010).

Importantly, BE is not limited to individuals with EDs; it also affects the general population, with varying degrees of frequency and severity. For example, a significant number of people from non-clinical populations report experiencing recurrent BEEs (e.g., Duarte et al., 2015; Goldschmidt et al., 2015; Sonneville et al., 2013). This widespread occurrence underscores the relevance of BE beyond clinical settings and highlights its importance as a feature that transcends diagnostic boundaries. Given the prevalence of BE in both clinical and non-clinical populations, as well as the high rates of relapse among those with recurrent BEEs (Fichter et al., 2008; Quadflieg & Fichter, 2019), it is crucial to gain a deeper understanding of the underlying mechanisms of BE to refine current treatment approaches. A further focus of this work will, therefore, be to examine BE behavior as a proxy for disordered eating behavior along a spectrum.

## 1.2. Mechanisms Underlying Eating Behavior

The substantial burden of disordered eating behaviors, both within and beyond EDs, along with the lack of effective treatments, underscores the need for further research. Understanding the mechanisms that contribute to the development of disordered eating, such as BE, could help identify valuable targets for treatment and prevention. Human eating behavior is influenced by genetic, physiological, psychological, social, and cultural factors, which affect meal timing, food intake, and food preferences (Grimm & Steinle, 2011; Higgs et al., 2017; Higgs & Thomas, 2016; Story et al., 2002). From a clinical perspective, patients with eating and weight disorders report difficulties in perceiving emotions, hunger, and satiety (Bruch, 1962, 1964). This chapter will, therefore, focus on these factors as underlying mechanisms of eating behavior.

### 1.2.1. Hunger and Satiety

The regulation of food intake is primarily determined by the perception of physiological hunger and satiety cues and initiates appropriate actions to maintain physical homeostasis, i.e. food seeking, consumption, and meal termination (Maniscalco & Rinaman, 2018; Tack et al., 2021). Disruptions in this delicate balance between hunger and satiety signals can lead to imbalances between energy intake and energy expenditure, potentially resulting in weight loss, weight gain or obesity (Hellström et al., 2004; Tack et al., 2021). Individuals who report difficulty relying on hunger and satiety cues are more likely to engage in disordered eating behaviors (Poovey et al., 2022). Similarly, those diagnosed with an ED have been found to rely less on these cues compared to healthy controls (van Dyck, Herbert, et al., 2016).

Hunger and satiety are distinct constructs and should not be viewed as opposite ends of a single spectrum. Hunger is defined as the conscious sensation of a strong desire to eat, usually accompanied by physical sensations in different body parts, such as the stomach (Blundell et al., 2010). Regarding satiety, a distinction is made between 'intra-meal satiety' and 'inter-meal satiety' (Blundell et al., 2010). Intra-meal satiety, also known as 'satiation', refers to processes that determine meal size and meal termination, which may be accompanied by a sense of satisfaction (Benelam, 2009). Inter-meal satiety, also known as 'satiety', refers to the feeling of fullness that lasts after a meal and may suppress further eating until hunger returns (Benelam, 2009).

The gastrointestinal tract plays a crucial role in the perception of satiety. When food enters the stomach, it causes the stomach to expand, activating gastric stretch receptors and mechanoreceptors. These receptors send signals to the brain via vagal afferents, providing first feedback on the body's state of satiety and fullness (Janssen et al., 2011). Research suggests that gastric distention (i.e., meal volume) modulate food intake (Powley & Phillips, 2004). The notion that gastric distention promotes satiation and signals meal termination has been supported by several experimental studies (e.g., Camps et al., 2018; Geliebter et al., 1988; Geliebter, 1970, 2019).

After food intake, when the stomach gradually empties into the small intestine, the regulation of satiety shifts from gastric distention to the detection of nutrients by enteroendocrine cells in the small intestine (Janssen et al., 2011). These cells release hormones and peptides that signal fullness to the brainstem and hypothalamus, either directly via the vagal nerves or through the bloodstream. The arcuate nucleus in the hypothalamus plays a crucial role in regulating eating behavior, containing two distinct populations of neurons with opposing effects on food intake: one that stimulates appetite and one that inhibits it (Koliaki et al., 2020). Ghrelin, produced in the gastric mucosa and pancreas, is well-known as an appetite-stimulating hormone that promotes meal initiation. When an individual is in a nutrient-depleted state, elevated circulating ghrelin levels stimulate food intake, whereas in a satiated state, circulating ghrelin levels decrease (e.g., Cummings, 2006; Wren et al., 2001). Key intestinal hormones reducing appetite and food intake include peptide tyrosine-tyrosine (PYY), glucagon-like peptide 1 (GLP-1), oxyntomodulin (OXM), pancreatic polypeptide (PP), amylin and cholecystokinin (CCK) (Koliaki et al., 2020). Additionally, insulin (secreted by the pancreas) and leptin (produced by adipose cells and in small amounts by the stomach) contribute to longer-term signals of satiety (Koliaki et al., 2020). For a detailed summary of the roles of each hormone, refer to the review of Koliaki et al. (2020).

As outlined above, eating behavior is regulated by a complex interplay of physiological, neurobiological, and hormonal mechanisms. While disturbances in gastrointestinal hormones in EDs have been confirmed by meta-analytic findings (Prince et al., 2009), the current thesis will focus on the psychophysiological mechanisms underlying hunger and satiety perception (e.g., gastric distention), which determine meal initiation, termination, and the amounts of food consumed.

### 1.2.2. Emotions

Emotions unfold over a brief period, involving a combination of changes in feelings, expressions, and physiology. They are typically distinguished from moods, which are longer lasting and more diffuse affective states (Gross, 1998). Emotions drive human actions (Dolan, 2002) and can, therefore, also affect eating behavior including the quantity and types of food consumed (Gibson, 2006). A recent review by Ha & Lim (2023) highlights that different types and intensities of emotions can affect eating behavior in diverse ways, with marked inter-individual differences. While negative emotions typically reduces food intake in healthy individuals, positive emotions often result in increased consumption, as confirmed by meta-analytic findings (Evers et al., 2018). However, this general pattern may not necessarily apply to everyone, particularly those who engage in disordered eating behaviors.

For restrained eaters – individuals who consciously restrict their food intake to control body shape and weight – negative emotions can disrupt their ability to adhere to these restrictions, leading to (over)eating despite their usual efforts (Evers et al., 2018). Emotional eaters, who consume food in response to emotions rather than hunger, may increase their food intake as a coping mechanism when experiencing negative emotions (Evers et al., 2018). Negative emotions are also closely linked to BE behavior, with several studies indicating that negative emotions often precede BEEs (e.g., Meule et al., 2021; Schaefer et al., 2020). These lines of research highlight the complex relationship between emotions and eating behavior, which varies significantly from person to person.

An important area of investigation is, therefore, how emotions are experienced and regulated, especially in individuals with disordered eating behaviors. Deficits in emotion processing and regulation represent transdiagnostic features across the ED spectrum, as confirmed by meta-analytic findings (Prefit et al., 2019; Westwood et al., 2017). Emotional disturbances, particularly depressive and anxiety symptoms, are strongly associated with disordered eating behaviors and EDs (Hambleton et al., 2022). Prevalences of mood disorders among individuals with EDs is notably high (Hambleton et al., 2022; Keski-Rahkonen & Mustelin, 2016), making this the norm rather than the exception. It is, therefore, plausible that emotional experience and regulation play important roles in the development and maintenance of disordered eating behavior.

In fact, emotional experiences are central to etiological models explaining the development and persistence of BE in individuals with recurrent BEEs. The escape theory, proposed by Heatherton & Baumeister (1991), suggests that individuals may engage in BE to avoid negative self-awareness and emotional distress. The affect regulation model, proposed by Polivy & Herman (1993), posits that BE is used as a strategy to manage or cope with negative emotions. Another well-known theory, put forward by Bruch (1964), suggest that individuals might misinterpret emotional states as hunger, leading to BE. Evidence from various lines of research supports each of these theoretical models (e.g., Blackburn et al., 2006; Kenny et al., 2017; Leehr et al., 2015; Munsch et al., 2012).

Effective emotional regulation depends on one's ability to fully recognize and feel the emotions we experience. Theories of emotions emphasize the crucial role of physiological cues in shaping emotional experiences (Damasio, 1996; James, 1922; Schachter & Singer, 1962). According to these theories, emotions arise from bodily changes in response to environmental or daily events. This perception of internal bodily changes is known as *interoception*. The concept of interoception, which plays a crucial role in emotion processing and regulation, as well as eating behavior, will be discussed in greater detail in the next chapter.

## 1.3. Interoception

The concept of interoception dates back to the early 20th century when Sherrington (1906) introduced the term "interoceptive" to describe the sensation of internal bodily states, particularly those related to the viscera, distinguishing it from external sensory input and muscle proprioception. Since then, research on interoception has flourished, especially in the twenty-first century, as the role of internal bodily sensations in shaping human experience, health, and behavior has gained increasing recognition (Khalsa et al., 2018).

Contemporary definitions describe interoception as the process by which the nervous system senses, interprets, and integrates signals originating from within the body, providing a continuous, real-time representation of the body's internal state at both conscious and unconscious levels (Khalsa et al., 2018). As a multidimensional construct, interoception encompasses several dimensions based on processing levels within the peripheral and central nervous systems, and their assessment approaches (S. N. Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2019; Suksasilp & Garfinkel, 2022).

Interoceptive deficits have been observed across different organ systems (i.e., interoceptive modalities) and are associated with disordered eating behaviors and EDs (Martin et al., 2019). Network analyses indicate that these deficits act as bridge symptoms of ED psychopathology (Christian et al., 2019; Monteleone & Cascino, 2021; Olatunji et al., 2018; Vervaet et al., 2021). This body of literature also provide strong evidence that deficits in interoceptive processing constitute a transdiagnostic feature in the etiology of disordered eating behavior and EDs. Of particular interest are interoceptive processes of the cardiovascular and gastrointestinal systems. The former has been linked to emotion processing and regulation (Füstös et al., 2013; Wiens, 2005), while the latter is associated with hunger and satiety perception (van Dyck et al., 2020; van

Dyck, Vögele, et al., 2016). This chapter will provide an overview of interoception and its role in disordered eating and EDs, with a focus on the cardiovascular and gastrointestinal systems, as well as self-reported interoceptive abilities.

### 1.3.1. Interoceptive Modalities and Dimensions

Interoception encompasses the processing of signals originating from multiple organ systems involved in maintaining physical homeostasis. Consequently, interoceptive processing occurs across various modalities, including the cardiovascular, pulmonary, gastrointestinal, genitourinary, nociceptive, chemosensory, osmotic, thermoregulatory, visceral, immune, and autonomic systems (Khalsa et al., 2018). Interoception is a multifaceted construct. Contemporary models distinguish, therefore, between dimensions based on the level of processing in the peripheral and central nervous system (CNS) and its assessment approach, including psychophysiological, behavioral, and self-report measures.

Garfinkel et al. (2015) were the first to acknowledge the multidimensional nature of interoception and proposed the three-dimensional model of interoception. This model distinguishes between *interoceptive accuracy* (IAcc; referring to degree of accuracy with which an individual monitor and perceive internal bodily signals, typically assessed through behavioral tasks), *interoceptive sensibility* (ISe; referring to the individuals' self-reported belief/confidence in their interoceptive accuracy), and *interoceptive awareness* (IAw; referring to the metacognitive evaluation of interoceptive accuracy, e.g., correspondence between confidence and accuracy). Recent advances in interoceptive research have expanded and redefined this model, incorporating additional dimensions and lower levels of processing such as visceral, neural, and preconscious levels of processing (Suksasilp & Garfinkel, 2022).

The terminology proposed by Suksasilp & Garfinkel (2022) will be used throughout (see Table 1), with a few exceptions. The dimensions relevant to this dissertation will be described in detail in the following sections, where 'dimension' refers to specific levels of signal processing within this framework. Additionally, the assessment approaches for processing levels in both the cardiovascular and gastrointestinal systems will be outlined.

**Table 1**

*Overview of interoceptive dimensions, along with their respective definitions and operationalization.*

| Dimension | Definition |
|---|---|
| Neural representation* | Central nervous activity associated with interoceptive processing, including the coupling of central activity with afferent physiological signals. |
| Strength of afferent signals* | The strength and nature of signals originating from the periphery that communicate interoceptive states to the central nervous system. |
| Preconscious impact of afferent signals | The effect of fluctuations in afferent signals on their central neural representation and the processing of external stimuli. |
| Interoceptive accuracy* | Correct and precise monitoring, i.e. the correspondence between objectively measured physiological events and individuals' reported experience of those events, ascertained through behavioral tests. |
| Interoceptive sensitivity* | Indicator of the ability to perceive the minimal threshold of changes in interoceptive signals. |
| Self-report and interoceptive beliefs* | Measures of beliefs, both available to and beyond conscious access, concerning individuals' interoceptive sensations and experiences. Includes self-report measures, such as questionnaires and confidence ratings, and task-based measures of (implicit) prior beliefs thought to influence interoceptive perception. |
| Interoceptive insight* | Metacognitive evaluation of experience/performance, e.g., the correspondence between accuracy during an interoceptive task, and (self-reported) perceived accuracy or confidence during the task. |
| Interoceptive attention | Observing internal bodily sensations. Includes purposefully attending to interoceptive sensations when instructed, as well as habitual tendency to attend to interoceptive sensations, relative to exteroceptive sensations. |
| Attribution of interoceptive sensations* | Interpretation of interoceptive sensations and their causes, such as perceived threat |

*Note.*

Adapted from *Towards a comprehensive assessment of interoception in a multi-dimensional framework* by C. Suksasilp and S. N. Garfinkel, 2022, *Biological Psychology*, 168, 108262. Dimensions relevant to the research in this dissertation are marked with an asterisk.

*Neural representation* refers to the cortical processing of afferent signal from visceral organs. In the cardiac domain, this involves the investigation of heartbeat-evoked potentials (HEPs), electrophysiological brain responses to cardio-afferent signals, using the R-wave in the electrocardiogram (ECG) as the event marker (Pollatos & Schandry, 2004). In the gastric domain, newer methods include stomach-brain coupling (Richter et al., 2017), where the phase of gastric activity modulates the amplitude of the cortical alpha rhythm, and gastric-evoked potentials, which are brain responses to gastric signals stimulated by a vibrating capsule in the stomach (Mayeli et al., 2023).

*Strength of afferent signals* (formerly referred to as *physiological state*; Forkmann et al., 2016) is considered the most basic level of interoceptive processing. It may affect higher levels of processing, such as the neural representation and the accuracy with which they are perceived. Psychophysiological methods are used for assessment, such as electrocardiography (ECG) and electrogastrography (EGG). Common indices include mean heart rate (HR) and heart rate variability (HRV) for cardiac activation, and the percentage distribution of EGG cycle durations across frequency bands for gastric activation.

*Interoceptive accuracy* (IAcc) is a behavioral indicator of interoception, reflecting the precision with which individuals monitor and report their internal physiological experiences during an interoceptive task. In the cardiac domain, the heartbeat counting task (HCT; Schandry, 1981) and the heartbeat discrimination task (HDT; Whitehead et al., 1977) are commonly used for assessing IAcc. In the HCT, participants count their heartbeats during specified time intervals, and their reported count is compared to the actual number of heartbeats measured within the same time frame. In the HDT, participants are asked to determine whether an external stimulus (e.g., visual, auditory, or tactile) is presented simultaneously with or delayed relative to their heartbeat. Correct judgments are categorized as ‘hits’ when participants identify correctly synchronous trials and as ‘correct rejections’ when they accurately identify asynchronous trials. Incorrect judgments are categorized as ‘misses’ for failures to identify synchronous trials, and as ‘false alarms’ for incorrect identification of asynchronous trials. IAcc in the HDT is then quantified using the *d’* parameter derived from the Signal Detection Theory (Wickens, 2001). In the gastric domain, the behavioural indicator of interoception is referred to as *interoceptive sensitivity* (ISen), which is defined as the minimal threshold for perceiving changes in interoceptive signals (Schulz & Vögele, in press; van Dyck et al., 2016). The two-step Water Load Test (WLT-II; van Dyck et al., 2016) is used to assess various indices of ISen. This paradigm involves the ingestion of non-caloric water until satiety (step 1) and fullness (step 2). Indices of gastric ISen include the volume of water ingested until satiety, additional volume needed to achieve maximum stomach fullness, total volume of ingested water, and the percentage of satiation relative to the total volume.

*Self-report and interoceptive beliefs* (IBe; formerly referred to as *interoceptive sensibility* [ISe], Garfinkel et al., 2015) refers to self-reported experiences and beliefs about internal sensations. This level of processing is usually assessed using questionnaire-based scales (e.g., the Multidimensional Assessment of Interoceptive Awareness, Mehling et al., 2012), or through confidence ratings concerning interoceptive task performance. Specifically, in the cardiac domain, individuals provide confidence ratings on their perception of their heartbeat during a heartbeat perception task. In the gastric domain, the WLT-II questionnaire (van Dyck, Vögele, et al., 2016) is used, where participants focus on their abdominal sensations and rate their feelings of satiety, fullness, and negative affect (NA). The latter, however, rather reflects the attribution of interoceptive sensations (AIS; see below).

*Interoceptive insight* (formerly referred to as *interoceptive awareness*; Garfinkel et al., 2015) refers to the metacognitive evaluation of one's experience or performance during an interoceptive task. This higher level of interoceptive processing is operationalized by the correspondence between task performance and self-report measures, such as confidence ratings.

*Attribution of interoceptive sensations* (AIS) refers to how individuals interpret the nature, intensity, and causes of internal bodily signals. This level of interoceptive processing is assessed using self-reports. Depending on the modality, participants rate their emotional experience in relation to heartbeat perception or stomach distention.

### 1.3.2. Cardiac Interoception

Cardiac interoception refers to the processing — sensing, interpreting, integrating — of cardio-afferent signals, and has been associated in particular with emotion processing (Wiens, 2005) and regulation (Füstös et al., 2013). Evidence indicates deficits in emotion processing and regulation in individuals with disordered eating behaviors and EDs. Meta-analytical results provide strong support for both elevated levels of alexithymia, i.e. difficulties in identifying and describing one's own emotions (Westwood et al., 2017) and greater difficulties in emotion regulation in individuals across the ED spectrum (Prefit et al., 2019). Impairments in emotional clarity and limited access to adaptive emotion regulation strategies likely undermine individuals' ability to address emotional needs effectively, leading to maladaptive coping mechanisms, such as BE. Consequently, emotion regulation is a core aspect of current approaches to the treatment of EDs (e.g., Hilbert & Tuschen-Caffier, 2010; Munsch et al., 2011). Despite the availability of evidence-based interventions, relapse and mortality rates in individuals with EDs remain high (Fichter et al., 2008; Fichter et al., 2017; Quadflieg & Fichter, 2019). This highlights the need for a more thorough understanding of the mechanisms underlying emotional dysregulation, which could be crucial for refining interventions and improving treatment outcomes.

Evidence on cardiac interoception in EDs is mixed, with findings indicating enhanced, unaltered, or impaired interoceptive processes. The following provides an overview of findings on cardiac interoception in EDs.

Recent reviews and meta-analyses confirm cardiovascular alterations (i.e., strength of afferent signals) in EDs. Patients with AN and BN exhibit increased parasympathetically-mediated heart rate variability (HRV) compared to healthy controls (HCs), whereas no significant alterations have been reported in individuals with BED (Christensen et al., 2023). These cardiovascular alterations may, therefore, be a consequence of fasting or purging behaviors (Heiss et al., 2021; Peyser et al., 2021; Vögele et al., 2009).

Evidence regarding IAcc in EDs is particularly inconclusive, both within and between different ED subtypes. In AN, some studies report lower IAcc scores (Demartini et al., 2021; Fischer et al., 2016; Pollatos et al., 2008, 2016; Wollast et al., 2022), while others found similar scores (Ambrosecchia et al., 2017; Datta & Lock, 2023; Demartini et al., 2017; Eshkevari et al., 2014; Kinnaird et al., 2020; A. P. Lutz et al., 2023; Richard et al., 2019), or a trend toward higher scores (Lutz, van Dyck, et al., 2019) compared to HCs. In BN, findings are also inconsistent. Most studies report no differences between individuals with BN and HC (Eshkevari et al., 2014; Lutz, van Dyck, et al., 2019; Pollatos & Georgiou, 2016), while one study found lower IAcc scores in individuals recovered from BN compared to HCs (Klabunde et al., 2013). In BED, IAcc scores were comparable to those of HCs (Lutz et al., 2023)

Research on IBe and IIn in relation to heartbeat perception is limited. Confidence ratings were either reduced or unaltered in AN (Kinnaird et al., 2020; Lutz et al., 2023), and unaltered in

BN or BED (Lutz et al., 2023; Lutz, van Dyck, et al., 2019). To the best of our knowledge, evidence on IIn is limited to one study, which found no significant differences among AN, BN and BED (Lutz et al., 2023).

Studies investigating the neural representation of cardio-afferent signals in EDs are scarce. Lutz et al. (2019) observed higher HEP amplitudes in patients with AN compared to HCs, indicating enhanced cortical processing. A more recent study by Cambi et al. (2024) used high-density EEG to localize HEP sources and found that individuals with AN exhibited hypo-activation in brain regions involved in interoceptive processing, such as the anterior cingulate and orbitofrontal areas, compared to HCs. However, comparing results across these studies is challenging due to differing methodological approaches. In BN and BED, no significant differences in the neural representation have been observed (Lutz et al., 2023; Lutz, van Dyck, et al., 2019), suggesting unaltered neural representation.

An important shortcoming in the literature on cardiac interoception concerns the limited research on BED, with the findings discussed above stemming from only a single study (Lutz et al., 2023). Additionally, most studies tend to assess interoceptive processes in isolation, although each level of interoceptive processing may contribute differently to cognitions, emotions, and symptom presentation (Suksasilp & Garfinkel, 2022). To the best of our knowledge, only one study has investigated cardiac interoception at multiple levels among individuals with AN, BN, BED, obesity (OB), and HCs (Lutz et al., 2023).

### 1.3.3. Gastric Interoception

Gastric interoception refers to the processing — sensing, interpreting, integrating — of gastro-afferent signals, and has been associated in particular with hunger and satiety (van Dyck et al., 2020; van Dyck, Vögele, et al., 2016). Progress in understanding the relationship between gastric interoception, disordered eating behaviors, and EDs has been limited by a predominant reliance on self-report measures (for details, see section 1.3.4. Self-report and interoceptive beliefs). Compared to the cardiovascular system, relatively few studies have investigated interoceptive processes within the gastrointestinal system. The following provides an overview of findings on gastric interoception in EDs.

As previously outlined, gastric distention and gastric motility are two key mechanisms underlying the perception of satiety during food intake (Janssen et al., 2011). Evidence suggests varying responses to gastric distension among different ED types, reflecting altered ISen. For example, patients with AN report earlier satiety and postprandial fullness compared to HCs following a standardized meal (Garfinkel et al., 1978; Garfinkel, 1974; Garfinkel et al., 1979; Klastrup et al., 2020). In a recent study, participants with AN were instructed to drink water until they felt full, and they consumed significantly less water to reach the same level of perceived fullness as HCs (Brown et al., 2022). In contrast, individuals with BN and BED consumed significantly more water to reach the satiety threshold compared to HCs, suggesting lower sensitivity to gastric distention (van Dyck et al., 2020).

Regarding gastric motility (i.e., strength of afferent signals), research indicates alterations in gastric motility across AN, BN, and BED. These individuals exhibit lower normogastric activity and higher bradygastric or tachygastric activity compared to HCs, both before and after water intake (Alyami et al., 2023; Koch et al., 1998; Ogawa et al., 2004).

The study by van Dyck et al. (2020) provided a more comprehensive assessment of gastric interoception in individuals with BN or BED, including strength of afferent signals, ISen, and IBe. Participants underwent the WLT-II (van Dyck, Vögele, et al., 2016). Compared to HCs, individuals with BN and BED drank significantly more water to reach the satiety threshold, indicating reduced

ISen. The study also assessed gastric motor function, revealing similar patterns of alterations as reported in previous research (Alyami et al., 2023; Koch et al., 1998; Ogawa et al., 2004). Fullness and satiety ratings were significantly higher in BN and BED compared to HC, indicating altered IBe. Negative affect ratings related to abdominal sensations were higher in BN and BED compared to HC, indicating altered AIS. Patients with AN also report greater negative attribution of abdominal sensations after a meal (Norris et al., 2015). To the best of our knowledge, there are no studies providing evidence on IIn.

The neural representation of gastric activity is a relatively new area of research, having so far been investigated primarily in healthy individuals. Richter and collegues (2017) discovered significant phase-amplitude coupling (PAC) in parieto-occipital regions and the anterior insula. In their study, the phase of gastric slow waves modulated the amplitude of the cortical alpha rhythm (10-11 Hz). This gastric-alpha PAC accounted for 8% of the variance in fluctuations of alpha rhythm amplitude. Similarly, Todd and collegues (2021) investigated the relationship between gastric-alpha phase amplitude coupling (PAC) and body image. They found that reduced gastric-alpha PAC was associated with higher levels of shame and weight preoccupation. The potential link between gastric-alpha PAC and eating behavior remains unexplored in individuals with disordered eating behaviors.

A significant shortcoming in the literature is the lack of investigation into gastric interoception, despite evidence of altered responses to hunger and satiety in individuals with disordered eating behaviors. Further research is necessary to elucidate the relationship between various levels of gastric interoceptive processing and eating behaviors. Examining the neural representation of gastric activity in individuals with disordered eating may provide new insights into the role of stomach-brain coupling in regulating eating behavior.

### 1.3.4. Self-report and interoceptive beliefs

Self-report measures provide valuable insights into individuals' beliefs and interpretations of their bodily sensations. They may serve in some cases as better predictors of clinical conditions than interoceptive tasks or psychophysiological measures (Suksasilp & Garfinkel, 2022). Various questionnaires and scales have been developed for use in research and clinical practice.

Empirical findings on self-reported interoceptive abilities in disordered eating behavior and EDs have primarily been obtained using the Interoceptive Awareness (IA) subscale of the Eating Disorder Inventory (EDI; Garner et al., 1983) and its revisions. The EDI-IA assesses self-reported difficulties in "recognizing and accurately identifying emotions and sensations of hunger or satiety" (Garner et al., 1983, p.18). A recent meta-analysis confirmed the presence of important, self-reported interoceptive deficits in individuals with EDs, and the improvement of these deficits after recovery (Jenkinson et al., 2018).

Despite its utility in identifying interoceptive deficits, the EDI-IA has several limitations that warrant discussion. First, several items of the subscale reflect ED-specific symptomatology rather than interoceptive abilities (e.g., "When I am upset, I worry that I will start eating."). Second, most items focus on interoceptive deficits related to emotional states (e.g., "When I am upset, I don't know if I am sad, frightened, or angry."), while only one item addresses uncertainty in the perception of hunger and satiety ("I get confused as to whether or not I am hungry."). The EDI-IA, therefore, conflates interoceptive facets.

To account for the multidimensional nature of interoception, the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) was developed and validated in various populations to assess different facets of interoception. Brown et al. (2017) validated the MAIA in a sample of adult and adolescent ED patients and found that some but not all subscales were associated with ED symptoms. It should be noted, however, that the MAIA is a self-report measure of general interoceptive abilities and is not specifically designed for ED populations. This broad focus may limit its capacity to identify specific interoceptive deficits relevant to EDs.

Distinguishing between interoceptive sensations—particularly emotions, hunger, and satiety—is clinically relevant, as these aspects may contribute in different ways to the development and maintenance of ED symptoms. As outlined in the previous chapters, the literature supports the association between deficits in the perception of hunger and satiety and disordered eating behaviors. Individuals who report less reliance on hunger and satiety signals also tend to engage more frequently in disordered eating behaviors (Anderson et al., 2016; Bennett & Latner, 2022; Linardon & Mitchell, 2017; Romano et al., 2018). Similarly, individuals with EDs report lower reliance on hunger and satiety cues compared to HCs (van Dyck, Herbert, et al., 2016).

In a study by Poovey et al. (2022), the relative importance of different scales in relation to disordered eating behaviors was examined. The findings indicate that the Intuitive Eating Scale-2 (IES-2), which specifically measures hunger/satiety-specific interoceptive perception, was more strongly associated with and served as a better predictor of disordered eating behaviors than general measures of interoception, including the Multidimensional Assessment of Interoceptive Awareness-2 (MAIA-2; Mehling et al., 2018) and the EDI-IA (Garner, 1991). Although the IES-2 may be more suitable for investigating interoceptive processes related to hunger and satiety, it should be noted that it assesses these perceptions as part of a continuum rather than as distinct constructs. As discussed in the previous chapter on gastric interoception, hunger and satiety are distinct from each other and should be considered as such.

## 1.4. Research Aims

Scientific consensus suggests that deficits in interoceptive processing play an important role in the development and maintenance of disordered eating behaviors and EDs. However, alterations across interoceptive dimensions and modalities have not been consistently observed across studies (Martin et al., 2019). Inconsistencies in the literature may stem from methodological limitations. First, most studies focus on diagnostic categories rather than transdiagnostic characteristics. Second, interoceptive processes are usually assessed in isolation. Third, existing self-report measures of interoception either conflate interoceptive sensations (i.e., EDI-IA), or lack specificity to EDs (i.e., MAIA). Addressing these methodological issues is crucial for advancing our understanding of interoceptive processes related to disordered eating and EDs.

The aims of the present research project were two-fold. The first objective was to develop and validate a novel self-report measure to assess ED-specific interoceptive perception (EDIP) in terms of the ability to perceive and discriminate between emotions, hunger, and satiety. Across three online studies (**Studies 1-3**), we examined the factor structure and psychometric properties (i.e., item analysis, internal consistency, construct validity, and incremental validity) of the new measure. Statistical analyses were conducted using independent samples of individuals with and without self-reported EDs. Group differences in EDIP were examined based on sex, current versus past ED diagnosis (Diagnostic Status I), and ED types (Diagnostic Status II).

The second objective was to investigate interoceptive processing in two organ systems of relevance for eating behavior, i.e. the cardiovascular system (**Study 4**) and the gastrointestinal system (**Study 5**). Study samples included individuals with recurrent BEEs and HCs, covering the spectrum of BE behavior. A range of physiological, behavioral and self-report measures were used to assess different levels of cardiac and gastric interoceptive processing, including IAcc/ISen, IBe, IIn, AIS, as well as the strength and neural representation of afferent signals. This comprehensive and multidimensional approach aimed to elucidate alterations in interoceptive processes related to BE as a proxy for disordered eating behavior.

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## 2. Development and Initial Validation of a Self-Report Measure to assess Eating Disorder-specific Interoceptive Perception (Studies 1 and 2)

Ortmann, J., Lutz, A. P. C., Rose, G., Happ, C., Vögele, C., Schulz, A., & van Dyck, Z. (2024). Development and initial validation of a self-report measure to assess eating disorder-specific interoceptive perception. *Psychological Assessment, 36*(2), 162–174. https://doi.org/10.1037/pas0001283

## 2.1. Abstract

**Objective:** Interoceptive deficits – particularly with respect to the perception of emotions, hunger, and satiety – constitute important targets for intervention in eating disorders (EDs). Suitable self-report measures to identify these deficits, however, are lacking. We, therefore, developed and validated a multidimensional questionnaire to assess eating disorder-specific interoceptive perception (EDIP) in terms of the ability to perceive and discriminate between emotions, hunger, and satiety. **Methods and Results:** In two independent samples with a total of 2058 individuals (22.74% with self-reported EDs), exploratory and confirmatory factor analyses revealed a four-factor solution of the EDIP Questionnaire (EDIP-Q) with the subscales Emotions, Hunger, Satiety, and Discrimination. The EDIP-Q has sound psychometric properties and was related to convergent questionnaires but unrelated to divergent self-report measures, supporting its construct validity. Participants with self-reported EDs had significantly lower EDIP-Q scores compared to participants without self-reported ED diagnosis. While individuals with self-reported anorexia nervosa (AN), bulimia nervosa (BN) and binge-eating disorder (BED) report similar difficulties in perceiving emotions, participants with BN and BED report greater difficulties in perceiving satiety and differentiating between hunger and emotional states compared to participants with AN. In contrast, individuals with AN report higher sensibility to satiety, but lower sensibility to hunger compared to individuals with BN and BED. **Conclusion:** The EDIP-Q is a valuable clinical tool to establish profiles of deficits in EDIP that provides the basis for developing more targeted treatment approaches for EDs.

*Key words:* eating disorders, interoception, scale development, self-report

## 2.2. Introduction

Eating disorders (EDs) are defined by severe disturbances in eating and eating-related behaviors, as well as an unhealthy relationship with food, resulting in impaired physical health, psychosocial functioning and quality of life (American Psychiatric Association, 2013). Despite the availability of empirically supported interventions, relapse and mortality rates are still high in the long-term (Fichter et al., 2017; Fichter & Quadflieg, 2016, 2019). This underlines the importance of improving our understanding of the factors that contribute to the development and maintenance of ED symptoms. Several lines of research highlight that interoceptive deficits constitute a key transdiagnostic feature in EDs (e.g. Monteleone & Cascino, 2021) and may, therefore, represent important targets for intervention. Interoception refers to the ability to perceive the internal state of the body and comprises the processing of afferent signals from visceral organs and their integration and representation at the cortical level (Cameron, 2001). Established self-report instruments to assess interoceptive processes in EDs (e.g. Eating Disorder Inventory, EDI; Garner et al., 1983), however, typically focus on the awareness of *emotional* states, thereby omitting a core aspect of interoceptive deficits in EDs, i.e. impaired perception of *hunger* and *satiety* cues. Although the literature points to a differential contribution of emotions, hunger and satiety signals to ED symptoms (Poovey et al., 2022; van Dyck et al., 2016), there is no instrument that allows for its differential assessment. The aims of the present studies are, therefore, (1) to develop and validate a new self-report measure to assess eating disorder-specific interoceptive perception (EDIP) in terms of the ability to perceive emotions, hunger, and satiety and to discriminate between those physiological states and (2) to investigate differences in EDIP in individuals with a self-reported diagnosis of anorexia nervosa (AN), bulimia nervosa (BN) and binge-eating disorder (BED).

Interoception encompasses signal processing originating from multiple organ systems involved in physical homeostasis, such as the cardiovascular, pulmonary and gastrointestinal systems (Khalsa et al., 2018). Contemporary models distinguish several dimensions of interoception (Forkmann et al., 2016; Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2019; Suksasilp & Garfinkel, 2022), based on the level of processing in the peripheral and central nervous system and its assessment approach, including psychophysiological, behavioral and self-report measures. Using different methodological approaches, altered interoceptive processes have been found in eating and weight disorders (Martin et al., 2019), and may contribute to the heterogeneous clinical picture, ranging from severe restrictive eating to uncontrolled overeating. Particularly deficits in emotional processing and in the perception of hunger and satiety have been described. A recent meta-analysis showed that individuals with EDs exhibited higher levels of alexithymia, i.e. greater difficulties in identifying or describing their emotions (Westwood et al., 2017). Although this emphasizes a general impairment in emotional processing across the ED spectrum, a more heterogeneous picture emerges in the perception of hunger and satiety signals. Following a standardized meal, patients with AN report earlier satiety and postprandial fullness compared to healthy controls (HC) (Garfinkel et al., 1978; Garfinkel, 1974; Garfinkel et al., 1979; Klastrup et al., 2020). In contrast, individuals with BN and BED are less sensitive to satiety and gastric distention compared to HC (van Dyck et al., 2020).

In the self-report domain, empirical findings on interoceptive processing in EDs were primarily obtained using the interoceptive awareness subscale of the EDI (EDI-IA) which measures self-reported difficulties in "recognizing and accurately identifying emotions and sensations of hunger or satiety" (Garner et al., 1983, p.18). Results of a recent meta-analysis by Jenkinson et al. (2018) emphasize the presence of important, self-reported interoceptive deficits in individuals with EDs, and the improvement of these deficits after recovery. Nevertheless, the use of EDI-IA as a measure of interoception in EDs is questionable for two reasons: First, several items of the subscale are more likely to reflect ED-specific symptomatology rather than interoceptive abilities (e.g. “When I am upset, I worry that I will start eating.”). Second, most items measure interoceptive deficits in relation to emotional states (e.g. “When I am upset, I don’t know if I am sad, frightened or angry.”), whereas only one item addresses the impaired perception of interoceptive signals of hunger and satiety (“I get confused as to whether or not I am hungry.”). The EDI-IA, therefore, does not distinguish between interoceptive facets, although these may contribute in different ways to the development and maintenance of ED symptoms.

To reveal the role of potentially altered interoceptive processing in the etiology and maintenance of EDs, a novel instrument is required that is ED-specific and allows for the differential assessment of interoceptive deficits in EDs. Study 1 concerned the development of the EDIP Questionnaire (EDIP-Q), including the investigation of its factor structure using exploratory factor analysis (EFA) and psychometric properties (i.e. item analyses, internal consistency, and construct validity). Study 2 aimed at confirming the factor structure derived from Study 1 using confirmatory factor analysis (CFA) and to provide further evidence of its construct validity. As a second objective, we examined differences in EDIP, including sex differences and differences between participants with a self-reported current and past ED diagnosis (diagnostic status I), as well as between different types of self-reported EDs (diagnostic status II), compared with healthy participants.

Consistent with the definition of EDIP, we expected the items to load on four independent, but interrelated factors forming the subscales of the EDIP-Q. Furthermore, we expected the EDIP-Q to have sound psychometric properties and to be related to other scales measuring similar or related constructs. We hypothesized that EDIP-Q scores would be inversely related to ED symptom severity, maladaptive eating behavior, and poor awareness of bodily states, particularly in relation to emotions, hunger, and satiety. Regarding group differences, we hypothesized that the EDIP-Q would discriminate well between individuals with and without a self-reported ED diagnosis. More specifically, individuals with a self-reported ED diagnosis would report lower subscale scores compared to HC, indicating greater deficits in EDIP. To the best of our knowledge, there are no studies that systematically examine differences in emotional processing and the perception of hunger and satiety *between* different ED types. Given the available evidence, however, we assumed no differences in emotional processing between ED types, but differences in the perception of hunger and satiety. We, therefore, hypothesized that individuals with AN would report higher sensitivity to satiety than to hunger, and that individuals with BN and BED would report higher sensitivity to hunger than to satiety, as well as greater difficulty in distinguishing between physical states.

## 2.3. Study 1

### 2.3.1. Methods

**Scale development and Expert Review**

The item pool was generated in several consecutive steps. First, to account for its multi-faceted nature, EDIP was defined as the ability to perceive emotions, hunger and satiety, and to discriminate between those physiological states. Based on this definition, a collection of existing items sourced from self-report measures focusing on the perception of bodily sensations related to emotions, hunger and satiety was compiled. An expert panel (consisting of three clinical psychologists and a psychology student) with extensive experience in ED research or treatment, reviewed the items for quality and relevance to the content domain. Items that adequately assessed either the accuracy in perceiving emotions, hunger or satiety signals were directly included in the item pool. Items that were only partially applicable were reformulated or removed. In a next step, the item pool was complemented by generating new items to address the facets of EDIP. A 7-point Likert scale was chosen as response format (1 = strongly disagree, 7 = strongly agree), with higher scores indicating better EDIP. A pilot study was then conducted in which seven psychology students completed the questionnaire and provided feedback on which items were difficult to understand or misleadingly worded. The expert panel revised or removed difficult items, leaving a final item pool of 76 items. This version was worded in German.

**Procedure**

German-speaking participants were recruited through online advertisements and flyers distributed at the University of Luxembourg as well as by sending invitation emails to students and employees. Moreover, student councils of several universities in Germany, Austria and Switzerland were asked to send the link to the online survey to their students. To recruit a representative sample of individuals with ED, the link was published in various ED community groups. For snowball sampling, participants were asked to forward the link to the survey to their friends and acquaintances, and to publish it on social media websites. The introduction to the survey comprised an information sheet and consent form. Participants were requested to confirm that they were at least 18 years of age. The survey itself consisted of a series of socio-demographic questions and a set of eating- and body-related measures, including the item pool to assess EDIP. Completing the survey took approximately 30-40 minutes. As an incentive for participation, gift vouchers of a total value of 250€ were raffled among participants. The survey was established and assembled using the platform SoSci Survey (https://www.soscisurvey.de/). Ethics approval was sought from the study program of psychology at the University of Luxembourg.

**Participants**

The online survey was completed by 1088 participants. The dataset was inspected carefully for ensuring data integrity. First, we checked for multiple respondents with the same start and end time for participation, which was not the case. Second, we identified and removed eight participants with high rates of missing or low item responses. Third, we inspected the response pattern of outliers in response times, none of which were found to be fraudulent. In addition, seven participants were excluded from statistical data analyses because they met the exclusion criteria (bariatric surgery: $n = 2$, current pregnancy: $n = 1$, being underage: $n = 1$, ED not officially diagnosed: $n = 3$). The remaining sample consisted of 1073 participants aged between 18 and 75 years, with a mean age of 29.9 years ($SD = 10.8$) for women ($n = 888$), and 31.5 years ($SD = 10.8$) for men. The sample comprised 735 German, 234 Luxemburgish, 59 Austrian, 24 French, and 19 Swiss participants, as well as 76 participants of other nationalities. 446 participants were employed, whereas 479 were university students. The remaining participants stated that they were not in employment ($n = 20$ homeworkers, $n = 26$ pensioners, $n = 27$ jobseekers, $n = 25$ high school students, and $n = 50$ "others"). The Body Mass Index (BMI) was calculated based on self-reported height and body weight (kg/m²). The mean BMI was 23.5 kg/m² ($SD = 6.4$ kg/m²) in women and 24.0 kg/m² ($SD = 3.9$ kg/m²) in men.

ED diagnoses were assessed via self-report. Only participants who were diagnosed by a mental health professional, e.g. clinical psychologist or psychiatrist, were included in the ED subsample. Participants were requested to indicate whether they had a history of EDs, and if so, who established the diagnosis. Furthermore, they were asked to specify whether they had recovered from or whether they were currently affected by their ED. Possible diagnoses were AN, BN, BED, and Eating Disorders Not Otherwise Specified (EDNOS). As only seven males reported an ED, we decided to discard their data from further analysis. The ED subsample consisted of 212 females, of which 78 individuals reported to have been diagnosed with AN, 53 with BN, 34 with BED, and 34 with EDNOS. A total of 135 participants indicated to have a current ED, of which 43 individuals were diagnosed with AN, 36 with BN, 21 with BED, and 35 with EDNOS. Due to the heterogeneity of the EDNOS group, individuals with EDNOS diagnoses were excluded from statistical analyses.

## Measures

### *Eating Disorder-Inventory-2 (EDI-2)*

The German version of the EDI-2 (Paul & Thiel, 2005) is a 91-item questionnaire to assess ED psychopathology. In the present study, only the first three subscales Drive for Thinness (DT; 7 items), Bulimia/Bulimic Tendencies (BT; 7 items), and Body Dissatisfaction (BD; 9 items) were used to assess core ED psychopathology. Items are answered using a 6-point Likert scale ranging from 1 (never) to 6 (always), with higher scores indicating higher severity of ED symptoms. Cronbach's α (mean inter-item correlation, MIIC) in the current sample was .93 (.65), .91 (.59) and .93 (.61) for the three subscales.

### *Intuitive Eating Scale-2 (IES-2)*

The German version of the IES-2 (van Dyck et al., 2016) is a 23-item questionnaire to assess intuitive eating, which is characterized by eating in response to physiological hunger and satiety signals rather than for situational or emotional reasons. The IES-2 is composed of four subscales, i.e. Unconditional Permission to Eat (UPE), Eating for Physical Reasons (EPR), Reliance on Hunger/Satiety Cues (RHSC), and Body-Food Choice Congruence (B-FCC). Responses are given on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating a higher level of intuitive eating. Cronbach's α (MIIC) in the current sample was .85 (.52), .86 (.61), .94 (.72) and .79 (.55) for the four subscales, and .93 (.37) for the total score.

***Multidimensional Assessment of Interoceptive Awareness (MAIA)***

The German version of the MAIA (Bornemann et al., 2014) is a 32-item questionnaire and composed of eight subscales to assess multiple facets of self-reported interoceptive abilities, i.e. Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. Each item is answered along a scale ranging from 1 (never) to 5 (always), with higher values indicating better interoceptive awareness. Cronbach's α (MIIC) in the current sample ranged from .58 to .92 (.29 to .79).

***Body Consciousness Questionnaire (BCQ)***

In the present study, we used the Private Body Consciousness subscale (PBC; 5 items) of the BCQ (Miller et al., 1981) to assess one's disposition to focus on internal physical state. Items were translated from English into German and backtranslated into English by independent bilingual researchers. The back-translation was compared with the original English version. In case of discrepancies, the item formulations were discussed, and necessary adjustments were made. Items are answered on a 5-point Likert scale ranging from 0 (extremely uncharacteristic) to 4 (extremely characteristic), with higher scores indicating a stronger tendency to focus on internal bodily sensations. Cronbach's α (MIIC) in the current sample was .60 (.24).

***Satisfaction with Life Scale (SWLS)***

The German version of the SWLS (Glaesmer et al., 2011) is a 5-item questionnaire to assess overall life satisfaction. Cronbach's α (MIIC) in the current sample was .92 (.71).

***Interpersonal Reactivity Index (IRI)***

The German version of the IRI (Paulus, 2009) is a self-report measure of affective and perspective empathetic tendencies. In the present study, we used the subscales Empathic Concern (EC; 4 items) and Perspective Taking (PT; 4 items) to assess the respondents' tendency to experience feelings of concern or compassion for others and their ability to adopt another person's perspective or point of view. Items are rated on a five-point Likert scale from 1 (does not apply at all) to 5 (applies very well), with higher scores indicating greater perspective taking and empathic concern. Cronbach's α (MIIC) in the current sample was .74 (.42) for EC and .80 (.52) for PT.

**Statistical Analyses**

A series of item analyses were performed to determine which items should be included in EFAs. Frequency analyses were conducted to identify and remove items with high rates of missing data or no variance. Corrected item-to-total correlations $r_{i(t-1)}$ were calculated to determine and remove items with weak correlations to the total score ($r_{i(t-1)} < .3$). Item difficulties $p_m$ were calculated, retaining items with an intermediate item difficulty ($.2 < p_m < .8$). Point biserial correlations $r_{pb}$ were calculated between items and diagnostic group (1 = individuals with self-reported EDs; 0 = individuals without self-reported EDs), to remove items that did not differentiate between group modality ($r_{pb} < .2$). All thresholds were set in accordance with recommendations on scale development (Bortz & Döring, 2016; Bühner, 2011). To examine the factorial structure of the EDIP-Q, we proceeded as follows: First, the number of factors to be extracted was determined by visual inspection of the scree plot as well as Horn's parallel analysis (Horn, 1965). Subsequently, a principal component analysis (PCA) was performed for the total sample ($N$ = 1073) with oblique (promax) rotation to allow for intercorrelation between the dimensions of EDIP. Item reductions were based on poor factor loadings (< .5) and cross-loadings (> .3). This procedure, from selecting the appropriate number of factors to item reduction, was repeated until the remaining items could be clearly assigned to one component. To examine the similarity of factors between different subsamples, we conducted PCAs with oblique (promax) rotation separately for sex and diagnostic group and calculated Tucker's (1951) congruence coefficients ($\phi$) as index of the similarity between factors, whereas $\phi$ = .85 - .94 indicate fair similarity, and $\phi \geq$ .95 good similarity (Lorenzo-Seva & ten Berge, 2006). To evaluate internal consistencies, Cronbach's $\alpha$ and mean inter-item correlations (MIIC) were calculated for the identified EDIP-Q subscales. Given the large sample size, distributions of all variables were examined by visually inspecting stem- and-leaf plots, boxplots, and Q-Q plots, and by checking values of the skewness and kurtosis statistics (Field, 2013). As no obvious signs of deviation from a normal distribution were found, Pearson correlation coefficients were calculated to determine convergent and divergent validity between EDIP-Q and related and unrelated concepts, whereas $r$ = .10 is considered as "small", $r$ = .30 a "medium", and $r$ = .50 "large" (Cohen, 1992). Statistical analyses were performed with IBM SPSS Statistics (Version 27; IBM Corp., Armonk, NY, USA). Critical alpha-level was set to .05 in all analyses. This study was not preregistered. Materials and analysis code for this study are available by emailing the corresponding author.

### 2.3.2. Results

**Exploratory Factor Analysis**

The Kaiser-Meyer-Olkin (KMO) coefficient yielded a value of .98, and the Bartlett's test of sphericity was significant ($p$ < .001), both indicating that the dataset was adequate for factor analysis (Tabachnik & Fidell, 2007). Parallel analysis and the inspection of the scree plot suggested a four-factor solution. PCA also revealed a four-factor solution, explaining 65.34% of the total variance. Table 1 contains item factor loadings for each factor obtained from PCA. These results led to the specification of a 25-item instrument with four subscales named *Emotions* (7 items assessing the perception of emotions), *Hunger* (5 items assessing the perception of hunger signals), *Satiety* (7 items assessing the perception of satiety signals), and *Discrimination* (6 items assessing the ability to discriminate between hunger and emotional states). The subscale scores are computed by taking the average of the respective item scores, thus ranging from 1 to 7, with lower scores indicating greater difficulty in EDIP.

**Factor Structure Congruence**

For the subsamples of men, women, participants with and without a self-reported ED diagnosis, the KMO coefficients ranged from .87 to .96, and Bartlett's tests for sphericity were significant (*ps* $< .001$). The datasets were, therefore, adequate for factor analysis (Tabachnik & Fidell, 2007). Item factor loadings for and Tucker's congruence coefficients ($\phi$) between the two sexes, and between participants with and without a self-reported ED diagnoses are summarized in the supplemental materials (Table S1 and S2). Congruence coefficients were in a high range ($.95 \leq \phi \leq .98$), indicating a high degree of factor similarity.

**Item Analysis**

Corrected item-total correlation, item difficulty, and point-biserial correlation for each item are summarized in Table 1. Corrected item-total correlations were in the medium to high range. Item difficulties were in the medium range. Point-biserial correlations between the items and group (1 = ED group, 0 = control group) were in the medium range, indicating that items were moderately related to the group modality.

**Table 1**

*Item Factor Loadings and Item Parameters of the EDIP-Q (n = 1073).*

| EDIP-Q Items | Factor Loadings | | | | Item parameters | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | $r_{i(t-1)}$ | $p_m$ | $r_{pb}$ |
| Factor 1: Satiety | | | | | | | |
| Item 16 | **.88** | -.05 | -.02 | -.02 | .63 | .59 | .28** |
| Item 31 | **.86** | .08 | -.05 | .02 | .72 | .59 | .41** |
| Item 65 | **.85** | .02 | .07 | -.04 | .73 | .63 | .38** |
| Item 36 [R] | **.81** | -.10 | .20 | -.08 | .65 | .61 | .28** |
| Item 37 | **.75** | .12 | -.15 | .05 | .61 | .51 | .33** |
| Item 43 | **.75** | .12 | -.18 | .04 | .58 | .56 | .24** |
| Item 24 [R] | **.70** | -.12 | .26 | .10 | .72 | .69 | .38** |
| Factor 2: Emotions | | | | | | | |
| Item 49 | .02 | **.86** | .00 | -.02 | .70 | .65 | .38** |
| Item 58 | .02 | **.85** | .00 | .02 | .73 | .72 | .44** |
| Item 76 | -.05 | **.84** | .01 | -.02 | .63 | .67 | .38** |
| Item 67 | -.05 | **.80** | .17 | -.03 | .71 | .76 | .40** |
| Item 10 | .05 | **.78** | .04 | .00 | .70 | .71 | .41** |
| Item 33 | .00 | **.76** | .00 | .05 | .64 | .80 | .38** |
| Item 30 | .13 | **.64** | -.06 | .05 | .61 | .62 | .35** |
| Factor 3: Discrimination | | | | | | | |
| Item 42 [R] | -.06 | .01 | **.84** | .03 | .61 | .84 | .31** |
| Item 23 [R] | -06 | .04 | **.81** | .81 | .67 | .80 | .38** |
| Item 53 [R] | .04 | .12 | **.78** | -.08 | .66 | .80 | .37** |
| Item 61 [R] | .08 | -.03 | **.76** | -.02 | .58 | .77 | .27** |
| Item 21 [R] | .09 | .03 | **.76** | -.02 | .64 | .74 | .34** |
| Item 15 [R] | -.18 | -.01 | **.71** | .10 | .43 | .85 | .27** |
| Factor 4: Hunger | | | | | | | |
| Item 32 [R] | -.08 | -.10 | .06 | **.84** | .41 | .71 | .32** |
| Item 01 | .04 | .03 | -.09 | **.83** | .49 | .71 | .35** |
| Item 08 [R] | -.05 | .01 | .22 | **.71** | .58 | .79 | .38** |
| Item 70 [R] | .02 | .09 | .03 | **.68** | .48 | .66 | .37** |
| Item 74 | .17 | .03 | -.13 | **.63** | .43 | .67 | .24** |

*Note.* EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire; Extraction Method: Principal Component Analysis, Rotation Method: Promax with Kaiser Normalization; Factor loadings above .30 are in bold; [R] = reversed coded items; $r_{i(t-1)}$ =corrected item-total correlations,, $p_m$ = item difficulty, $r_{pb}$ = point-biserial correlations.

** $p < .001$

**Internal Consistencies**

Internal consistencies of the EDIP-Q subscales were high, with α (MIIC) = .91 (.61) for Emotions, .81 (.47) for Hunger, .92 (.61) for Satiety, and .89 (.56) for Discrimination.

**Construct Validity**

Correlations between the EDIP-Q subscales and other variables are presented in Table 2. Regarding convergent validity, intercorrelations of the EDIP-Q subscales were in the medium to high range. EDIP-Q subscales were moderately to strongly inversely related to the EDI-2 subscales and moderately to strongly related to IES-2 total score and subscales, except for a small correlation between EDIP-Q Hunger and EPR. Moderate to strong relationships were found between EDIP-Q subscales and the MAIA mean score and subscales Noticing, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening and Trusting, and weak to moderate relationships for Not Distracting and Not-Worrying. In addition, moderate relationships were found between the EDIP-Q subscales and PBC and SLWS. Regarding divergent validity, weak correlations were found between the EDIP-Q subscales and EC and PT.

**Table 2**

*Intercorrelations of Measured Variables (n = 1073).*

| | Convergent validity | | | | Discriminant validity | | | |
|---|---|---|---|---|---|---|---|---|
| **EDIP-Q** | S | E | D | H | S | E | D | H |
| Satiety (S) | | | | | | | | |
| Emotions (E) | .62** | | | | | | | |
| Discrimination (D) | .56** | .59** | | | | | | |
| Hunger (H) | .40** | .53** | .42** | | | | | |
| **EDI-2** | | | | | | | | |
| DT | -.55** | -.53** | -.50** | -.42** | | | | |
| BT | -.69** | -.56** | -.63** | -.35** | | | | |
| BD | -.53** | -.50** | -.44** | -.36** | | | | |
| **IES-2** | | | | | | | | |
| Mean Score | .75** | .63** | .62** | .50** | | | | |
| UPE | .40** | .44** | .41** | .41** | | | | |
| EPR | .60** | .44** | .52** | .16** | | | | |
| RHSC | .75** | .64** | .56** | .50** | | | | |
| B-FCC | .34** | .36** | .25** | .34** | | | | |
| **MAIA** | | | | | | | | |
| Mean Score | .56** | .73** | .45** | .46** | | | | |
| Noticing | .40** | .52** | .29** | .32** | | | | |
| Not Distracting | .27** | .34** | .24** | .30** | | | | |
| Not-Worrying | .21** | .24** | .22** | .09** | | | | |
| AR | .44** | .57** | .37** | .31** | | | | |
| EA | .34** | .49** | .24** | .32** | | | | |
| Self-Regulation | .40** | .51** | .27** | .32** | | | | |
| Body Listening | .41** | .54** | .30** | .35** | | | | |
| Trusting | .57** | .71** | .50** | .49** | | | | |
| **BCQ - PBC** | .30** | .23** | .32** | .30** | | | | |
| **SWLS** | .49** | .36** | .37** | .49** | | | | |
| **IRI** | | | | | | | | |
| EC | | | | | .01 | .08** | -.04 | .02 |
| PT | | | | | .13** | .17** | .07** | .03 |

*Note.* EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, EDI-2 = Eating Disorder Inventory-2, DT = Drive for Thinness, BT = Bulimic tendencies, BD = Body dissatisfaction, IES-2 = Intuitive Eating Scale 2, UPE = Unconditional Permission to Eat, ERP = Eating for Physical Rather Than Emotional Reasons, HSS = Reliance on Hunger and Satiety Cues, B-BFCC = Body-Food Choice Congruence, MAIA = Multidimensional Assessment of Interoceptive Awareness, AR = Attention Regulation, EA = Emotional Awareness, BCQ-PBC= Private Body Consciousness subscale of the Body Consciousness Questionnaire, SWLS = Satisfaction With Life Scale, IRI = Interpersonal Reactivity Index, EC = Empathetic concern, PT = Perspective Taking.

$^{**}p < 0.01$.

## 2.4. Study 2

### 2.4.1. Methods

**Procedure**

The procedure was the same as in Study 1.

**Participants**

The online survey was completed by 976 participants. To ensure data integrity, we followed the same procedure as in Study 1. A total of 16 participants were excluded from statistical analyses (high rates of missing or low item responses: $n = 2$; extreme response style: $n = 3$; bariatric surgery: $n = 3$; current pregnancy: $n = 1$; ED not officially diagnosed: $n = 7$). The remaining sample, therefore, consists of 958 participants aged between 18 and 76 years. Women ($n = 838$) had a mean age of 29.0 years ($SD = 10.8$) and mean BMI of 23.9 kg/m² ($SD = 7.2$ kg/m²), whereas men had a mean age 32.8 years ($SD = 13.7$) and mean BMI of 25.2 kg/m² ($SD = 6.9$ kg/m²). The sample included 692 German, 192 Luxembourgish, 32 Swiss, 27 Austrian, and 15 French participants, whereas 65 participants indicated another nationality. 351 participants were currently working and 343 were university students. The remaining participants stated that they were not in employment ($n = 25$ homeworkers, $n = 34$ pensioners, $n = 29$ jobseekers, $n = 63$ trainees, $n = 43$ high school students, and $n = 70$ "others").

The ED subsample was established in the same way as in Study 1 and consisted of 256 participants. As only seven males were diagnosed with an ED, we decided to discard their data from further analysis. The ED subsample finally consisted of 249 female participants, of which 156 individuals reported to have been diagnosed with AN, 116 with BN, 45 with BED, and 41 with EDNOS during their lifetime (multiple answers were possible). A total of 175 participants indicated to have a current ED (70.28% of the ED subsample), of which 49 individuals were diagnosed with AN, 47 with BN, 21 with BED, and 58 with EDNOS. As in Study 1, individuals with EDNOS diagnoses were excluded from statistical analyses for reasons of heterogeneity.

**Measures**

***Eating Disorder-specific Interoceptive Perception-Questionnaire (EDIP-Q)***

The 25-item version of the EDIP-Q derived from Study 1 to assess EDIP consists of four subscales: Emotions (7 items), Hunger (5 items), Satiety (7 items), and Discrimination (6 items). A 7-point Likert scale is used to assess the degree of agreement, whereby lower scores indicate greater difficulties in EDIP.

***Eating Disorder Examination-Questionnaire (EDE-Q)***

The German Version of the EDE-Q (Hilbert & Tuschen-Caffier, 2007) is a 28-item questionnaire for the assessment of ED psychopathology. In the present study, only six items were used to assess diagnostically-relevant core ED behaviors, i.e. the frequency of overeating episodes, loss of control over eating, binge eating, self-induced vomiting, laxative abuse, and excessive exercise. Participants were asked to indicate how often these behaviors occurred within the past 28 days.

***Dutch Eating Behavior Questionnaire (DEBQ)***

The German version of the DEBQ (Nagl et al., 2016) is a 33-item questionnaire to assess three distinct maladaptive eating behaviors, i.e. Emotional Eating, External Eating, and Restrained Eating. Each item is answered on a scale ranging from 1 (never) to 5 (very often), with higher scores indicating more frequent endorsement of maladaptive eating behavior. Cronbach's α (MIIC) in the current sample was .96 (.65), .77 (.25), and .93 (.56) for the three subscales.

### ***Multidimensional Assessment of Interoceptive Awareness (MAIA)***

The German version of the MAIA (Bornemann et al., 2014) is described in detail in the method section of Study 1. Cronbach's α (MIIC) in the current sample ranged from .62 to .93 (.31 to .82).

### ***Emotionale-Kompetenz-Fragebogen (eng.: emotional compentency questionnaire; EKF)***

The EKF (Rindermann, 2009) is a German 62-item questionnaire for the assessment of emotional competencies. In the present study, only the subscale Perception and Acknowledgement of one's own Emotions (EKF-Emotion; 15 items) was used to assess the ability to perceive and understand one's own emotions. Items were answered on a scale ranging from 1 (not at all true) to 5 (definitely true), with higher scores indicating a better ability to perceive and recognize emotions. Cronbach's α (MIIC) in the current sample was .94 (.51).

### ***Three-Factor-Eating Questionnaire (TFEQ)***

The German version of the TFEQ (Pudel & Westenhöfer, 1989) consists of 51 items to measure three dimensions of eating behavior, i.e. Cognitive Restraint of Eating, Disinhibition, and Hunger. In the present study, only the subscale Hunger (TFEQ-Hunger; 14 items) was used to measure experienced feelings of hunger, often perceived as disturbing. Higher sum scores indicate stronger endorsement of hunger feelings. Cronbach's α (MIIC) in the current sample was .83 (.47).

### ***Mindful Eating Questionnaire (MEQ)***

The MEQ (Framson et al., 2009) is a 28-item questionnaire to measure mindful eating, which is defined as "non-judgmental awareness of physical and emotional sensations while eating or in a food-related environment". In the present study, only the subscale Disinhibition (8 items) was used, which assesses the inability to stop eating despite of being full, with lower scores indicating greater inability. The items were translated from English into German and backtranslated into English by independent bilingual researchers. The back-translation was compared with the original English version. In case of discrepancies, the item formulations were discussed, and necessary adjustments were made. Cronbach's α (MIIC) in the current sample was .88 (.47).

**Statistical Analyses**

To test the four-factor structure of the EDIP-Q established in Study 1, we conducted CFA with maximum likelihood estimation and the covariance matrix as input using MPLUS (Version 8.7). Goodness-of-fit for the models was evaluated with the $\chi^2$-statistic. As the $\chi^2$-test is sensitive to sample size and usually significant in samples with more than 200 cases (Browne & Cudeck, 1993), we also used the Comparative Fit Index (CFI) and Normed Fit Index (NFI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) as guides in assessing fit. Levels of 0.90 or higher for CFI and NFI, and 0.08 or lower for RMSEA and SRMR indicate a good fit of the model to the data (Bentler & Bonett, 1980; Browne & Cudeck, 1993; Hu & Bentler, 1999). Following the same procedure as in Study 1, we visually inspected the distribution of each variable. As no obvious signs of deviation from a normal distribution were found, Pearson's *rs* were calculated to determine convergent and divergent validity between EDIP-Q and related and unrelated concepts according to Cohen's (1992) criteria. This study was not preregistered. Materials and analysis code for this study are available by emailing the corresponding author.

### 2.4.2. Results

**Confirmatory Factor Analysis**

In a first step, we established a first-order model (based on the results from Study 1) and examined the magnitude and pattern of correlations among the hypothesized factors in the first-order solution. The EDIP-Q items were specified to load on their respective latent first-order factor. Relationships between the four latent factors were estimated. The four-factor solution provided a good fit for the data, CFI = 0.95, TLI = 0.94, SRMR = 0.047, RMSEA = 0.052, 90% CI [0.049, 0.056], $\chi^2(1, 269) = 978.122$, $p < 0.001$. Factor loadings of all items were high (> .50) and the first-order factors were significantly interrelated (*rs* range from .45 to .64, $p < .001$), indicating the viability of a postulated second-order model (Brown, 2015).

In a second step, we specified, therefore, a second-order model, in which the first-order factors loaded on a higher-order EDIP factor. This model provided a good fit for the data, CFI = 0.95, TLI = 0.94, SRMR = 0.050, RMSEA = 0.053, 90% CI [0.050, 0.057], $\chi^2(1, 271) = 922.17$, $p < 0.001$. Both the item-factor loadings and the first-order factor loadings on the higher-order EDIP factor were high (≥ 0.50; Backhaus et al., 2015). Table 3 includes the item-factor loadings as well as the first-order factor loadings on the higher order EDIP factor for the overall sample.

**Table 3**

*Standardized Item and Factor Loadings of the EDIP Questionnaire obtained by Confirmatory Factor Analyses of the Overall Sample (n = 958).*

| Factor and EDIP-Q items | First order | Second order |
|---|---|---|
| Factor 1: Satiety | | .80 |
| Item 16 | .79 | |
| Item 31 | .86 | |
| Item 65 | .82 | |
| Item 36 [R] | .82 | |
| Item 37 | .76 | |
| Item 43 | .61 | |
| Item 24 [R] | .80 | |
| Factor 2: Emotions | | .80 |
| Item 49 | .79 | |
| Item 58 | .83 | |
| Item 76 | .72 | |
| Item 67 | .77 | |
| Item 10 | .85 | |
| Item 33 | .68 | |
| Item 30 | .71 | |
| Factor 3: Discrimination | | .76 |
| Item 42 [R] | .74 | |
| Item 23 [R] | .82 | |
| Item 53 [R] | .82 | |
| Item 61 [R] | .71 | |
| Item 21 [R] | .72 | |
| Item 15 [R] | .56 | |
| Factor 4: Hunger | | .63 |
| Item 32 [R] | .66 | |
| Item 01 | .78 | |
| Item 08 [R] | .85 | |
| Item 70 [R] | .61 | |
| Item 74 | .60 | |

*Note.* EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire; [R] reversed coded items;

**Internal consistencies**

Internal consistencies for the EDIP-Q were high, with α (MIIC) = .94 (.40) for the total score (TS), .92 (.65) for Emotions, .86 (.53) for Hunger, .93 (.64) for Satiety, and .88 (.55) for Discrimination.

**Construct Validity**

Correlations between the EDIP-Q TS and subscales and other variables are presented in Table 4. Regarding convergent validity, the intercorrelations of the EDIP-Q TS and subscales were in the medium to high range. The EDIP-Q (TS and subscales) was inversely related to core ED behaviors as assessed by the EDE-Q. Specifically, moderate to strong negative relationships were found between the EDIP-Q (TS and subscales) and Loss of control and Binge Eating. Weak to moderate negative relationships were found between the EDIP-Q (TS and subscales) and Self-induced vomiting, Laxative/Diuretics abuse and Excessive exercise. Weak negative relationships were found between the EDIP-Q (TS and subscales) and Overeating. The EDIP-Q (TS and subscales) was negatively related to DEBQ subscales. Specifically, moderate to large correlations were found for Restrained and Emotional Eating, except for a small relationship between EDIP-Q Hunger and Emotional Eating. Weak to moderate relationships were found between the EDIP-Q (TS and subscales) and External Eating. There was only a weak correlation between the EDIP-Q (TS and subscales) and BMI. The correlations between the EDIP-Q subscales and the MAIA subscales were comparable to those obtained in Study 1. Moderate to large correlations were identified between the EDIP-Q TS and MAIA mean score and subscales.

To further address the convergent validity of the EDIP-Q Emotions, Hunger and Satiety, we examined their relationship to subscales designed to measure the same construct. EDIP-Q Emotions was strongly related to EKF-Emotion. EDIP-Q Satiety was significantly inversely related to MEQ-Disinhibition. EDIP-Q Hunger and TFEQ Hunger were weakly negatively correlated. In addition, the EDIP-Q subscales correlated with subscales measuring different constructs. Specifically, we found small to medium negative relationships between EDIP-Q Emotions and TFEQ-Hunger and MEQ-Disinhibition. EDIP-Q Hunger was moderately related to EKF-Emotion, and weakly related to MEQ-Disinhibition. EDIP-Q Satiety was largely correlated with EKF-Emotion, and largely inversely with TFEQ-Hunger.

**Table 4**

*Intercorrelations of Measured Variables (n = 958).*

| | Convergent validity | | | | |
|---|---|---|---|---|---|
| **EDIP-Q** | TS | S | E | D | H |
| Total Score (TS) | | | | | |
| Satiety (S) | .84** | | | | |
| Emotions (E) | .84** | .60** | | | |
| Discrimination (D) | .78** | .39** | .52** | | |
| Hunger (H) | .68** | .37** | .50** | .39** | |
| **EDE-Q** | | | | | |
| Overeating | -.06 | -.03 | -.04 | -.07** | -.07** |
| Loss of control | -.46** | -.47** | -.35** | -.39** | -.20** |
| Binge Eating | -.50** | -.51** | -.35** | -.44** | -.23** |
| Self-induced vomiting | -.32** | -.25** | -.28** | -.23** | -.26** |
| Laxative/Diuretics abuse | -.18** | -.12** | -.18** | -.11** | -.17** |
| Excessive exercise | -.27** | -.20** | -.20** | -.16** | -.31** |
| **DEBQ** | | | | | |
| Restrained Eating | -.49** | -.39** | -.40** | -.35** | -.43** |
| Emotional Eating | -.56** | .-.59** | -.39** | -.60** | -.15** |
| External eating | -.13 | -.28** | -.04 | -.18** | -.17** |
| **BMI** | -.13** | -.19** | -.04 | -.16 | .02 |
| **MAIA** | | | | | |
| Mean Score | .70** | .52** | .76** | .42** | .45** |
| Noticing | .50** | .40** | .58** | .28** | .30** |
| Not Distracting | .44** | .32** | .44** | .26** | .37** |
| Not-Worrying | .21** | .19** | .20** | .19** | .09** |
| AR | .59** | .45** | .63** | .39** | .36** |
| EA | .39** | .30** | .49** | .15** | .28** |
| Self-Regulation | .50** | .41** | .54** | .28** | .31** |
| Body Listening | .51** | .42** | .55** | .27** | .32** |
| Trusting | .70** | .55** | .76** | .42** | .45** |
| **EKF-Emotion** | .67** | .49** | .76** | .48** | .41** |
| **TFEQ-Hunger** | -.41** | -.58** | -.26** | -.42 ** | -.08** |
| **MEQ-Disinhibition** | -.02 | -.62** | -.24** | -.35** | -.02 |

*Note.* EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, EDE-Q = Eating Disorder Examination Questionnaire, DEBQ = Dutch Eating Behaviour Questionnaire, BMI = Body Mass Index, MAIA = Multidimensional Assessment of Interoceptive Awareness, AR = Attention Regulation, EA = Emotional Awareness, EKF = Emotionale Kompetenz Fragebogen, TFEQ = Three-Factor-Eating Questionnaire, MEQ = Mindful Eating Questionnaire.

**$p < 0.01$.

## 2.5. Study 1 and 2: Group Comparisons

### 2.5.1. Methods

**Procedure and Participants**

The procedure and samples are described in the methods sections of Study 1 and Study 2.

**Statistical Analyses**

Sex differences in EDIP were examined using Multivariate Analyses of Variance (MANOVA), with EDIP-Q TS and subscales as dependent variables and Sex as between-group factor. Compared to HC, differences between participants with self-reported current and past ED diagnoses and between different types of EDs were examined using MANOVA, with EDIP-Q TS and subscales as dependent variables and Diagnostic Status as between-subjects factor. Only the female subgroup of the non-clinical sample was included in the analysis, because the ED subgroup included female participants only. Wilks' Lamba ($\Lambda$) was used as test statistic for *F*-tests in all MANOVA models, because it is more robust with unequal sample sizes and variances (Ateş et al., 2019). When *F*-tests were significant for the comparison of more than two groups, post-hoc analyses were conducted using the Games-Howell multiple comparison procedure for unequal sample sizes and variances (Games & Howell, 1976). Partial eta squared ($\eta_p^2$) was calculated for estimation of effect sizes, where $\eta_p^2 = .01$ is considered as "small", $\eta_p^2 = .06$ "medium", and $\eta_p^2 = .14$ "large" (Cohen, 1988). Statistical analyses were performed with IBM SPSS Statistics (Version 27; IBM Corp., Armonk, NY, USA). Critical alpha-level was set to .05 in all analyses.

### 2.5.2. Results

**Sex differences**

EDIP-Q mean scores and *SDs* for men and women are presented in Table 5. In sample 1, the MANOVA with EDIP-Q TS and subscales as dependent variables and Sex as between-subject factor revealed higher EDIP scores in men than in women, $\Lambda = .98$, $F(5,1067) = 3.625$, $p < .01$, $\eta_p^2 = .02$. The same effect was found in sample 2, $\Lambda = .97$, $F(5,952) = 5.236$, $p < .01$, $\eta_p^2 = .03$.

**Diagnostic Status I: Healthy controls (HC) versus self-reported past and current ED**

EDIP-Q mean scores and *SDs* for female healthy participants and participants with self-reported current and past ED diagnoses are presented in Table 6. In sample 1, the MANOVA with EDIP-Q TS and subscales as dependent variables and Diagnostic status I as between-subjects factor revealed an overall effect for Diagnostic status I, $\Lambda = .60$, $F(10,1762) = 51.47$, $p < .001$, $\eta_p^2 = .23$. The same effect was found in sample 2, $\Lambda = .71$, $F(10,1662) = 31.48$, $p < .001$, $\eta_p^2 = .16$. Group differences on the TS and all subscales were significant (*ps* < .05), except for a marginally significant group difference ($p = 0.08$) on Emotions between HC and participants with self-reported past ED in sample 2. Overall, HC had the highest scores, followed by participants with self-reported past and current EDs.

**Table 5**

*EDIP Mean Scores (M) and Standard Deviations (SD) for Men and Women in Studies 1 and 2.*

| EDIP-Q | Study 1 | | | | | | | Study 2 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men (*n* =185) | | Women (*n* = 888) | | *F(1,1071)* | *p* | $\eta_p^2$ | Men (*n* = 120) | | Women (*n* = 838) | | *F(1,956)* | *p* | $\eta_p^2$ |
| | *M* | *SD* | *M* | *SD* | | | | *M* | *SD* | *M* | *SD* | | | |
| TS | 5.5 | 0.8 | 5.1 | 1.1 | 19.17 | < .001 | .02 | 5.4 | 0.8 | 4.9 | 1.2 | 21.75 | < .001 | .02 |
| E | 5.5 | 0.9 | 5.2 | 1.3 | 13.46 | .003 | .01 | 5.5 | 1.0 | 4.8 | 1.4 | 22.23 | < .001 | .02 |
| H | 5.5 | 1.1 | 5.2 | 1.4 | 10.27 | .015 | .01 | 5.3 | 1.3 | 4.9 | 1.5 | 7.68 | .006 | .01 |
| S | 5.0 | 1.3 | 4.5 | 1.6 | 31.36 | < .001 | .01 | 4.9 | 1.3 | 4.3 | 1.6 | 15.65 | < .001 | .02 |
| D | 6.1 | 1.0 | 5.7 | 1.4 | 23.06 | < .001 | .01 | 5.9 | 1.3 | 5.5 | 1.4 | 8.53 | .004 | .01 |

*Note*. Group differences were calculated using MANOVA, EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, TS = Total Score, E = Emotion subscale, H = Hunger subscale, S = Satiety subscale, D = Discrimination subscale.

**Table 6**

*EDIP Mean Scores (M) and Standard Deviations (SD) for Female Healthy Participants and Participants With Past and Current Self-Reported Eating Disorder, for Studies 1 and 2.*

| EDIP-Q | Study 1 | | | | | | | | | Study 2 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HC (*n* = 676) | | Past ED (*n* = 77) | | Current ED (*n* = 135) | | *F(2,885)* | *p* | $\eta_p^2$ | HC (*n* = 589) | | Past ED (*n* = 74) | | Current ED (*n* = 175) | | *F(2,835)* | *p* | $\eta_p^2$ |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | |
| TS | $5.5_a$ | 0.9 | $5.0_b$ | 1.1 | $3.5_c$ | 1.0 | 275.16 | < .001 | .38 | $5.2_a$ | 1.1 | $4.8_b$ | 1.1 | $3.7_c$ | .9 | 143.29 | < .001 | .26 |
| E | $5.5_a$ | 1.0 | $5.02_b$ | 1.3 | $3.50_c$ | 1.3 | 202.74 | < .001 | .31 | $5.2_a$ | 1.3 | $4.9_a$ | 1.4 | $3.5_b$ | 1.2 | 122.06 | < .001 | .23 |
| H | $5.6_a$ | 1.1 | $4.99_b$ | 1.3 | $3.6_c$ | 1.5 | 154.27 | < .001 | .26 | $5.3_a$ | 1.3 | $4.6_b$ | 1.5 | $3.7_c$ | 1.5 | 96.85 | < .001 | .19 |
| S | $4.9_a$ | 1.4 | $4.35_b$ | 1.7 | $2.8_c$ | 1.3 | 126.16 | < .01 | .22 | $4.6_a$ | 1.5 | $4.1_b$ | 1.5 | $3.2_c$ | 1.4 | 59.97 | < .001 | .13 |
| D | $6.1_a$ | 1.1 | $5.61_b$ | 1.4 | $4.2_c$ | 1.7 | 134.94 | < .01 | .23 | $5.8_a$ | 1.3 | $5.6_a$ | 1.3 | $4.5_b$ | 1.5 | 62.03 | < .001 | .13 |

*Note*. Group differences were calculated using MANOVA, means with different subscripts differ at the *p* = .05 level, HC = Healthy control participants, Past ED = participants with past self-reported eating disorder, Current ED = participants with current self-reported eating disorder, EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, TS = Total Score, E = Emotion subscale, H = Hunger subscale, S = Satiety subscale, D = Discrimination subscale.

**Diagnostic Status II: Healthy controls (HC) versus types of EDs**

EDIP-Q mean scores and *SDs* for female healthy participants and participants reporting a current diagnosis of AN, BN and BED are presented in Table 7. In sample 1, the MANOVA with EDIP-Q TS and subscales as dependent variables and Diagnostic status II as between-subject factor revealed an overall effect for Diagnostic status II, $\Lambda = .57$, $F(15,2120) = 31.81$, $p < .001$, $\eta_p^2 = .17$. Post-hoc tests showed that all types of EDs scored significantly lower on the TS and subscale scores compared to HC. Among types of EDs, there were no significant group differences on the TS and Emotions. Individuals with BN and BED, however, scored higher on Hunger ($p = .044$ and $p = .017$, resp.) and lower on Satiety ($p = .05$ and $p = .09$, resp.) than participants with AN. Furthermore, participants with BN and BED scored lower on Discrimination compared to participants with AN ($p = .032$ and $p = .033$, resp.). No other post hoc comparisons reached statistical significance.

In sample 2, the MANOVA with EDIP-Q TS and subscales as dependent variables and Diagnostic status III as between-subjects factor showed an overall effect for Diagnostic status II, $\Lambda = .71$, $F(15,2131) = 19.18$, $p < .001$, $\eta_p^2 = .11$. Post-hoc tests revealed that all types of EDs scored significantly lower on the TS and subscale scores compared to HC. Post-hoc tests between ED subgroups yielded significant group differences on the TS and the subscales Satiety and Discrimination. In detail, individuals with AN had a higher TS compared to participants with BN ($p = .019$) and BED ($p = .051$). Participants with BN and BED scored significantly lower on Satiety ($p < .001$ and $p = .045$, resp.) and Discrimination (*ps* $< .001$) compared to participants with AN. No other post hoc comparisons reached statistical significance.

**Table 7**

*EDIP Mean Scores (M) and Standard Deviations (SD) for Healthy Control Participants and Participants With Current Self-Reported Anorexia nervosa (AN), Bulimia nervosa and Binge-Eating Disorder (BED), for Studies 1 and 2.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Study 1 | | | | | | | | | | |
| EDIP-Q | HC (*n* = 676) | | AN (*n* = 43) | | BN (*n* = 36) | | BED (*n* = 21) | | *F(3,776)* | *p* | $\eta_p^2$ |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | |
| TS | $5.5_a$ | 0.9 | $3.6_b$ | 1.0 | $3.3_b$ | 1.0 | $3.5_b$ | 0.9 | 148.87 | < .001 | .37 |
| E | $5.2_a$ | 1.0 | $3.4_b$ | 1.4 | $3.4_b$ | 1.3 | $3.8_b$ | 1.0 | 111.98 | < .001 | .30 |
| H | $5.6_a$ | 1.1 | $3.1_c$ | 1.3 | $4.0_b$ | 1.5 | $4.4_b$ | 1.6 | 83.77 | < .001 | .25 |
| S | $4.9_a$ | 1.4 | $3.3_b$ | 1.5 | $2.5_b$ | 1.2 | $2.5_b$ | 1.0 | 70.24 | < .001 | .21 |
| D | $6.1_a$ | 1.1 | $4.8_b$ | 1.5 | $3.8_c$ | 1.7 | $3.6_c$ | 1.5 | 83.37 | < .001 | .25 |
| | Study 2 | | | | | | | | | | |
| EDIP-Q | HC (*n* = 589) | | AN (*n* = 49) | | BN (*n* = 47) | | BED (*n* = 21) | | *F(3,776)* | *p* | $\eta_p^2$ |
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | |
| TS | $5.2_a$ | 1.1 | $4.0_b$ | 0.9 | $3.3_c$ | 0.7 | $3.3_{bc}$ | 1.0 | 78.90 | < .001 | .23 |
| E | $5.2_a$ | 1.3 | $3.5_b$ | 1.2 | $3.4_b$ | 1.1 | $3.0_b$ | 1.1 | 66.58 | < .001 | .21 |
| H | $5.2_a$ | 1.3 | $3.5_b$ | 1.4 | $3.8_b$ | 1.4 | $4.2_b$ | 1.5 | 39.21 | < .001 | .13 |
| S | $4.6_a$ | 1.5 | $3.7_b$ | 1.3 | $2.5_c$ | 1.0 | $2.7_c$ | 1.4 | 39.98 | < .001 | .13 |
| D | $5.8_a$ | 1.3 | $5.1_b$ | 1.5 | $3.8_c$ | 1.3 | $3.6_c$ | 1.2 | 51.87 | < .001 | .17 |

*Note*. Group differences were calculated using MANOVA, means with different subscripts differ at the *p* = .05 level, HC = Healthy control, AN = Anorexia nervosa, BN = Bulimia nervosa, BED = Binge-eating disorder, EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, TS = Total Score, E = Emotion subscale, H = Hunger subscale, S = Satiety subscale, D = Discrimination subscale.

## 2.6. General Discussion

Although the literature points to a differential contribution of emotions, hunger and satiety signals to ED symptoms (e.g., Poovey et al., 2022; van Dyck et al., 2016), there is a lack of appropriate measures that distinguish between the perception of these visceral signals. The first objective of the present studies, therefore, concerned the development and initial validation of the EDIP-Q, a multifaceted assessment of EDIP. The second objective was to investigate differences in EDIP using the EDIP-Q, including sex differences and differences between participants with a self-reported current and past ED diagnosis (diagnostic status I), as well as between different types of EDs (diagnostic status II), compared with healthy participants.

**Factor Structure**

In Study 1, the factor structure of the original scale was examined using EFA in a large sample of individuals with and without self-reported EDs, and in different subsamples. With a high degree of factor similarity between the different subsamples, our results led to the specification of a 25-item instrument, with four factors forming the subscales *Emotions* (assessment of emotion perception), *Hunger* (assessment of the perception of hunger signals), *Satiety* (assessment of the perception of satiety signals), and *Discrimination* (assessment of the ability to discriminate between hunger and emotional states). In Study 2, the hypothesized four-factor structure was confirmed using CFA in an equally large sample of individuals with and without self-reported EDs. The moderate to strong intercorrelations of the first-order factors (i.e. Emotions, Hunger, Satiety, and Discrimination) indicated the presence of a higher-order EDIP factor. Hence, we tested a second-order model, in which the first-order factors loaded on a higher-order EDIP factor. The second-order model also provided a good fit for the data. These results provide initial empirical evidence that the first-order factors are independent of each other but represent important components of EDIP. Accordingly, EDIP-Q subscale scores and the TS should be calculated, the latter reflecting the general ability of EDIP.

**Construct Validity**

Regarding convergent validity, the EDIP-Q TS and subscales were inversely related to self-reports of ED symptoms and different maladaptive eating styles, including non-intuitive, emotional, external, and restrictive eating. The correlation coefficients fell predominantly within the moderate to high range, except for the small correlation between EDIP-Q Hunger and IES-EPR. This can be ascribed to the fact that the latter measures the individual tendency to eat due to physical hunger rather that to cope with emotional distress. Some items refer to emotional eating as a coping strategy (e.g. "I find myself eating when I'm feeling emotional (e.g. anxious, depressed, sad), even when I'm not physically hungry."). The EDIP-Q Hunger items refer, however, exclusively to the perception of physiological hunger, which explains the weak association between the two subscales. Overall, these findings indicate that impaired EDIP is associated with ED symptom severity and maladaptive eating behaviors. Although the BMI has been associated with both maladaptive eating and interoceptive deficits (e.g., Jenkinson et al., 2018; Nagl et al., 2016; Richard et al., 2019), only small correlations were found between the EDIP-Q (TS and subscales) and BMI. This weak association may be explained by other factors affecting the BMI such as age, sex, metabolism, muscle mass, bone density. In line with our hypothesis, the EDIP-Q TS and subscale scores were moderately positively related to self-report measures on the perception of internal bodily states (i.e. BCQ, MAIA). This suggest that deficits in EDIP are associated with general difficulties in focusing on physical states. In addition, the correlation coefficients were in a higher range than those found in other studies investigating the relationship between different self-report measures of interoception (e.g., Murphy et al., 2020), which indicates a higher degree of convergence of the EDIP-Q. EDIP-Q subscale scores were moderately related to self-reported overall life satisfaction. In summary, our findings imply that the EDIP-Q is a suitable measure of interoceptive processing in the domain of maladaptive eating behaviors and EDs. Further research is, however, warranted to investigate the relationship between the EDIP-Q and other interoceptive dimensions.

To investigate further aspects of convergent validity of EDIP-Q subscales Emotions, Hunger and Satiety, we investigated whether these subscales correlated with subscales of other questionnaires designed to measure the same construct. In line with our hypothesis, EDIP-Q Emotions was strongly related to the perception and acknowledgement of one's own emotions (assessed by EKF-Emotion), indicating a high degree of convergence between the two subscales. As expected, EDIP-Q Satiety was strongly inversely related to the inability to stop eating despite of being full (assessed by MEQ-Disinhibition), providing evidence that EDIP-Q Satiety is an appropriate measure of the perception of satiety signals. Contrary to our expectations, we found a small correlation between EDIP-Q Hunger and TFEQ-Hunger. Comparing the content of the items, it becomes apparent that TFEQ-Hunger assesses experienced appetite as response to external stimuli (e.g. "When I see a real delicacy, I often get so hungry that I have to eat right away"), whereas EDIP-Q Hunger was designed to directly assess the perception of physiological hunger signals. Interestingly, we also found small to large correlations between the EDIP-Q subscales Emotion, Hunger and Satiety with subscales designed to measure another physical state (e.g. moderate relationships between EDIP-Q Hunger and Satiety with EKF-Emotion). These associations can be attributed to the fact that similar bodily processes are involved in the perception of emotions, hunger and satiety. Together with the strong intercorrelations found between the

EDIP-Q subscales, these findings provide additional evidence that the EDIP-Q factors are independent but interrelated.

To address divergent validity, we examined the relationship between the EDIP-Q and self-reports on empathetic concern and perspective taking. As expected, EDIP-Q subscales were unrelated to EC and PT, supporting the divergent validity of the EDIP-Q.

**Group Comparisons**

In both study samples, women had significantly lower EDIP-Q scores than men, indicating a sex-specific trend towards difficulties in perceiving and discriminating between emotion, hunger and satiety signals. Given the higher prevalence of EDs among females (Galmiche et al., 2019), it is reasonable to assume that this sex-specific trend represents a possible risk factor for the development of ED symptoms in women.

We examined group differences in EDIP based on diagnostic status. In both study samples, we observed the lowest EDIP-Q scores in female participants with self-reported current ED diagnosis, followed by participants with self-reported past ED diagnosis and HCs. These results suggest that EDIP is especially impaired in individuals currently experiencing ED symptoms and improves during recovery, although these are not comparable to scores of participants without a self-reported ED history. Together with the high correlations found between the EDIP-Q and self-reports of ED severity, these findings support etiological models, in which impaired interoceptive processing plays a crucial role in the development and maintenance of EDs (e.g., Martin et al., 2019).

To determine whether EDIP plays a differential role in the development and maintenance of different EDs, we examined differences between women with self-reported AN, BN and BED compared to HC. As expected, individuals with EDs had significantly lower total and subscale scores than HC, indicating an overall impaired ability of EDIP in EDs. As expected, individuals with AN, BN and BED have equal difficulty in perceiving emotions and differ in their perception of hunger and satiety signals and in their ability to distinguish between emotional states and hunger. Compared to AN, female participants with BN or BED reported higher sensitivity to hunger, lower sensitivity to satiety, and greater difficulty distinguishing between emotional states and feelings of hunger. These results are consistent with previous findings which show binge eating in response to unpleasant emotional states in individuals with BN and BED (e.g. Meule et al., 2021; Schaefer et al., 2020) and reflect the clinical picture of BN and BED, which is characterized by recurrent episodes of binge eating, i.e. eating large amounts of food in a short period of time (APA, 2013). The opposite picture was observed in individuals with AN, who reported greater difficulty perceiving hunger signals but lesser difficulty perceiving satiety signals and distinguishing between emotional states and hunger compared with BN and BED.

Although profiles of deficits in EDIP were evident in both study samples, not all differences reached statistical significance. A possible explanation could be that ED diagnoses were self-reported, resulting in a certain degree of heterogeneity within groups and thus, less meaningful group differences in EDIP. Although only participants who indicated being diagnosed by a qualified mental health professional were included in the clinical subsample, it was not possible to verify the validity of the diagnoses and to determine whether the participants fulfilled the diagnostic criteria. Future research should, therefore, consider using the EDIP-Q in a controlled clinical setting and examine group differences in individuals diagnosed with a standardized clinical interview. Notwithstanding the former, together with EFA and CFA results, these differences between ED types point to the need to differentiate the components of EDIP and to develop more targeted treatment approaches for EDs.

## Limitations

Selection and response bias are common in web-based data collection. Both samples consisted primarily of female participants (82.80% in Study 1 and 87.47% Study 2), since women are more interested in, and seek treatment for, EDs, which may have led to a greater willingness to participate. Previous research on EDs using a similar study design observed a similar gender ratio in their sample population (e.g. van Dyck et al., 2016). Although the risk of response bias in the data cannot be excluded, a number of studies have shown that the study format does not affect psychometric properties of self-report measures and leads to comparable questionnaire results (e.g. Mayr et al., 2012). Moreover, the use of anonymous web-based surveys can be even more beneficial for collecting unbiased data on sensitive issues, such as eating- and body related information (Kays et al., 2012). Cronbach's $\alpha$ coefficients for some subscales (e.g. BCQ) were below the acceptable range ($\alpha < .60$). Since the $\alpha$ coefficient depends on the number of items in the scale, the MIIC was additionally considered as a direct indicator of internal consistency. All MIIC were above the lower cut-off value of .15 (Clark & Watson, 2016), indicating a sufficient level of internal consistency. All subscales were therefore retained.

## Conclusions

In summary, our findings imply that the EDIP-Q is a suitable measure of interoceptive processing in the domain of maladaptive eating behaviors and EDs. The EDIP-Q has sound psychometric properties and excellent construct validity. Using the EDIP-Q, we were able to show (1) that deficits in EDIP are significantly present in EDs and improve with recovery, and (2) that the ability to perceive and distinguish between emotions, hunger and satiety is differentially impaired in AN, BN and BED. The EDIP-Q provides a differential indication of deficits regarding EDIP, making it a useful clinical assessment tool that offers the basis for developing more targeted and personalized treatment approaches and can be used throughout the course of psychotherapy to track treatment progress.

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## 2.8. Supplemental Materials

**Table S1**

Item factor loadings for and Tucker's congruence coefficients (ϕ) between the subsamples of men and women from Study 1.

| EDIP-Q Items | Factor loadings for men (*n* = 185) | | | | Factor loadings for women (*n* = 888) | | | | ϕ |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| Factor 1: Satiety | | | | | | | | | .96 |
| Item 16 | **.75** | .12 | -.02 | -.02 | **.90** | -.08 | -.02 | -.02 | |
| Item 31 | **.90** | -.06 | -.05 | .07 | **.84** | .10 | -.05 | .01 | |
| Item 65 | **.91** | -.03 | .02 | -.07 | **.84** | .03 | .07 | -.03 | |
| Item 36 [R] | **.83** | -.11 | .22 | -.20 | **.80** | -.11 | .20 | -.06 | |
| Item 37 | **.80** | .00 | -.12 | .05 | **.73** | .15 | -.15 | .04 | |
| Item 43 | **.65** | .09 | -.12 | .25 | **.76** | .14 | -.18 | .00 | |
| Item 24 [R] | **.69** | .15 | .12 | -.02 | **.69** | -.16 | .28 | .13 | |
| Factor 2: Emotions | | | | | | | | | .96 |
| Item 49 | .10 | **.75** | .00 | -.07 | .01 | **.86** | .01 | -.01 | |
| Item 58 | .10 | **.76** | .02 | -.07 | .01 | **.86** | .00 | .03 | |
| Item 76 | .02 | **.79** | -.11 | -.12 | -.05 | **.82** | .03 | .00 | |
| Item 67 | -.14 | **.69** | .24 | -.06 | -.03 | **.80** | .15 | -.03 | |
| Item 10 | -.13 | **.74** | .06 | .08 | .09 | **.77** | .03 | -.01 | |
| Item 33 | .13 | **.57** | -.01 | .13 | -.02 | **.78** | .00 | .04 | |
| Item 30 | .06 | **.64** | -.10 | .15 | .13 | **.64** | -.05 | .04 | |
| Factor 3: Discrimination | | | | | | | | | .98 |
| Item 42 [R] | -.01 | -.02 | **.81** | .04 | -.06 | .01 | **.84** | .03 | |
| Item 23 [R] | .22 | -.04 | **.72** | .05 | .03 | .05 | **.82** | -.03 | |
| Item 53 [R] | .12 | .04 | **.68** | -.02 | .02 | .14 | **.79** | -.09 | |
| Item 61 [R] | .13 | -.09 | **.69** | .04 | .06 | -.01 | **.77** | -.04 | |
| Item 21 [R] | -.09 | .14 | **.73** | .03 | .11 | .02 | **.75** | -.02 | |
| Item 15 [R] | -.22 | .02 | **.59** | -.09 | -.15 | -.04 | **.71** | .14 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Factor 4: Hunger | | | | | | | | | .95 |
| Item 32 [R] | -.23 | .01 | .09 | **.79** | -.05 | -.11 | .05 | **-85** | |
| Item 01 | .11 | -.04 | -.23 | **.73** | .02 | .05 | -.08 | **.83** | |
| Item 08 [R] | -.09 | -.06 | .31 | **.67** | -.05 | .03 | .20 | **.72** | |
| Item 70 [R] | .19 | -.09 | .05 | **.58** | -.06 | .13 | .03 | **.68** | |
| Item 74 | .04 | .16 | -.06 | **.54** | .19 | .03 | -.15 | **.64** | |

*Note*. EDIP-Q = Eating Disorder specific Interoceptive Perception Questionnaire; Extraction Method: Principal Component Analysis, Rotation Method: Promax with Kaiser Normalization; Factor loadings above .40 are in bold; [R] = reversed coded items

**Table S2**

Item factor loadings for and Tucker's congruence coefficients (ϕ) between the subsamples of female healthy control participants and female participants with a self-reported eating disorder diagnosis (ED) from Study 1.

| EDIP-Q Items | Factor loadings for HC (*n* = 676) | | | | Factor loadings for ED (*n* = 212) | | | | ϕ |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | |
| Factor 1: Satiety | | | | | | | | | .96 |
| Item 16 | **.87** | -.02 | -.11 | .02 | **.86** | -.14 | .11 | -.04 | |
| Item 31 | **.89** | .03 | -.03 | -.03 | **.73** | .24 | -.10 | .02 | |
| Item 65 | **.87** | -.01 | .04 | -.02 | **.76** | .12 | .09 | -.06 | |
| Item 36 [R] | **.77** | -.07 | .19 | -.02 | **.80** | -.10 | .21 | -.12 | |
| Item 37 | **.76** | .08 | -.04 | -.05 | **.47** | .37 | -.30 | .16 | |
| Item 43 | **.72** | .17 | -.20 | .06 | **.73** | .11 | .02 | -.04 | |
| Item 24 [R] | **.65** | -.14 | .26 | .13 | **.79** | -.19 | .27 | .12 | |
| Factor 2: Emotions | | | | | | | | | .95 |
| Item 49 | .01 | **.80** | .05 | -.06 | -.09 | **.85** | .02 | .06 | |
| Item 58 | .01 | **.82** | -.02 | .04 | .00 | **.87** | .03 | -.03 | |
| Item 76 | -.07 | **.79** | -.02 | .00 | -.03 | **.76** | .13 | -.01 | |
| Item 67 | -.02 | **.75** | .14 | .01 | -.06 | **.82** | .19 | -.09 | |
| Item 10 | .12 | **.76** | -.06 | -.03 | .04 | **.74** | .16 | .01 | |
| Item 33 | -.02 | **.73** | .04 | .03 | -.04 | **.77** | -.02 | .02 | |
| Item 30 | .07 | **.63** | -.01 | .00 | .26 | **.56** | -.12 | .07 | |
| Factor 3: Discrimination | | | | | | | | | .96 |
| Item 42 [R] | -.03 | -.02 | **.78** | .02 | -.09 | .09 | **.86** | .08 | |
| Item 23 [R] | .01 | .05 | **.81** | -.06 | .08 | .02 | **.81** | .02 | |
| Item 53 [R] | -.02 | .08 | **.82** | -.08 | .09 | .22 | **.69** | -.11 | |
| Item 61 [R] | .06 | -.03 | **.75** | .01 | .10 | .08 | **.67** | -.06 | |
| Item 21 [R] | .12 | .00 | **.71** | .00 | .12 | .06 | **.75** | -.04 | |
| Item 15 [R] | -.15 | .01 | **.59** | .09 | -.09 | -.11 | **.78** | .21 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Factor 4: Hunger | | | | | | | | | .96 |
| Item 32 R | -.01 | -.15 | .02 | **.80** | -.18 | -.01 | .10 | **.82** | |
| Item 01 | .00 | .11 | -.14 | **.77** | .10 | -.07 | .01 | **.86** | |
| Item 08 R | -.08 | .11 | .21 | **.61** | .00 | -.11 | .21 | **.84** | |
| Item 70 R | -.03 | .02 | .04 | **.71** | -.21 | .33 | -.03 | **.53** | |
| Item 74 | .14 | -.01 | -.07 | **.58** | .28 | .14 | -.23 | **.59** | |

*Note*. EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire; Extraction Method: Principal Component Analysis, Rotation Method: Promax with Kaiser Normalization, Factor loadings above .40 are in bold, R = reversed coded items; HC = Healthy control participants, ED = participants with self-reported eating disorder diagnosis.

# 3. Multilingual Validation and Application of the Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) in English-, French-, and German-speaking samples (Study 3)

Ortmann, J., Infanti, A., van Dyck, Z. & Vögele, C. (2024). *Multilingual Validation and Application of the Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) in English-, French-, and German-speaking samples.* Manuscript under review.

## 3.1. Abstract

**Objective**: The Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) is a multidimensional questionnaire used in German-speaking countries to assess the ability to perceive and discriminate between emotions, and hunger and satiety. The present study validated the English and French versions of the EDIP-Q and aimed at replicating previous findings on lower EDIP-Q scores in individuals with a self-reported ED, including anorexia nervosa (AN), bulimia nervosa (BN) and binge-eating disorder (BED). **Method**: We used confirmatory factor analysis (CFA) to examine the postulated factor structure of the EDIP-Q language versions, and multiple group CFA to test for measurement invariance between language groups (German-speaking sample, $n$ = 551; English-speaking sample, $n$ = 307; French-speaking sample, $n$ = 285). Relationships between the EDIP-Q language versions and other measures were determined to evaluate construct validity. Hierarchical regression analyses were conducted to explore the incremental validity of the EDIP-Q. Group differences were examined using multivariate analysis of variance. **Results**: The EDIP-Q language versions have sound psychometric properties. Compared to healthy controls (HC), individuals with EDs show overall lower EDIP-Q scores. ED groups exhibit similar difficulties in emotion perception. Individuals with BN and BED report higher sensibility to hunger, lower sensibility to satiety, and greater difficulty discriminating between emotional states and hunger. The opposite picture was found for individuals with AN. **Discussion**: Our results support the construct and incremental validity of the EDIP-Q language versions. Using the EDIP-Q language versions, we replicated previous findings and identified important interoceptive deficits to varying degrees in AN, BN, and BED, highlighting the need to develop more targeted and individualized treatment approaches for EDs.

*Keywords:* eating disorders, interoception, self-report, confirmatory factor analysis, measurement invariance, psychometric properties

## 3.2. Introduction

Eating Disorders (EDs) are characterized by aberrant eating and eating-related behaviors, as well as an unhealthy relationship with food, with potential risks for physical health, psychosocial functioning and quality of life (American Psychiatric Association, 2013). Although prevalence rates differ between population groups, epidemiological findings consistently highlight that EDs constitute a global mental health concern (Silén & Keski-Rahkonen, 2022). In view of the high mortality rates associated with EDs, and their resistance to treatment in the long-term (Fichter et al., 2017; Fichter & Quadflieg, 2016; Quadflieg & Fichter, 2019), research into etiological mechanisms is essential to define new targets for novel interventions, and eventually improve treatment outcomes.

Interoceptive deficits – referring to the impaired perception, interpretation, and integration of information about the state of internal body systems (Khalsa et al., 2018) – have been proposed to play an important role in the etiology and maintenance of EDs. Studies using network analyses further underscore the significance of interoceptive deficits as transdiagnostic features of disordered eating behaviors and EDs (Monteleone & Cascino, 2021; Olatunji et al., 2018; Vervaet et al., 2021). A promising avenue for more targeted interventions could, therefore, be to address interoceptive deficits.

Interoceptive deficits in the processing of emotions and the perception of hunger and satiety have been described in EDs in particular (Bruch, 1962, 1964) and supported by several lines of research. According to a recent systematic literature review and meta-analyses by Westwood et al. (2017), individuals across the ED spectrum exhibited elevated levels of alexithymia, characterized by greater difficulties in identifying and expressing their emotional experience. This indicates a general impairment in emotional processing in EDs. The perception of hunger and satiety, however, plays a differential role in the symptom presentation of EDs.

In anorexia nervosa (AN), a core symptom is the severe restriction of food intake aimed at preventing weight gain or promoting weight loss. In the purging type of AN, this restriction is accompanied by binge eating and purging behaviors (APA, 2013). Compared to HC, individuals with AN report earlier satiety and postprandial fullness after eating a standardized meal (Garfinkel et al., 1978; Garfinkel, 1974; Garfinkel et al., 1979; Klastrup et al., 2020), possibly contributing to their restrictive eating pattern.

In contrast, bulimia nervosa (BN) and binge-eating disorder (BED) are characterized by recurrent binge eating episodes, where individuals consume large amounts of food within a discrete period of time. Unlike individuals with BED, those with BN engage in inappropriate compensatory behaviors to prevent weight gain, such as self-induced vomiting, misuse of laxatives, diuretics, or other medications, and excessive exercise (APA, 2013). Compared to HC, participants with BN or BED demonstrate a delayed response to satiety and gastric distention (van Dyck et al., 2020) and require higher food intake to reach a similar level of fullness (Kissileff et al., 1996; Sysko et al., 2007), which may increase their susceptibility to binge eating episodes. These lines of research show that disturbances in the perception of hunger and satiety vary across different ED types and might contribute to the diverse symptom presentation in EDs, ranging from severe dietary restriction to uncontrolled overeating.

Current conceptualizations define interoception as a multifaceted construct with distinguishable dimensions (Forkmann et al., 2016; Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2019; Suksasilp & Garfinkel, 2022). These dimensions are assessed using different approaches, including psychophysiological, behavioral and self-report measures. Research on the relationship between interoception and EDs have thrived over the recent years, with a large body of evidence of altered interoceptive processes across dimensions and across the ED spectrum (Martin et al., 2019).

Most research examining the relationship between interoception and EDs, however, relies on the interoceptive awareness subscale of the Eating Disorder Inventory (EDI-IA; Garner et al., 1983). This subscale assesses self-reported difficulties in “recognizing and accurately identifying emotions and sensations of hunger or satiety” (Garner et al., 1983, p.18) and targets per definition *interoceptive sensibility* (i.e., self-reported tendency to be focused on visceral signals; Garfinkel et al., 2015). A recent meta-analysis confirmed significant interoceptive deficits (as assessed by the EDI-IA) among individuals with EDs, with improvements noted over the course of recovery (Jenkinson et al., 2018).

Despite the widespread use of the EDI-IA, its application as measure of interoceptive sensibility has notable limitations. Some items primarily reflect symptoms specific to EDs rather than interoceptive abilities (“When I am upset, I worry that I will start eating.”). In addition, most items refer to the perception of emotional states (e.g., "When I am upset, I don’t know if I am sad, frightened, or angry."), while only one item specifically addresses the uncertainty in the identification of sensations of hunger and satiety ("I get confused as to whether or not I am hungry."). Consequently, the EDI-IA fails to distinguish *between* interoceptive facets, although they may contribute differentially to the etiology and maintenance of EDs. To address these limitations, a more comprehensive self-report measure is needed that allows for more differentiated assessment of interoceptive deficits in EDs.

With this scope in mind, Ortmann et al. (2024) developed the Eating Disorder-specific Interoceptive Perception-Questionnaire (EDIP-Q) in German. The authors defined EDIP as “the ability to perceive emotions, hunger, and satiety, and to discriminate between these physiological states" (Ortmann et al., 2024, p. 164). The factor-structure of the EDIP-Q includes four subscales: *Emotions* (assessing the ability to perceive emotions), *Hunger* (assessing the ability to perceive hunger cues), *Satiety* (assessing the ability to perceive satiety cues), and *Discrimination* (assessing the ability to discriminate between hunger and emotional states). A total score (TS) can also be calculated, which reflects the overall ability of ED-specific interoceptive perception (EDIP). Lower total or subscale scores indicate general or partial deficits in EDIP, while higher scores reflect unimpaired EDIP.

Previous research by Ortmann et al. (2024) supported the four-factor structure with the higher order EDIP factor in two independent large samples of individuals with and without a self-reported ED diagnosis, as well as a high degree of factor similarity between different subsamples (i.e., between sexes, and between participants with and without self-reported a ED diagnosis). Internal consistencies for the EDIP-Q TS and subscales ranged from good to excellent (Cronbach's alphas = .81 - .94). The EDIP-Q demonstrated strong convergent validity, with moderate-to-strong inverse relationships with ED symptoms and maladaptive eating patterns (i.e., non-intuitive, restrictive, emotional, and external eating), and moderate correlations with measures of internal bodily sensations, surpassing other self-report measures of interoception (e.g., Murphy et al., 2020). Divergent validity was supported by the lack of correlation with measures of empathetic concern and perspective taking. In summary, these findings provide initial evidence of sound psychometric properties and construct validity of the EDIP-Q.

Ortmann et al. (2024) used the EDIP-Q to investigate various group differences in EDIP. Women scored significantly lower on the EDIP-Q TS and subscale scores than men, indicating greater deficits in EDIP. The authors suggest that this sex-specific trend could represent a potential risk factor for developing disordered eating behaviors and could help explain the higher prevalence of EDs in women (Galmiche et al., 2019). Those with current EDs had the lowest scores, followed by past EDs, and then HC, showing improvement of EDIP during recovery. Findings on the differences in EDIP *between* ED types are, however, of particular clinical importance. The degree of impairment in the dimensions of EDIP varies by ED type, contributing to the distinct clinical manifestations of AN, BN, and BED. Difficulties in emotion perception were consistent across all ED groups. Individuals with BN and BED, however, reported greater difficulties in perceiving satiety and distinguishing between hunger and emotional states compared to those with AN. These results align with previous research showing that individuals with BN and BED frequently engage in binge eating in response to negative emotional states (e.g., Meule et al., 2021; Schaefer et al., 2020), a core symptom of these EDs. In contrast, individuals with AN reported greater sensibility to satiety and lower sensibility to hunger than those with BN and BED, reflecting the disorder's central symptom of persistent energy intake restriction.

In summary, the findings by Ortmann et al. (2024) based on the EDIP-Q underscore the differential contribution of the perception and discrimination of emotions, and hunger and satiety in ED psychopathology, highlighting the need to consider these factors as targets in the treatment of EDs.

To increase the employability of the EDIP-Q, we translated the questionnaire into English and French. Hence, the first objective of the current study was to validate the two new language versions. This includes its translation into the target languages and the investigation of its factor structure, internal consistencies, construct validity, and incremental validity. To examine whether the translated language versions measure the same underlying construct as the original (German) EDIP-Q, we administered the respective language version to German-, English- and French-speaking samples and tested for measurement invariance between the language groups. We expected the EDIP-Q language versions to show good fit with the four-factor structure observed for the original scale. To ensure comparability with previous work on the development and validation of the original EDIP-Q (Ortmann et al., 2024), construct validity was assessed by examining the relationships between the EDIP-Q language versions and measures of similar constructs used in previous validation studies. We expected the EDIP-Q TS and its subscale scores to be inversely related to ED symptoms, maladaptive eating styles, poor interoceptive awareness, and symptoms of anxiety and depression. Incremental validity of the EDIP-Q has not been previously investigated. Hence, we sought to examine whether the EDIP-Q would account for variance in core ED psychopathology and maladaptive eating behaviors beyond existing self-report measures of interoception (i.e., MAIA, Mehling et al., 2012).

The second objective of the current study was to replicate previous research findings and to investigate group differences in EDIP, including gender differences, differences between participants with a self-reported current and past ED diagnosis (Diagnostic Status I) and between different types of self-reported EDs (Diagnostic Status II), compared with HC. We anticipated observing similar gender differences and ED-specific profiles of deficits in the EDIP as reported in previous studies (Ortmann et al., 2024). Specifically, we expected healthy women to score lower than healthy men on EDIP-Q TS and subscale scores. In addition, we hypothesized individuals with a current ED diagnosis to report the lowest EDIP-Q scores, followed by participants with past ED diagnosis and HC. When comparing ED types, we assumed that individuals with self-reported AN, BN or BED would have the same difficulties in perceiving emotions but would differ on the subscales Hunger, Satiety and Discrimination. Specifically, we predicted individuals with BN and BED to report higher sensibility to hunger and lower sensibility to satiety, as well as greater difficulties in discriminating between hunger and emotional states, compared to individuals with AN. In contrast, we expected individuals with AN to report lower sensibility to hunger and higher sensibility to satiety, as well as less difficulties in discriminating between hunger and emotional states than individuals with BN or BED.

## 3.3. Methods

**Procedure**

Participants were recruited through online advertisements and flyers distributed at the University of Luxembourg, and by sending invitation emails to students and employees. In addition, student councils of several universities in countries with German, English, and French as national languages were asked to circulate the link to the online survey in their respective student communities. To recruit a representative sample of individuals with EDs, the link was shared within community groups. After providing informed consent and confirming that they were of legal age, participants completed a series of sociodemographic questions and a set of eating- and body-related measures. Study participation was possible in German, English, and French and took a maximum of 45 minutes. As an incentive, €0.10 was donated to a non-profit aid organization in Luxembourg for each completed participation. The online survey was established and assembled using the survey platform SoSci Survey (https://www.soscisurvey.de/). The study was approved by the Ethics Review Panel of the University of Luxembourg (ERP 22-017A2 EDIP).

**Participants**

The online survey was completed by 1,196 participants. We carefully checked the dataset for data integrity by identifying multiple respondents with the same start and end times and inspecting the response patterns of outliers in response times. Additionally, Mahalanobis distance was calculated to detect inattentive responses across questionnaires (Ehlers et al., 2009).

Specifically, regression analyses were conducted for each self-report measure to compute Mahalanobis distance values, which were subsequently transformed into probabilities using the Chi-Square distribution. An average probability value below an alpha level of .05 across the questionnaires indicated potential inattentiveness, leading to the identification and exclusion of four fraudulent respondents.

Furthermore, participants were excluded from statistical analyses if they met predefined criteria, such as being underage, lacking sufficient language proficiency (below B1/B2 according to the Common European Framework of Reference for Languages, CEFR), or having conditions that could influence eating behaviors (e.g., pregnancy, breastfeeding, bariatric surgery). A total of 49 participants met these criteria and were consequently excluded from statistical analyses (bariatric surgery: $n = 8$, current pregnancy: $n = 12$, and breastfeeding: $n = 29$).

The remaining sample, therefore, consists of 1,143 participants (German-speaking sample: $n = 551$, English-speaking sample: $n = 307$, French-speaking sample: $n = 285$). Sociodemographic sample characteristics are presented in Table 1 for the total sample and each language group.

**Table 1**

*Sociodemographic Characteristics and Group Allocation*

| | Total sample (*n* = 1143) | | German speaking sample (*n* = 551) | | English speaking sample (*n* = 307) | | French speaking sample (*n* = 285) | |
|---|---|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % | *n* | % |
| Gender | | | | | | | | |
| Male | 123 | 10.8 | 52 | 9.4 | 32 | 10.4 | 39 | 13.7 |
| Female | 988 | 86.4 | 494 | 89.7 | 169 | 87.6 | 225 | 78.9 |
| Other | 32 | 2.8 | 5 | 0.9 | 6 | 2.0 | 21 | 7.4 |
| Age range | | | | | | | | |
| 18 – 24 years | 377 | 33.0 | 186 | 33.8 | 73 | 23.8 | 118 | 41.4 |
| 25 – 34 years | 377 | 33.0 | 207 | 37.6 | 91 | 29.6 | 79 | 69.1 |
| 35 – 44 years | 208 | 18.2 | 96 | 17.4 | 73 | 23.8 | 39 | 13.7 |
| 45 – 54 years | 97 | 8.5 | 34 | 6.2 | 36 | 11.7 | 27 | 9.5 |
| 55 – 64 years | 69 | 6.0 | 24 | 4.4 | 27 | 8.8 | 18 | 6.3 |
| ≥ 65 years | 15 | 1.3 | 4 | 0.7 | 7 | 2.3 | 4 | 1.4 |
| Nationality[1] | | | | | | | | |
| Luxembourg | 280 | 24.5 | 154 | 27.9 | 64 | 20.8 | 62 | 21.8 |
| Germany | 387 | 33.9 | 370 | 67.2 | 14 | 4.6 | 3 | 1.1 |
| France | 200 | 17.5 | 5 | 0.9 | 10 | 3.3 | 185 | 64.9 |
| United Kingdom | 82 | 7.2 | 0 | 0 | 81 | 26.4 | 1 | 0.4 |
| United States of America | 21 | 1.8 | 1 | 0.2 | 20 | 6.5 | 0 | 0 |
| Ireland | 17 | 1.5 | 0 | 0 | 14 | 4.6 | 1 | 0.4 |
| Canada | 16 | 1.4 | 0 | 0 | 14 | 4.5 | 2 | 0.7 |
| Other | 263 | 23.0 | 54 | 9.8 | 136 | 44.3 | 73 | 25.6 |
| Marital status | | | | | | | | |
| Single, never married | 474 | 41.5 | 241 | 43.7 | 106 | 34.5 | 127 | 44.6 |
| Single, divorced or widowed | 44 | 3.8 | 18 | 3.3 | 14 | 4.6 | 12 | 4.2 |
| In a relationship / Married but living apart | 140 | 12.2 | 80 | 14.5 | 32 | 10.4 | 28 | 9.8 |
| In a relationship / married and cohabiting | 485 | 42.4 | 212 | 38.5 | 155 | 50.5 | 118 | 41.4 |
| Education level | | | | | | | | |
| Primary school | 2 | 0.2 | 2 | 0.4 | 0 | 0 | 0 | 0 |
| Secondary school | 79 | 6.9 | 33 | 6.0 | 32 | 10.4 | 14 | 4.9 |
| Higher education | 257 | 22.5 | 158 | 28.7 | 36 | 11.7 | 63 | 22.1 |
| Vocational education | 87 | 7.6 | 76 | 13.8 | 6 | 2.0 | 5 | 1.8 |
| Bachelor's degree or equiv. | 300 | 26.2 | 122 | 22.1 | 93 | 30.3 | 85 | 29.8 |
| Master's degree or equiv. | 361 | 31.5 | 142 | 25.8 | 118 | 38.4 | 101 | 35.4 |
| Doctoral degree or equiv. | 43 | 3.7 | 12 | 2.2 | 16 | 5.2 | 15 | 5.3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Other | 14 | 1.2 | 6 | 1.1 | 6 | 2.0 | 2 | 0.7 |
| Employment[1] | | | | | | | | |
| Employed full-time | 437 | 38.2 | 202 | 36.7 | 136 | 44.3 | 99 | 34.7 |
| Employed part-time | 192 | 16.8 | 105 | 19.1 | 54 | 17.6 | 33 | 11.6 |
| In marginal or irregular employment | 43 | 3.8 | 32 | 5.8 | 7 | 2.3 | 4 | 1.4 |
| Student | 436 | 38.1 | 194 | 35.2 | 114 | 37.1 | 128 | 44.9 |
| Actively looking for a job | 28 | 2.4 | 7 | 1.3 | 8 | 2.6 | 13 | 4.6 |
| On maternity/paternal leave | 5 | 0.4 | 3 | 0.5 | 2 | 0.7 | 0 | 0 |
| Sick leave | 32 | 2.8 | 22 | 4.0 | 5 | 1.6 | 5 | 1.8 |
| Fulfilling domestic tasks (unpaid) | 32 | 2.8 | 14 | 2.5 | 12 | 3.9 | 6 | 2.1 |
| Retired | 42 | 3.7 | 19 | 3.4 | 14 | 4.5 | 9 | 3.2 |
| Other | 52 | 4.5 | 20 | 3.6 | 5 | 1.6 | 27 | 9.5 |
| Healthy Control | 818 | 73.4 | 367 | 66.61 | 257 | 83.77 | 194 | 68.07 |
| Lifetime ED Diagnosis[2] | 297 | 25.89 | 167 | 30.14 | 48 | 15.58 | 82 | 28.77 |
| Current ED Diagnosis[2] | 230 | 20.05 | 132 | 23.83 | 34 | 11.03 | 64 | 22.46 |
| Anorexia nervosa | 60 | | 28 | | 4 | | 28 | |
| Bulimia nervosa | 43 | | 33 | | 3 | | 7 | |
| Binge-eating Disorder | 57 | | 28 | | 17 | | 12 | |
| OSFED | 70 | | 43 | | 10 | | 17 | |

*Note*. ED = Eating Disorder, OSFED = Other Specified Feeding or Eating Disorder.

[1]Multiple answers were possible

[2]Only officially diagnosed ED were included

Lifetime ED diagnoses were assessed via self-report. Participants were asked to indicate who established their diagnosis and whether they were currently experiencing ED symptoms or had recovered from them. Possible current diagnoses were AN, BN, BED, and Other Specified Feeding or Eating Disorder (OSFED). Only individuals who received their diagnosis from a mental health professional were included in the ED subsample ($n$ = 297). HC and ED groups (i.e., individuals with self-reported past EDs or current AN, BN, BED and OSFED) differed in age, body mass index (BMI; kg/m$^2$) and educational level coded according to the International Standard Classification of Education (ISCED 2011; 2012) (see Table 2 for details). For the latter, pairwise comparisons with adjusted $p$-values revealed no significant ED group differences ($ps$ > .05).

**Table 2**

*Descriptive Data with regard to Age, Body Mass Index, and Education Level for Healthy Controls and Individuals Reporting a Lifetime Eating Disorder Diagnosed by a Mental Health Professional.*

| | HC (*n* = 818) | | Past ED (*n* = 67) | | Current ED (*n* = 230) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AN (*n* = 60) | | BN (*n* = 43) | | BED (*n* = 57) | | OSFED (*n* = 70) | | $F(5,1109)$ | *p* | $\eta^2$ |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD | | | |
| Age | $33.5_{a}$ | 12.4 | $29.6_{ab}$ | 9.5 | $26.6_{b}$ | 8.0 | $28.0_{b}$ | 8.8 | $31.1_{ab}$ | 10.7 | $25.4_{b}$ | 6.3 | 11.88 | < .001 | 0.05 |
| BMI | $25.5_{b}$ | 6.7 | $23.8_{b}$ | 6.1 | $16.4_{d}$ | 1.6 | $23.9_{bc}$ | 5.2 | $35.4_{a}$ | 12.1 | $23.1_{c}$ | 5.8 | 48.91 | < .001 | 0.18 |
| | Mean Rank | | Mean Rank | | Mean Rank | | Mean Rank | | Mean Rank | | Mean Rank | | $H(5)$ | *p* | $\eta^2$ |
| Education level* | $577.3_{a}$ | | $575.0_{a}$ | | $492.5_{a}$ | | $445.5_{a}$ | | $501.6_{a}$ | | $488.0_{a}$ | | 17.09 | <.01 | 0.01 |

*Note*. Differences in age and body mass index (BMI) were calculated using ANOVA and followed by Bonferroni-corrected multiple comparisons. Differences in education level were calculated using Kruskal-Wallis *H* test and followed by pairwise comparisons with adjusted *p*-values. Group differences means with different subscripts differ at the $p = .05$ level. Abbreviations: HC = Healthy control participants, Past ED = participants with past self-reported eating disorder, Current ED = participants with current self-reported eating disorder, AN = Anorexia nervosa, BN = Bulimia nervosa, BED = Binge-eating Disorder, OSFED = Other Specified Feeding or Eating Disorder, BMI = body mass index; *Coded according to International Standard Classification of Education (ISCED 2011).

## Measures

### *Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) and its translation*

The EDIP-Q is a 25-item questionnaire originally worded in German to assess EDIP in terms of the ability to perceive and discriminate between emotions, and hunger and satiety. We developed the French and English versions of the EDIP-Q using independent forward translation, independent back translation and reconciliation. Specifically, two translators translated the EDIP-Q into their respective native languages, English and French. These translations were then back-translated into German by two bilingual researchers from the field of EDs. The back translations were carefully examined and compared with the original German EDIP-Q. In the event of discrepancies in the reconciliation, the item formulations were discussed, and necessary adjustments were made. Responses were given on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Mean scores for each subscale and the TS were calculated, with lower scores indicating deficits in EDIP. Cronbach's α in the current sample was .91 for Emotions, .83 for Hunger, .93 for Satiety, .87 for Discrimination, and .94 for the TS. Internal consistencies for the English and French language versions are reported in the results section (see *Internal consistencies*).

### *Eating Disorder Inventory 2 (EDI-2)*

The EDI-2 (German version by Paul & Thiel, 2005; English version by Garner, 1991; French version by Bouvard & Cottraux, 2005) is a 91-item questionnaire to assess ED psychopathology. In the present study, only the first three subscales Drive for Thinness (DT; 7 items), Bulimia/Bulimic Tendencies (BU; 7 items), and Body Dissatisfaction (BD; 9 items) were used to assess core ED psychopathology. Responses were given on a 6-point Likert scale ranging from 1 (never) to 6 (always). Sum scores were calculated for each subscale, with higher scores indicating higher severity of ED symptoms. Cronbach's α in the German-speaking sample was .94, .92 and .94 for DT, BU and BD, respectively. Cronbach's α in the English-speaking sample was .91, .90 and .93 for DT, BU and BD, respectively. Cronbach's α in the French-speaking sample was .91, .90 and .93 for DT, BU and BD, respectively.

***Dutch Eating Behavior Questionnaire (DEBQ)***

The DEBQ (German version by Nagl et al., 2016; English version by van Strien et al., 1986; French version by Lluch et al., 1996) is a 33-item questionnaire to assess three distinct maladaptive eating behaviors, i.e. Restrained, Emotional, and External Eating. Responses were given on a 5-point Likert scale, ranging from 1 (never) to 5 (very often). Sum scores were calculated for each subscale, with higher scores indicating more frequent endorsement of maladaptive eating behavior. Cronbach's α in the German-speaking sample was .94, .96, and .76 for Restrained, Emotional, and External Eating, respectively. Cronbach's α in the English-speaking sample was .93, .97, and .77 for Restrained, Emotional, and External Eating, respectively. Cronbach's α in the French-speaking sample was .94, .96, and .74 for Restrained, Emotional, and External Eating, respectively.

***Multidimensional Assessment of Interoceptive Awareness***

The MAIA (German version by Bornemann et al., 2014; English version by Mehling et al., 2012; French version by Da Costa Silva et al., 2022) is a 32-item questionnaire and composed of eight subscales to assess multiple facets of self-reported interoceptive abilities, i.e. Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. Responses were given on a 6-point Likert scale ranging from 0 (never) to 5 (always). Mean scores were calculated for each subscale, with higher values indicating better interoceptive awareness. Cronbach's α in the German-speaking sample was .63 for Noticing, .62

for Not-Distracting, .55 for Not-Worrying, .91 for Attention Regulation, .87 for Emotional Awareness, .89 for Self-Regulation, .88 for Body Listening, and .93 for Trusting. Cronbach's α in the English-speaking sample was .65 for Noticing, .62 for Not-Distracting, .70 for Not-Worrying, .90 for Attention Regulation, .85 for Emotional Awareness, .86 for Self-Regulation, .87 for Body Listening, and .92 for Trusting. Cronbach's α in the French-speaking sample was .72 for Noticing, .64 for Not-Distracting, .74 for Not-Worrying, .86 for Attention Regulation, .86 for Emotional Awareness, .88 for Self-Regulation, .88 for Body Listening, and .93 for Trusting.

***Patient Health Questionnaire-9 (PHQ-9)***

The PHQ-9 (Kroenke et al., 2001) is a 9-item measure of depression severity, assessing depressive symptoms during the last two weeks. Translations, including German and French, are available for download on the PHQ website (https://www.phqscreeners.com/). Items are answered on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Higher sum scores indicate more severe depressive symptoms. Cronbach's α .90, .87, and .92 was in the German-, English-, and French-speaking samples, respectively.

***Generalized Anxiety Disorder-7 (GAD-7)***

The GAD-7 (Spitzer et al., 2006)is a 7-item measure of generalized anxiety disorder symptoms during the last two weeks. Translations, including German and French, are available for download on the PHQ website (https://www.phqscreeners.com/). Items are answered on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Cronbach's α was .90, .89, and .93 in the German-, English-, and French-speaking samples, respectively.

**Statistical Analyses**

Due to the large sample size, the distribution of all variables was examined visually by inspecting histograms, Q-Q-plots, and values of skewness and kurtosis (Field, 2013). No obvious signs of deviation from a normal distribution were found, allowing for the use of parametric tests in the subsequent data analyses.

To test the postulated factor structure of the EDIP-Q language versions, confirmatory factor analysis (CFA) with maximum likelihood estimation and the covariance matrix as input was conducted separately for the German-, English-, and French-speaking samples. Goodness-of-fit for the models was evaluated with the $\chi^2$-statistic. As the $\chi^2$-test is sensitive to sample size and usually significant in samples with more than 200 cases (Browne & Cudeck, 1993), we also used the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) as guides in assessing fit. Acceptable fit required at least two indices falling within the following ranges: CFI and TLI $\geq$ 0.90, and RMSEA and SRMR $\leq$ 0.08 (Bentler & Bonett, 1980; Browne & Cudeck, 1993; Hooper et al., 2008; Hu & Bentler, 1999). To assess measurement invariance across the language groups, multiple group CFA (MGCFA) were conducted. Configural, metric and scalar models were estimated, and the fit statistics of each model were compared. The configural model, which is the baseline model of invariance testing, implies that the overall factor structure is equivalent across language groups. The metric model restricts the factor loadings to be equivalent across language groups. The scalar model is the most restrictive model, in which factor loadings and intercepts are equivalent across language groups (Brown, 2015). As the $\chi^2$-test is sensitive to sample size, changes in CFI, RMSEA, and SRMR were used as additional indicators of model equivalence. According to Chen (2007), $\Delta$CFI $\geq$ .01, accompanied by either $\Delta$RMSEA $\geq$ .015 or $\Delta$SRMR $\geq$ .30, indicates a significant deterioration in model fit, and thus a rejection of the more restrictive model.

To determine the construct validity of the EDIP-Q, its relationships to related concepts were investigated. The distribution of each variable was inspected visually. As no obvious signs of deviation from a normal distribution were found, Pearson correlation coefficients were calculated to determine construct validity according to Cohen's criteria (Cohen, 1992).

Hierarchical regression procedures were used to assess whether the EDIP-Q provides additional predictive validity for core ED psychopathology (i.e., drive for thinness, bulimic tendencies, and body dissatisfaction) and maladaptive eating behaviors (i.e., restraint, emotional and external eating) over and above existing self-report measures of interoception (i.e., incremental validity). In the first model, MAIA subscales were used as predictors of ED psychopathology and maladaptive eating behaviors. In the second model, EDIP-Q subscales were added. Changes in $R^2$ were examined to determine the increase in explained variance. Cohen's $f^2$ was calculated for estimation of effect sizes, where $f^2 = .02$ is considered as "small", $f^2 = .15$ "medium", and $f^2 = .35$ "large" (Cohen, 1988).

Compared to HC, group differences between participants with self-reported current and past ED diagnoses (Diagnostic status I) and between different types of EDs (Diagnostic status II) were examined using Multivariate Analyses of Variance (MANOVA), with EDIP-Q TS and subscales as dependent variables and Group as between-group factor. Only female participants ($n = 992$) were included in the statistical analyses, as only seven of the ED subsamples identified themselves as male and 12 selected the "other" category. With respect to the group differences based on Diagnostic status 2, the OSFED group ($n = 61$) was excluded from the analyses due to its heterogeneity. Wilks' Lamba (Λ) was used as test statistic for F-tests in all MANOVA models due to its robustness to unequal sample sizes and variances (Ateş et al., 2019). When F-tests were significant for the comparison of more than two groups, post-hoc analyses were conducted using the Games-Howell multiple comparison procedure for unequal sample sizes and variances (Games & Howell, 1976). Partial eta squared ($\eta p^2$) was calculated for estimation of effect sizes, where $\eta p^2$ = .01 is considered as "small", $\eta p^2$ = .06 "medium", and $\eta p^2$ = .14 "large" (Cohen, 1988).

CFAs and MGCFAs were performed using R Statistical Software (Version 4.3.0) and the lavaan R package (Version 0.6-15; Rosseel, 2012). For all other statistical analyses, IBM SPSS Statistics (Version 27) was used. Critical alpha-level was set to .05.

## 3.4. Results

**Confirmatory factor analysis**

Based on the previous work of Ortmann et al. (2024), we established second-order models for the German-, English- and French-speaking samples. The EDIP-Q items were specified to load on their respective first-order latent factor, and the first-order factors were specified to load on a higher-order EDIP factor.

For the German-speaking sample, the model provided a good fit for the data, CFI = 0.96, TLI = 0.95, SRMR = 0.046, RMSEA = 0.053, 90% CI [0.048, 0.058], $\chi^2(1, 271) = 691.65$, $p < 0.001$.

For the English-speaking sample, the model provided an acceptable fit for the data, CFI = 0.89, TLI = 0.88, SRMR = 0.082, RMSEA = 0.073, 90% CI [0.067, 0.080], $\chi^2(1, 271) = 719.55$, $p < 0.001$. The modification indices suggested correlating the residuals between some items (i.e., items 4 and 8, items 8 and 25, items 6 and 11, and items 18 and 22) to improve model fit. Since the items were either similar in content or sentence structure, and it is both acceptable and preferable to correlate the residuals between certain items that share common method effects (Brown, 2015; Knapp-Kline & Kline, 2005), we implemented the suggested modifications. The refined model provided a good fit for the data, CFI = 0.91 TLI = 0.90, SRMR = 0.079, RMSEA = 0.067, 90% CI [0.061, 0.074], $\chi^2(1, 267) = 639.40$, $p < 0.001$.

For the French-speaking sample, the model provided a good fit for the data, CFI = 0.92, TLI = 0.91, SRMR = 0.058, RMSEA = 0.068, 90% CI [0.061, 0.075], $\chi^2(1, 271) = 623.21$, $p < 0.001$.

Applying the same modification indices as proposed for the English-speaking sample, the models for the German- and French-speaking samples improve. For the German-speaking sample, the fit indices are CFI = 0.96, TLI = 0.95, SRMR = 0.045, RMSEA = 0.053, 90% CI [0.048, 0.058], $\chi^2(1, 267) = 674.23$, $p < 0.001$. For the French-speaking sample, the fit indices are CFI = 0.93, TLI = 0.92, SRMR = 0.057, RMSEA = 0.066, 90% CI [0.059, 0.073], $\chi^2(1, 267) = 596.64$, $p < 0.001$.

Table 3 includes the item-factor loadings as well as the first-order factor loadings on the higher order EDIP factor for German-, English- and French-speaking samples. All factor loadings were high in both samples (≥ 0.50; Backhaus et al., 2015).

**Table 3**

*Standardized Item and Factor Loadings of the EDIP-Q obtained by Confirmatory Factor Analyses, separately for the German-, English- and French-speaking Sample.*

| Factor and EDIP-Q items | German-speaking sample (*n* = 551) | | English-speaking sample (*n* = 308) | | French-speaking sample (*n* = 285) | |
|---|---|---|---|---|---|---|
| | 1st order | 2nd order | 1st order | 2nd order | 1st order | 2nd order |
| Factor 1: Emotions | | .82 | | .74 | | .85 |
| Item 02 | .84 | | .76 | | .87 | |
| Item 09 | .74 | | .64 | | .70 | |
| Item 12 | .74 | | .61 | | .63 | |
| Item 15 | .88 | | .85 | | .93 | |
| Item 19 | .91 | | .91 | | .80 | |
| Item 21 | .81 | | .80 | | .74 | |
| Item 23 | .69 | | .60 | | .71 | |
| Factor 2: Hunger | | .71 | | .60 | | .66 |
| Item 01 | .80 | | .86 | | .83 | |
| Item 06$^R$ | .70 | | .63 | | .64 | |
| Item 11$^R$ | .53 | | .60 | | .66 | |
| Item 16 | .61 | | .52 | | .65 | |
| Item 25$^R$ | .85 | | .74 | | .84 | |
| Factor 3: Satiety | | .76 | | .75 | | .78 |
| Item 04 | .86 | | .78 | | .82 | |
| Item 08$^R$ | .84 | | .70 | | .74 | |
| Item 10 | .89 | | .86 | | .87 | |
| Item 13$^R$ | .81 | | .72 | | .76 | |
| Item 17$^R$ | .66 | | .66 | | .62 | |
| Item 20 | .93 | | .72 | | .88 | |
| Item 24 | .80 | | .81 | | .84 | |
| Factor 4: Discrimination | | .79 | | .69 | | .65 |
| Item 03$^R$ | .61 | | .58 | | .50 | |
| Item 05$^R$ | .72 | | .73 | | .69 | |

| | | | |
|---|---|---|---|
| Item 07$^R$ | .81 | .83 | .70 |
| Item 14$^R$ | .85 | .77 | .70 |
| Item 18$^R$ | .85 | .75 | .80 |
| Item 22$^R$ | .69 | .64 | .75 |

*Note*. EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire; R reversed coded items.

## Measurement Invariance across Language Groups

Fit indices of the multi-group models are presented in Table 4. The configural model provided a good fit to the data, indicating that the overall factor structure is equivalent across language groups. Since configural invariance has been established, we proceeded to examine the remaining levels of measurement invariance. Both the metric and scalar models demonstrated a good fit to the data. Changes in CFI, RMSEA, and SRMR were minimal and within Chen's recommendations (Chen, 2007). These findings provide evidence that the factor structure, factor loadings, and item intercepts of the EDIP-Q are equivalent across language groups.

**Table 4**

*Measurement Invariance Testing for the Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) across Language Groups (German-speaking sample, n = 551; English-speaking sample, n = 307; French-speaking sample, n = 285)*

| Model | $\chi^2$ | *df* | CFI | TLI | RMSEA | SRMR | $\chi^2$ difference test | ΔCFI | ΔRMSEA | ΔSRMR |
|---|---|---|---|---|---|---|---|---|---|---|
| Configural model | 1910.3 | 801 | .94 | .93 | 0.060 | 0.055 | | | | |
| German-speaking sample | 674.2 | | | | | | | | | |
| English-speaking sample | 639.4 | | | | | | | | | |
| French-speaking sample | 596.6 | | | | | | | | | |
| Metric model | 2023.1 | 849 | .94 | .93 | 0.060 | 0.065 | | | | |
| German-speaking sample | 699.6 | | | | | | | | | |
| English-speaking sample | 678.2 | | | | | | | | | |
| French-speaking sample | 645.3 | | | | | | | | | |
| Scalar model | 2218.73 | 889 | .93 | .93 | 0.063 | 0.067 | | | | |
| German-speaking sample | 737.7 | | | | | | | | | |
| English-speaking sample | 747.2 | | | | | | | | | |
| French-speaking sample | 733.9 | | | | | | | | | |
| Configural versus metric model | | | | | | | 112.84*** | 0.004 | 0.00 | -0.01 |
| Metric versus scalar model | | | | | | | 195.62*** | 0.008 | -0.003 | -0.002 |

*Note*. CFI = Comparative Fit Index, Tucker-Lewis Index, RMSEA = root mean square error of approximation, SRMR = standardized root mean square residual.

***$p$ < 0.001.

**Internal Consistencies**

Cronbach's α in the German-speaking sample was .92 for Emotions, .82 for Hunger, .94 for Satiety, .89 for Discrimination, and .94 for TS. α in the English-speaking sample was .89 for Emotions, .80 for Hunger, .90 for Satiety, .87 for Discrimination, and .92 for TS. Cronbach's α in the French-speaking sample was .91 for Emotions, .85 for Hunger, .92 for Satiety, .85 for Discrimination, and .93 for the TS.

**Construct Validity**

Correlations between the EDIP-Q (TS and subscales) and other variables are presented in Table 5, separately for the German-, English- and French-speaking samples. In the three language samples, intercorrelations of the EDIP-Q (TS and subscales) were in the medium to high range. In addition, the EDIP-Q (TS and subscales) was moderately to strongly inversely related to the EDI-2 subscales and moderately to strongly related to the DEBQ subscales, except for small correlations between EDIP-Q Hunger and the subscales Drive for Thinness, Bulimic Tendencies, Body Dissatisfaction, Emotional Eating and External Eating. Moderate to strong relationships were found between EDIP-Q (TS and subscales) and the MAIA subscales Noticing, Attention Regulation, Self-Regulation, Body Listening and Trusting, and weak to moderate relationships for Not Distracting, Not-Worrying and Emotional Awareness. In addition, moderate to strong relationships were found between EDIP-Q (TS and subscales) and the PHQ-9 and GAD-7.

**Table 5**

*Intercorrelations of measured variables, separately for the German-, English- and French-speaking sample.*

| | German-speaking sample ($n$ = 551) | | | | | English-speaking sample ($n$ = 308) | | | | | French-speaking sample ($n$ = 285) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EDIP-Q | TS | E | H | S | D | TS | E | H | S | D | TS | E | H | S | D |
| Total score (TS) | | | | | | | | | | | | | | | |
| Emotions (E) | .84** | | | | | .80** | | | | | .85** | | | | |
| Hunger (H) | .71** | .54** | | | | .65** | .45** | | | | .68** | .49** | | | |
| Satiety (S) | .84** | .57** | .43** | | | .81** | .50** | .36** | | | .84** | .62** | .41** | | |
| Discrimination (D) | .82** | .58** | .47** | .59** | | .74** | .44** | .27** | .47** | | .73** | .48** | .34** | .48** | |
| EDI-2 | | | | | | | | | | | | | | | |
| Drive for Thinness | -.62** | -.47** | -.42** | -.60** | -.48** | -.46** | -.34** | -.18** | -.46** | -.36** | -.50** | -.36** | -.28** | -.46** | -.42** |
| Bulimic tendencies | -.70** | -.55** | -.34** | -.68** | -.62** | -.61** | -.39** | -.18** | -.65** | 54** | -.60** | -.44** | -.26** | -.58** | -.56** |
| Body dissatisfaction | -.57** | -.46** | -.36** | -.57** | -.42** | -.53** | -.35** | -.22** | -.57** | -.39** | -.41** | -.35** | -.18** | -.37** | -.35** |
| DEBQ | | | | | | | | | | | | | | | |
| Restrained Eating | -.51** | -.37** | -.43** | -.45** | -.40** | -.33** | -.19** | -.19** | -.37** | -.22** | -.35** | -.21** | -.28** | -.30** | -.30** |
| Emotional Eating | -.61** | -.49** | -.23** | -.60** | -.58** | -.51** | -.34** | -.04 | -.52** | -.54** | -.41** | -.32** | -.02 | -.43** | -.45** |
| External Eating | -.30** | -.18** | -.04 | -.44** | -.24** | -.31** | -.15** | -.02 | -.44** | -.27** | -.19** | -.12** | .13* | -.26** | -.29** |
| MAIA | | | | | | | | | | | | | | | |
| Noticing | .47** | .56** | .30** | .35** | .29** | .38** | .44** | .27** | .30** | .14* | .51** | .54** | .32** | .45** | .25** |
| Not Distracting | .46** | .48** | .37** | .34** | .31** | .35** | .32** | .28** | .21** | .26** | .23** | .22** | .27** | .13* | .13* |
| Not-Worrying | .30** | .25** | .16** | .29** | .25** | .26** | .20** | .09 | .25** | .21** | .11 | .09 | -.08 | .16** | .13* |
| Attention Regulation | .55** | .61** | .40** | .43** | .34** | .48** | .48** | .20** | .40** | .32** | .42** | .46** | .27** | .39** | .14* |
| Emotional Awareness | .38** | .48** | .22** | .29** | .21** | .28** | .34** | .15** | .27** | .06 | .48** | .52** | .35** | .41** | .17** |
| Self-Regulation | .53** | .56** | .35** | .44** | .34** | .33** | .36** | .16** | .27** | .17** | .59** | .62** | .34** | .51** | .33** |
| Body Listening | .56** | .60** | .36** | .48** | .32** | .40** | .46** | .17** | .40** | .16** | .56** | .60** | .33** | .49** | .30** |
| Trusting | .68** | .71** | .47** | .55** | .47** | .59** | .57** | .33** | .49** | .37** | .68** | .70** | .40** | .57** | .42** |
| PHQ-9 | -.65** | -.65** | -.46** | -.49** | -.50** | -.52** | -.45** | -.34** | -.41** | -.37** | -.68** | -.62** | -.45** | -.53** | -.50** |
| GAD-7 | -.59** | -.60** | -.44** | -.41** | -.46** | -.39** | -.35** | -.30** | -.24** | -.29** | -.60** | -.55** | -.33** | -.48** | -.47** |

*Note.* EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, EDI-2 = Eating Disorder Inventory-2, DEBQ = Dutch Eating Behavior Questionnaire, MAIA = Multidimensional Assessment of Interoceptive Awareness, PHQ = Patient Health Questionnaier-9, GAD-7 = Generalized Anxiety Disorder-7.

**$p$ < 0.01, *$p$ < .05.

**Incremental Validity**

We conducted hierarchical regression analyses to examine the incremental validity of the EDIP-Q subscales over the MAIA subscales in predicting core ED psychopathology (drive for thinness, bulimic tendencies, and body dissatisfaction) and maladaptive eating behaviors (restraint, emotional, and external eating). Model 1 included the MAIA subscales as predictors, and Model 2 both the MAIA subscales and EDIP-Q subscales as predictors. Table 6 summarizes the hierarchical regression results for ED psychopathology, while Table 7 presents the hierarchical regression results for maladaptive eating behaviors.

Regarding ED psychopathology, the addition of the EDIP-Q subscales significantly increased the explained variance by 9% for drive for thinness ($F(4, 1102) = 43.95$, $p < .001$, $f^2 = .16$), 24% for bulimic tendencies ($F(4, 1102) = 140.10$, $p < .001$, $f^2 = .51$), and 7% for body dissatisfaction ($F(4, 1102) = 35.56$, $p < .001$, $f^2 = .13$).

Regarding maladaptive eating behaviors, the addition of the EDIP-Q subscales significantly increased the explained variance by 8% for restraint eating ($F(4, 1102) = 27.92$, $p < .001$, $f^2 = .11$), 23% for emotional eating ($F(4, 1102) = 105.80$, $p < .001$, $f^2 = .38$), and 14% for external eating ($F(4, 1102) = 48.10$, $p < .001$, $f^2 = .17$).

**Table 6**

Hierarchical regression analyses testing their incremental validity of the EDIP-Q subscales over the MAIA subscales to predict core ED psychopathology including drive for thinness, bulimic tendencies and body dissatisfaction

| | Drive for thinness | | | | | | | Bulimic tendencies | | | | | | | Body dissatisfaction | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subscale | *B* | 95% CI for *B* | | *SE B* | β | $R^2$ | $\Delta R^2$ | *B* | 95% CI for *B* | | *SE B* | β | $R^2$ | $\Delta R^2$ | *B* | 95% CI for *B* | | *SE B* | β | $R^2$ | $\Delta R^2$ |
| | | *LL* | *UL* | | | | | | *LL* | *UL* | | | | | | *LL* | *UL* | | | | |
| Model 1 | | | | | | .37 | .37*** | | | | | | .28 | .28*** | | | | | | .37 | .37*** |
| Constant | 39.91 | 37.06 | 42.76 | 1.45 | | | | 31.88 | 29.32 | 34.45 | 1.31 | | | | 50.50 | 47.09 | 53.91 | 1.74 | | | |
| Noticing | 0.68 | 0.20 | 1.34 | 0.34 | .07* | | | -0.23 | -0.82 | 0.37 | 0.30 | -.03 | | | 1.42 | 0.63 | 2.21 | 0.40 | .11*** | | |
| Not Distracting | -1.10 | -1.59 | 0.61 | 0.25 | -.11*** | | | -0.65 | -1.09 | -0.20 | 0.23 | -.08** | | | -0.91 | -1.50 | -0.32 | 0.30 | -.08** | | |
| Not-Worrying | -0.83 | -1.29 | -0.37 | 0.23 | -.09*** | | | -0.83 | -1.24 | -0.42 | 0.21 | -.11*** | | | -0.36 | -0.91 | 0.19 | 0.28 | -.03 | | |
| Attention Regulation | 0.49 | -0.14 | 1.12 | 0.32 | .05 | | | 0.08 | -0.48 | 0.65 | 0.29 | .01 | | | -0.12 | -0.87 | 0.64 | 0.39 | -.01 | | |
| Emotional Awareness | 0.34 | -0.26 | 0.94 | 0.31 | .04 | | | 0.00 | -0.54 | 0.54 | 0.27 | .00 | | | -0.10 | -0.82 | 0.61 | 0.37 | -.01 | | |
| Self-Regulation | -0.20 | -0.83 | 0.42 | 0.32 | -.03 | | | -0.26 | -0.82 | 0.30 | 0.29 | -.04 | | | 0.68 | -0.07 | 1.42 | 0.38 | .07 | | |
| Body Listening | -0.11 | 0.72 | 0.50 | 0.31 | -.01 | | | -0.07 | -0.62 | 0.49 | 0.28 | -.01 | | | -0.83 | -1.57 | -0.10 | 0.37 | -.09* | | |
| Trusting | -3.81 | -4.27 | -3.34 | .23 | -.57*** | | | -2.37 | -2.78 | -1.96 | .21 | -.42*** | | | -4.72 | -5.27 | -4.18 | 0.28 | -.60*** | | |
| Model 2 | | | | | | .46 | .09*** | | | | | | .52 | .24*** | | | | | | .47 | .07*** |
| Constant | 43.52 | 40.63 | 46.42 | 1.48 | | | | 37.23 | 34.95 | 39.95 | 1.16 | | | | 53.04 | 49.53 | 56.55 | 1.79 | | | |
| Noticing | -0.82 | 0.32 | 1.58 | 0.32 | .09** | | | 0.36 | -0.13 | 0.86 | 0.25 | .04 | | | 1.62 | 0.86 | 2.34 | 0.39 | .13*** | | |
| Not Distracting | -0.40 | -1.30 | -0.35 | 0.24 | -.08*** | | | -0.26 | -0.63 | 0.12 | 0.20 | -.03 | | | -0.76 | -1.33 | -1.18 | 0.29 | -.06** | | |
| Not-Worrying | 0.61 | -0.83 | 0.03 | 0.22 | -.04 | | | -0.15 | -0.50 | 0.20 | 0.17 | -.02 | | | 0.14 | -0.39 | 0.66 | 0.27 | .01 | | |
| Attention Regulation | 0.25 | 0.02 | 1.20 | 0.30 | .07* | | | 0.30 | -0.16 | 0.77 | 0.24 | .04 | | | -0.01 | -0.72 | .71 | 0.36 | .00 | | |
| Emotional Awareness | -0.14 | -0.31 | 0.81 | 0.29 | .03 | | | -0.09 | -0.53 | 0.35 | 0.23 | -.01 | | | -0.22 | -0.89 | 0.46 | 0.35 | -.02 | | |
| Self-Regulation | 0.05 | -0.72 | 0.44 | 0.30 | -.02 | | | -0.12 | -0.57 | 0.34 | 0.23 | -.02 | | | 0.71 | 0.01 | 1.42 | 0.36 | .07* | | |
| Body Listening | .81 | -0.53 | 0.62 | 0.29 | .01 | | | -0.14 | -0.28 | 0.63 | 0.23 | .03 | | | -0.59 | -1.29 | 0.11 | 0.36 | -.06 | | |
| Trusting | | -3.56 | -2.63 | 0.24 | -.47*** | | | -1.20 | -1.50 | -0.75 | 0.19 | -.20*** | | | -4.08 | -4.64 | -3.51 | 0.29 | -.51*** | | |
| Emotions | 0.81 | 0.27 | 1.34 | 0.27 | .11** | | | -0.14 | -0.57 | 0.28 | 0.22 | -.02 | | | 0.97 | 0.32 | 1.62 | 0.33 | .11** | | |
| Hunger | -0.25 | -0.63 | 0.13 | 0.19 | -.04 | | | 0.50 | 0.20 | 0.80 | 0.15 | .08** | | | 0.22 | -0.24 | 0.68 | 0.23 | .03 | | |
| Satiety | -1.91 | -2.30 | -1.52 | 0.20 | -.29*** | | | -2.27 | -2.58 | -1.96 | 0.16 | -.42*** | | | -2.30 | -2.77 | -1.83 | 0.24 | -.29*** | | |
| Discrimination | -0.94 | -1.33 | -0.55 | 0.20 | -.13*** | | | -1.80 | -2.11 | -1.50 | 0.16 | -.30*** | | | 0.89 | -1.36 | -0.42 | 0.24 | -.11*** | | |

Note. CI = confidence interval; LL =lower limit; UL = upper limit;
*$p$ < .05, **$p$ < .01, ***$p$ < .001.

**Table 7**

Hierarchical regression analyses testing their incremental validity of the EDIP-Q subscales over the MAIA subscales to predict restraint, emotional and external eating

| | Restraint eating | | | | | | | Emotional eating | | | | | | | External eating | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subscale | *B* | 95% CI for *B* | | *SE B* | β | *R²* | Δ*R²* | *B* | 95% CI for *B* | | *SE B* | β | *R²* | Δ*R²* | *B* | 95% CI for *B* | | *SE B* | β | *R²* | Δ*R²* |
| | | *LL* | *UL* | | | | | | *LL* | *UL* | | | | | | *LL* | *UL* | | | | |
| Model 1 | | | | | | .20 | .20*** | | | | | | .18 | .18*** | | | | | | .09 | .09*** |
| Constant | 3.94 | 3.63 | 4.27 | 0.16 | | | | 4.52 | 4.17 | 4.86 | 0.18 | | | | 3.82 | 3.62 | 4.02 | 0.10 | | | |
| Noticing | -0.02 | -0.09 | 0.06 | 0.04 | -.02 | | | -0.10 | -0.18 | -0.02 | 0.04 | -.09 | | | -0.02 | -0.06 | 0.03 | 0.02 | -.03 | | |
| Not Distracting | -0.09 | -0.14 | -0.03 | 0.03 | -.09** | | | -0.04 | -0.10 | 0.02 | 0.03 | -.04 | | | 0.00 | -0.04 | 0.03 | 0.02 | -.01 | | |
| Not-Worrying | 0.00 | -0.05 | 0.05 | 0.03 | .00 | | | -0.13 | -0.19 | -0.07 | 0.03 | -.13 | | | -0.11 | -0.14 | -0.07 | 0.02 | -.20*** | | |
| Attention Regulation | 0.12 | .05 | 0.19 | 0.04 | .13** | | | -0.06 | -0.14 | 0.01 | 0.04 | -.07 | | | -0.04 | -0.08 | 0.01 | 0.02 | -.07 | | |
| Emotional Awareness | 0.01 | -0-06 | 0.07 | 0.03 | .01 | | | 0.06 | -0.01 | 0.14 | 0.04 | .06 | | | 0.05 | 0.01 | 0.09 | 0.02 | .10* | | |
| Self-Regulation | 0.01 | -0.06 | 0.08 | 0.04 | .01 | | | 0.03 | -0.04 | 0.11 | 0.04 | .04 | | | 0.02 | -0.03 | 0.06 | 0.02 | .04 | | |
| Body Listening | 0.02 | -0.05 | 0.09 | 0.04 | .03 | | | -0.05 | 0.12 | 0.03 | 0.04 | -.05 | | | -0.06 | -0.11 | -0.02 | 0.02 | -.13** | | |
| Trusting | -0.32 | -0.37 | -0.27 | 0.03 | -.48*** | | | -0.21 | -0.26 | -0.15 | 0.03 | -.29 | | | -0.02 | -0.06 | 0.01 | 0.02 | -.06 | | |
| Model 2 | | | | | | .27 | .08*** | | | | | | .41 | .23*** | | | | | | .22 | .14*** |
| Constant | 4.40 | 4.06 | 4.73 | 0.17 | | | | 5.07 | 4.75 | 5.40 | 0.17 | | | | 3.82 | 3.62 | 4.02 | 0.10 | | | |
| Noticing | 0.00 | -0.07 | 0.08 | 0.04 | .00 | | | -0.04 | -0.11 | 0.03 | 0.04 | -.04 | | | -0.01 | -0.06 | 0.03 | 0.02 | -.02 | | |
| Not Distracting | -0.05 | -0.11 | 0.01 | 0.03 | -.05 | | | -0.02 | -0.07 | 0.03 | 0.03 | -.02 | | | -0.01 | -0.04 | 0.02 | 0.02 | -.02 | | |
| Not-Worrying | 0.02 | -0.03 | 0.08 | 0.03 | .03 | | | -0.05 | -0.09 | 0.00 | 0.03 | -.05 | | | -0.07 | -0.10 | -0.04 | 0.02 | -.13*** | | |
| Attention Regulation | 0.13 | 0.06 | 0.20 | 0.03 | .14*** | | | -0.04 | -0.11 | 0.02 | 0.03 | -.04 | | | -0.04 | -0.08 | 0.01 | 0.02 | -.07 | | |
| Emotional Awareness | 0.00 | -0.07 | 0.06 | 0.04 | .00 | | | 0.04 | -0.02 | 0.11 | 0.03 | .05 | | | 0.04 | 0.00 | 0.08 | 0.02 | .08* | | |
| Self-Regulation | 0.02 | -0.05 | 0.08 | 0.03 | .02 | | | 0.05 | -0.02 | 0.12 | 0.03 | .06 | | | 0.02 | -0.02 | 0.06 | 0.02 | .04 | | |
| Body Listening | 0.03 | -0.04 | 0.09 | 0.03 | .03 | | | -0.02 | -0.08 | 0.05 | 0.03 | -.02 | | | -0.04 | -0.08 | 0.00 | 0.02 | -.08 | | |
| Trusting | -0.26 | -0.31 | -0.20 | 0.03 | -.39*** | | | -0.07 | -0.13 | -0.02 | 0.03 | -.10*** | | | 0.00 | -0.03 | 0.04 | 0.02 | .01 | | |
| Emotions | 0.11 | 0.05 | 0.17 | 0.03 | .14*** | | | -0.05 | -0.11 | 0.01 | 0.03 | -.06 | | | 0.05 | 0.01 | 0.09 | 0.02 | .11* | | |
| Hunger | -0.11 | -0.15 | -0.06 | 0.02 | -.15*** | | | 0.17 | 0.13 | 0.21 | 0.02 | .22*** | | | 0.08 | 0.06 | 0.11 | 0.01 | .21*** | | |
| Satiety | -0.14 | -0.19 | -0.10 | 0.02 | -.22*** | | | -0.23 | -0.27 | -0.18 | 0.02 | -.32*** | | | -0.15 | -0.18 | -0.13 | 0.01 | -.41*** | | |
| Discrimination | -0.08 | -0.12 | -0.03 | 0.02 | -.11*** | | | -0.27 | -0.32 | -0.23 | 0.02 | -.36*** | | | -0.05 | -0.08 | -0.02 | 0.01 | -.12*** | | |

Note. CI = confidence interval; LL =lower limit; UL = upper limit;

## Group Comparisons

### *Gender Differences*

EDIP-Q mean scores and SDs for healthy men and women are presented in Table 8. The MANOVA with EDIP-Q T and subscales as dependent variables and Gender as between-subjects factor revealed an overall effect for Gender, $\Lambda = .98$, $F(4,793) = 3.48$, $p < .001$, $\eta_p^2 = .02$. Healthy men scored significantly higher on the TS and subscale scores than healthy women (*ps* < .05).

**Table 8**

*EDIP Mean Scores (M) and Standard Deviations (SD) for Healthy Men and Women.*

| EDIP-Q | Men ($n$ = 116) | | Women ($n$ = 682) | | $F$(1,798) | $p$ | $\eta_p^2$ |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | | | |
| Total Score | 5.3 | 0.8 | 4.9 | 1.1 | 12.62 | <.001 | .02 |
| Emotions | 5.3 | 1.0 | 5.0 | 1.2 | 1.09 | .022 | .01 |
| Hunger | 5.4 | 1.0 | 5.1 | 1.3 | 1.49 | .027 | .01 |
| Satiety | 4.9 | 1.2 | 4.3 | 1.6 | 1.68 | <.001 | .02 |
| Discrimination | 5.8 | 1.3 | 5.4 | 1.3 | 1.80 | .008 | .01 |

*Note*. Group differences were calculated using MANOVA, means with different subscripts differ at the $p$ = .05 level, HC = Healthy control participants, Past ED = participants with past self-reported eating disorder, Current ED = participants with current self-reported eating disorder, EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire.

### *Diagnostic Status I: Healthy controls (HC) versus self-reported past and current ED*

EDIP-Q mean scores and *SDs* for female HC and female participants with self-reported current and past ED diagnoses are presented in Table 9. The MANOVA with EDIP-Q TS and subscales as dependent variables and Diagnostic status I as between-subjects factor revealed an overall effect for Diagnostic status I, $\Lambda = .79$, $F(8,1914) = 30.82$, $p < .001$, $\eta_p^2 = .11$. Post-hoc tests revealed that participants with current EDs scored significantly lower on the TS and subscale scores than participants with past EDs and HC (*ps* < .001). Participants with past EDs did not differ from HC on the TS and subscale scores, except for a significant group difference on Emotions ($p = .006$), where they reported significantly lower scores. No other post hoc comparisons reached statistical significance.

**Table 9**

*EDIP Mean Scores (M) and Standard Deviations (SD) for Female Healthy Participants and Female Participants With Past and Current Self-Reported Eating Disorder.*

| EDIP-Q | HC ($n$ = 682) | | Past ED ($n$ = 62) | | Current ED ($n$ = 216) | | $F(2,957)$ | $p$ | $\eta_p^2$ |
|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | |
| Total Score | $4.9_a$ | 1.1 | $4.7_a$ | 1.1 | $3.7_b$ | 1.0 | 120.15 | <.001 | .20 |
| Emotions | $5.0_a$ | 1.2 | $4.5_b$ | 1.3 | $3.7_c$ | 1.3 | 91.29 | <.001 | .16 |
| Hunger | $5.1_a$ | 1.3 | $4.7_a$ | 1.5 | $3.9_b$ | 1.5 | 65.80 | <.001 | .12 |
| Satiety | $4.3_a$ | 1.6 | $4.3_a$ | 1.6 | $2.9_b$ | 1.3 | 72.87 | <.001 | .13 |
| Discrimination | $5.4_a$ | 1.3 | $5.4_a$ | 1.3 | $4.3_b$ | 1.6 | 53.61 | <.001 | .10 |

*Note*. Group differences were calculated using MANOVA, means with different subscripts differ at the $p = .05$ level, HC = Healthy control participants, Past ED = participants with past self-reported eating disorder, Current ED = participants with current self-reported eating disorder, EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire.

### ***Diagnostic Status II: Healthy controls (HC) versus ED types***

EDIP-Q mean scores and *SDs* for female HC and female participants reporting a current diagnosis of AN, BN and BED are presented in Table 10. The MANOVA with EDIP-Q TS and subscales as dependent variables and Diagnostic status II as between-subject factor revealed an overall effect for Diagnostic status II, $\Lambda = .73$, $F(12,2217) = 24.50$, $p < .001$, $\eta_p^2 = .10$. Post-hoc tests revealed that all types of EDs scored significantly lower on the TS and subscale scores compared to HC (*p*s < .05). Among types of EDs, there were no significant group differences on the TS and Emotions. On Hunger, individuals with AN and BN scored significantly lower than participants with BED ($p = .001$ and $p = .029$, resp.). On Satiety, individuals with BN scored marginally significantly lower than individuals with AN ($p = .059$). On Discrimination, individuals with BED scored significantly lower compared to participants with AN ($p = .003$). No other post hoc comparisons reached statistical significance.

**Table 10**

*EDIP mean scores (M) and standard deviations (SD) for female healthy participants and female participants with self-reported current anorexia nervosa, bulimia nervosa, and binge-eating disorder*

| EDIP-Q | HC ($n$ = 685) | | AN ($n$ = 57) | | BN ($n$ = 42) | | BED ($n$ = 56) | | $F(3,833)$ | $p$ | $\eta_p^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* | *M* | *SD* | | | |
| Total Score | $4.9_a$ | 1.1 | $3.6_b$ | 0.9 | $3.3_b$ | 1.0 | $3.5_b$ | 0.9 | 80.67 | <.001 | .23 |
| Emotions | $5.0_a$ | 1.2 | $3.6_b$ | 1.1 | $3.4_b$ | 1.4 | $3.8_b$ | 1.2 | 55.68 | <.001 | .17 |
| Hunger | $5.1_a$ | 1.3 | $3.4_c$ | 1.3 | $3.7_c$ | 1.4 | $4.4_b$ | 1.5 | 41.73 | <.001 | .13 |
| Satiety | $4.3_a$ | 1.6 | $2.9_b$ | 1.2 | $2.3_b$ | 1.1 | $2.6_b$ | 1.1 | 55.76 | <.001 | .17 |
| Discrimination | $5.4_a$ | 1.3 | $4.6_b$ | 1.8 | $3.9_{bc}$ | 1.6 | $3.6_c$ | 1.3 | 46.31 | <.001 | .14 |

*Note*. Group differences were calculated using MANOVA, means with different subscripts differ at the $p = .05$ level, HC = Healthy control participants, Past ED = participants with past self-reported eating disorder, Current ED = participants with current self-reported eating disorder, EDIP-Q = Eating Disorder-specific Interoceptive Perception Questionnaire, individuals with Other Specified Feeding or Eating Disorder (OSFED) were excluded from statistical analyses due to the heterogeneity of the OSFED-group.

## 3.5. Discussion

The EDIP-Q is a multidimensional questionnaire used in German-speaking countries to assess EDIP in terms of the "ability to perceive emotions, hunger and satiety, and to discriminate between those physiological states" (Ortmann et al., 2024, p. 164). The first aim of our study was to extend previous work and validate an English and French version of the EDIP-Q. This included examining the postulated factor structure of the translated language versions and assessing the psychometric equivalence (Putnick & Bornstein, 2016) of EDIP across German-, English-, and French-speaking samples. Furthermore, internal consistency, construct validity and incremental validity were evaluated. The second aim was to replicate previous findings (Ortmann et al., 2024) on differences in EDIP using the language versions of the EDIP-Q. This included gender differences, differences between participants with self-reported current and past ED diagnosis (Diagnostic Status I) and between different types of EDs (Diagnostic Status II), compared with HC.

**Factor Structure and Measurement Invariance**

The proposed factor structure of the EDIP-Q could largely be confirmed for each language version. Specifically, as for the original version, the four subscales Emotions, Hunger, Satiety, and Discrimination loaded on a higher order EDIP factor. As expected, $\chi^2$ goodness-of-fit indices were significant given the large subsample sizes. All other indices of fit, i.e., CFI, TLI, RMSEA and

SRMR, indicated a sufficient to good model fit for both the German-, English- and French-speaking sample.

Testing and establishing measurement invariance between translated versions of self-reports is a crucial prerequisite for conducting statistical group comparisons. Using MGCFA, we tested three levels of measurement invariance. Our results demonstrate configural, metric, and scalar measurement invariance across language groups, supporting psychometric equivalence of the construct of EDIP and its components across German-, English-, and French-speaking samples.

**Construct Validity**

In the previous work of Ortmann et al. (2024), the original version of the EDIP-Q demonstrated sound psychometric properties and excellent construct validity in two independent large samples of individuals with and without a self-reported ED disorder. To enable comparability between studies, we used the same eating- and body-related self-report measures and examined their relationships with the EDIP-Q language versions. The pattern of results on the relationships in our study was comparable to those previously reported (Ortmann et al., 2024). In both language versions, the EDIP-Q TS and subscales were moderately to strongly interrelated and were moderately to strongly related to ED symptoms and maladaptive eating styles. Furthermore, moderate-to-strong correlations were found with the MAIA. From these results, we conclude that deficits in the EDIP are associated with (1) greater endorsement of ED symptoms and maladaptive eating behaviors and (2) poorer interoceptive awareness. Consequently, the language versions of the EDIP-Q are suitable self-report measures of interoceptive processing in the domain of EDs and disordered eating behaviors.

The relationships between the EDIP-Q language versions and measured variables found in our study were somewhat weaker than those found in previous validation studies of the original questionnaire (Ortmann et al., 2024). The strength of the correlations is, however, influenced by the sample size and the associated lower variability in the measured variables (de Winter et al., 2016). As we divided our total sample by language group, the subsamples under investigation were two-thirds smaller than in the previous study (Ortmann et al., 2024), which may have led to comparatively smaller correlation coefficients.

To provide further evidence for the construct validity of the EDIP-Q, we examined its relationships with self-report measures of anxiety and depressive symptoms. Moderate-to-strong negative correlations were found between the EDIP-Q language versions (TS and subscales) and self-reported anxiety and depressive symptoms, suggesting that greater deficits in EDIP are associated with greater symptom severity. These results were expected, as mood and anxiety disorders are the most common mental disorders co-occurring with EDs (e.g., Hambleton et al., 2022).

While convergent validity has been demonstrated previously for the original EDIP-Q (Ortmann et al., 2024) and for the translation in the present study, further research is warranted to investigate its divergent validity by examining its relationship with constructs that are theoretically distinct from those already studied, e.g., measures of personality traits, physical health, or social support.

**Incremental Validity**

Extending previous work, we investigated the incremental validity of the EDIP-Q to determine whether its subscales enhance predictive accuracy for ED psychopathology and maladaptive eating behaviors beyond that offered by existing self-report instruments. Hierarchical regression analyses revealed that adding the EDIP-Q subscales significantly increased the explained variance for both core ED psychopathology (drive for thinness, bulimic tendencies, and body dissatisfaction) and maladaptive eating behaviors (restraint, emotional eating, and external eating) compared to the MAIA subscales.

For ED psychopathology, the inclusion of EDIP-Q subscales resulted in a substantial increase in explained variance ranging from 9% to 23%, accompanied by medium to large effect sizes. Similarly, the addition of EDIP-Q subscales enhanced the explained variance by 8% to 23% for maladaptive eating behaviors, with medium to large effect sizes.

These findings underscore the EDIP-Q's ability in assessing interoceptive deficits relevant to eating behavior and ED psychopathology beyond existing self-report measures (e.g., MAIA), emphasizing its potential to advance ED research and its application in clinical settings.

**Group Comparisons**

The second aim of our study was to replicate the findings by Ortmann et al. (2024). As anticipated, healthy females scored lower on the EDIP-Q TS and subscale scores compared to males, indicating a lower level of EDIP in women. This gender-specific trend, also found by Ortmann et al. (2024), may represent a risk factor for women developing disordered eating behaviors (Galmiche et al., 2019). Gender differences in interoception have also been proposed to account for the prevalence and presentation of certain other mental disorders, e.g. depression and anxiety (Murphy, Viding, et al., 2019). Nevertheless, evidence for gender differences in interoceptive dimensions and modalities remains inconsistent (Grabauskaitė et al., 2017; Longarzo et al., 2021; Naraindas et al., 2023; Prentice & Murphy, 2022), highlighting the need for further research.

Consistent with previous research (Ortmann et al., 2024), our study results further confirms differences in EDIP among women with and without self-reported EDs. Specifically, female participants with current self-reported EDs exhibited the lowest EDIP-Q TS and subscale scores, followed by those with past EDs, and then HC. Differences between female participants with past ED and HC were, however, not significant, except for a significant group difference on Emotions. These results indicate that EDIP scores improve with recovery even to a level comparable to a non-clinical sample. Together with findings of a meta-analysis (Jenkinson et al., 2018), they support hypotheses concerning the role of interoceptive deficits in the etiology and maintenance of EDs.

Profiles of deficits in EDIP specific to AN, BN, and BED were established in previous work (Ortmann et al., 2024). While the ED types reported equal difficulties in emotion perception, they differed in their ability to perceive hunger and satiety, and to discriminate between hunger and emotional states. In particular, women with BN and BED reported higher sensibility to hunger, lower sensibility to satiety, and greater difficulty in discriminating between hunger and emotional states, compared to women with AN. The respective deficit profile was established for individuals with AN.

In line with the findings of Ortmann et al. (2024), we found no differences on Emotions between female participants with self-reported AN, BN, and BED in the current sample, indicating similar difficulties in emotion perception in ED types. These findings are also consistent with previous research (Westwood et al., 2017), showing a general impairment in emotional processing across the ED spectrum. Regarding the perception of hunger and satiety, and the ability to discriminate between hunger and emotional states, we partially replicated the results of Ortmann et al. (2024). Among female participants, those with BED scored significantly higher on Hunger than those with AN and BN, indicating a higher sensibility to hunger cues. On Satiety, females with AN had marginally significant higher scores than those with BN, indicating a higher sensibility to satiety cues. On Discrimination, females with BED reported significantly lower scores than those with AN, indicating greater difficulties in discriminating between hunger and emotional states.

Contrary to our expectations, however, not all differences in EDIP between ED types reached significance (e.g., women with BN did not differ significantly from those with AN on Hunger). The reason for these less significant group differences could be that the ED diagnoses were assessed via self-report, leading to some heterogeneity within the groups. This important limitation is discussed in more detail in the next section. Notwithstanding the former, our results provide, however further important evidence for the differential contribution of the perception of emotions, and hunger and satiety to the etiology of EDs. This result has implications for the development of more tailored treatment approaches for EDs, with a particular focus on addressing interoceptive deficits.

**Strength and Limitations**

The anonymous internet-based survey format of our study may have benefitted the collection of unbiased data on sensitive topics, such as eating- and body related information (Kays et al., 2012). While the dataset was carefully inspected for data integrity, selection and response biases are common in internet-based research and cannot be ruled out. Follow-up studies should implement additional measures, such as including attention-check questions or Captcha systems, to ensure higher data quality.

Our language samples were comprehensive and diverse, covering a wide range of socio-demographic characteristics, including age, marital status, education level and employment status. This greater diversity may have led to more robust and generalizable results, which supports the external validity of our study. An important limitation, however, is the unequal gender distribution (86.5% female, 10.7% male, 2.8% other) in the overall sample. Previous research with similar study designs has reported a comparable gender ratio in their samples (e.g., Cunningham et al., 2021; Ortmann et al., 2024; van Dyck et al., 2016). This is likely because women show more interest in and seek treatment for EDs, leading to a higher willingness to participate in studies on eating behavior and EDs. Even though previous research has demonstrated a high degree of factor similarity of the EDIP-Q between sexes (Ortmann et al., 2024), future research is encouraged to specifically recruit sex- and gender-diverse individuals to ensure an adequate representation of these populations (Breton et al., 2023). Such efforts would facilitate subgroup analyses and the exploration of potential sex and gender differences in the psychometric properties of the EDIP-Q, which are essential for establishing its validity and reliability in diverse populations. Additionally, establishing norm values for sex, gender, and ED subtypes such as AN, BN and BED would be an important step toward further validating the EDIP-Q.

Our study findings regarding differences based on diagnostic status must be interpreted with caution. Firstly, the inclusion of only women in the statistical analyses might have limited the generalizability of the results (as discussed earlier). Secondly, group allocation was based on self-reported lifetime history of EDs. Even though we formed the groups with caution by including only participants who were officially diagnosed by a mental health professional, it was not possible to verify the diagnoses. This may have led to a certain degree of heterogeneity within the groups and less meaningful group differences in EDIP. Future research is warranted to use the EDIP-Q in a controlled clinical setting and to examine group differences in individuals diagnosed with a semi-structured interview by a clinician, thereby enhancing the generalizability and practical relevance of the results.

## Conclusions

The present study extends previous work by providing initial evidence of the validity of the English and French versions of the EDIP-Q. The different language versions exhibit sound psychometric properties, measurement equivalence, construct validity and incremental validity. This supports the use of the language versions in English- and French-speaking populations and fulfills the requirement for comparative research. Using the different language versions of the EDIP-Q, we replicated previous findings and identified important interoceptive deficits to varying degrees in AN, BN, and BED, highlighting the need to develop more targeted and individualized treatment approaches for ED.

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# 4. Cardiac Interoceptive Processing and Emotional Experience in Individuals with and without Binge Eating Behavior (Study 4)

Ortmann, J., Schulz, A., Lutz, A. P. C., van Dyck, Z. & Vögele, C. (2024). *Cardiac Interoceptive Processing and Emotional Experience in Individuals with and without Binge Eating Behavior.* [Manuscript submitted for publication]. Department of Behavioural and Cognitive Sciences, University of Luxembourg.

## 4.1. Abstract

**Objective**: The aim of this study was to provide a comprehensive assessment of cardiac interoception in individuals with binge eating (BE) behavior and to compare their emotional experience and affective state related to heartbeat perception with those of healthy controls (HCs). **Method**: Following a 5-minute resting phase, participants ($n$ = 28 BE group, $n$ = 28 healthy control [HC] group) completed the heartbeat counting task (HCT). EEG and ECG were recorded concurrently. Based on HCT results, indices for interoceptive accuracy (IAcc), interoceptive beliefs (IBe), and interoceptive insight (IIn) were computed. Heart rate (HR) and heart rate variability (HRV) were analyzed as indicators of bodily signal strength, and heartbeat-evoked potentials (HEPs) were derived for the neural representation of cardio-afferent signals at the cortical level. Participants' emotional experiences during the HCT and changes in affective state from pre- to post-task were assessed using self-reports. **Results**: The BE group exhibited a profile of interoceptive alterations characterized by heightened parasympathetic cardiac activity and altered cortical response to the HCT, while the dimensions of IAcc, IBe, and IAw remained unaltered. Negative affect (NA) increased from pre- to post-task in both groups. BE group differed from the HC group only post-task, reporting higher NA. **Discussion**: Altered neural representation may reflect disengagement from bodily sensations, which may impair emotion processing and regulation, potentially contributing to BE behavior. Further research is warranted to confirm the specificity of this profile for BE-related eating disorders (EDs) or its importance for EDs in general.


*Key words:* Cardiac interoception, heartbeat-evoked potentials, emotion processing, binge eating, eating disorders

## 4.2. Introduction

Eating disorders (EDs) share disordered eating and weight-control behaviors that manifest differently across diagnostic criteria. A core behavioral symptom observed across EDs concerns binge eating (BE), which refers to the consumption of large amounts of food in a short period of time, accompanied by a sense of loss of control over eating (American Psychiatric Association [APA], 2013). BE is further categorized into objective and subjective BE (OBE and SBE; Fairburn & Cooper, 1993). In OBE, large amounts of food are consumed, whereas in SBE, the quantity is within a normal range but is perceived as excessive by the individual. SBE contributes equally to, or even more significantly than, OBE to ED psychopathology, depression, poor quality of life, and psychological distress (Brownstone et al., 2013; Brownstone & Bardone-Cone, 2021; Mond et al., 2010). Although SBE is not a formal diagnostic criterion, its assessment is clinically important for the comprehensive understanding of patients' condition. Research has increasingly questioned the utility of maintaining rigid diagnostic boundaries for EDs. First, there is evidence for significant diagnostic crossover, in that symptoms and diagnoses can shift over the course of the disorder (Eddy et al., 2008). Second, individuals with subthreshold bulimia nervosa (BN) or binge-eating disorder (BED) exhibit similar levels of ED psychopathology, impaired mental health and well-being as those with full-syndrome BN or BED (Chapa et al., 2018; Johnson et al., 2021; Striegel-Moore et al., 2000). Third, SBE significantly affects both general and ED psychopathology, regardless of whether it occurs alone or in conjunction with OBE (Mond et al., 2010). Fourth, BE behavior is not confined to clinical populations. A considerable number of people from non-clinical populations report recurrent BE episodes (BEEs) (e.g., Duarte et al., 2015; Goldschmidt et al., 2015; Sonneville et al., 2013), which are linked to adverse health outcomes, such as obesity, and depressive and anxiety symptoms. It is crucial, therefore, to improve our understanding of the factors contributing to the development and maintenance of BE behavior across individuals with recurrent BEEs. Adopting a transdiagnostic approach will offer valuable insights into recurrent BEEs, regardless of the underlying ED diagnosis.

Etiological models explaining the occurrence and maintenance of BE behavior in individuals with recurrent BEEs emphasize the role of emotional experience and emotion regulation. These models propose that affected individuals may engage in BE as a means of escaping negative self-awareness and emotional distress (escape theory; Heatherton & Baumeister, 1991), to regulate or cope with negative emotions (affect regulation model; Polivy & Herman, 1993), or in response to emotional states they misinterpret and confound with feelings of hunger (Bruch, 1964). Evidence from various lines of research supports each of these approaches (e.g., Blackburn et al., 2006; Kenny et al., 2017; Leehr et al., 2015; Munsch et al., 2012; Ortmann et al., 2024). Meta-analytical results provide strong support for the notion that individuals across the ED spectrum have elevated levels of alexithymia, i.e. difficulties in identifying and describing one's own emotions (Westwood et al., 2017). This lack of emotional clarity likely hampers their ability to adequately respond to emotional needs, leading to maladaptive coping mechanisms, such as BE. Emotion regulation is a core aspect of current approaches to the treatment of BE (e.g., Hilbert & Tuschen-Caffier, 2010; Munsch et al., 2011), but relapse rates in individuals with recurrent BEEs remain high (Fichter et al., 2008; Quadflieg & Fichter, 2019). A more thorough understanding of the mechanisms underlying emotional dysregulation may help fine-tune interventions and improve treatment outcomes.

Theories of emotions emphasize the crucial role of physiological cues in emotional experiences (Damasio, 1996; James, 1922; Schachter & Singer, 1962), suggesting that emotions arise from bodily changes in response to environmental or daily events. This perception of internal bodily changes, known as *interoception*, involves the processing of visceral signals (i.e., sensing, interpreting, integrating) from various organ systems to maintain physical homeostasis, providing a continuous, real-time representation of the body's internal state at both conscious and unconscious levels (Khalsa et al., 2018). Several dimensions of interoception can be distinguished based on processing levels in the peripheral and central nervous systems as well as assessment approaches (Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2019; Suksasilp & Garfinkel, 2022). In the current study, we will use the terminology proposed by Suksasilp & Garfinkel (2022) (see Table 1) and focus on the cardiovascular system, because cardiac interoception has been linked in particular to emotion processing (Wiens, 2005) and regulation (Füstös et al., 2013).

**Table 1**
*Overview of interoceptive dimensions relevant to the present study, along with their respective definitions and operationalization.*

| Dimension | Definition |
|---|---|
| Interoceptive accuracy (IAcc) | Correct and precise monitoring i.e. the correspondence between directly measured physiological events and individuals' reported experience of those events, ascertained through behavioural tests. |
| Self-report and interoceptive beliefs (IBe) | Measures of beliefs, both available to and beyond conscious access, concerning individuals' interoceptive sensations and experiences. Includes self-report measures, such as questionnaires and confidence ratings, and task-based measures of (implicit) prior beliefs thought to influence interoceptive perception. |
| Interoceptive insight (IIn) | Metacognitive evaluation of experience/performance e.g., the correspondence between accuracy during an interoceptive task, and (self-reported) perceived accuracy or confidence during the task. |
| Neural representation | Central nervous activity associated with interoceptive processing, including the coupling of central activity with afferent physiological signals |
| Strength of afferent signals | The strength and nature of signals originating from the periphery that communicate interoceptive states to the central nervous system. |

*Note.*
Adapted from "Towards a comprehensive assessment of interoception in a multi-dimensional framework," by C. Suksasilp and S. N. Garfinkel, 2022, *Biological Psychology*, 168, 108262

Previous studies showed that individuals with EDs, including BN and BED, report lower *interoceptive beliefs* (IBe) scores as assessed via self-report questionnaires (Brown et al., 2017; Jenkinson et al., 2018; Ortmann et al., 2024). Experimental studies on cardiac interoception, however, suggest that interoceptive processes remain largely intact in individuals with BEEs. While one study reported reduced cardiac *interoceptive accuracy* (IAcc) in individuals recovered from BN (Klabunde et al., 2013), most studies indicate no significant alterations in IAcc among those with BN (Eshkevari et al., 2014; Pollatos & Georgiou, 2016; Lutz, van Dyck et al., 2019; Lutz et al., 2023) and BED (Lutz et al., 2023). Additionally, two recent studies investigated IAcc, IBe, and *interoceptive insight* (IIN) in individuals with BN (Lutz, Schulz, et al., 2019) and BED (Lutz et al., 2023; Lutz, Schulz, et al., 2019), both finding no significant alterations in these dimensions.

Regarding cardiac activation (i.e., *strength of afferent signals*), meta-analytic findings indicate increased parasympathetically-mediated heart rate variability (HRV) in BN (Peschel et al., 2016; Watford et al., 2020), but no alterations in BED (Christensen et al., 2023). It appears likely, therefore, that such alterations are linked to purging behavior rather than BE.

The *neural representation* and processing of cardiac signals at the cortical level is a crucial processing step between the physiological state of the cardiovascular system and its perception. One methodological approach involves the assessment of heartbeat-evoked potentials (HEPs), an electrophysiological brain response that reflects the cortical processing of cardio-afferent signals. HEPs are event-related brain potentials with the R-wave in the ECG as 'event' (Pollatos & Schandry, 2004). These are modulated by arousal or attention to the cardiac signals (for a review, see Coll et al., 2021), with increased HEP amplitudes indicating heightened cortical processing. Altered cortical processing of cardiac signals has been associated with changes in emotion processing. For example individuals with emotional disturbances such as depression and borderline personality disorder show lower HEP amplitudes compared to healthy controls (HCs) (Müller et al., 2015; Terhaar et al., 2012). As individuals with BEEs experience similar symptoms of emotional dysregulation and higher levels of depressive symptoms (Hambleton et al., 2022), we would expect a similar reduction in HEP amplitudes. Initial studies investigating HEPs in BN and BED found, however, no significant alterations (Lutz et al., 2023; Lutz, van Dyck, et al., 2019). It should be noted that these studies were limited in terms of their sample size and absence of a transdiagnostic approach focusing on BE.

Important shortcomings in the literature concern the lack of studies investigating BED, the focus on diagnostic categories rather than transdiagnostic characteristics, and the isolated assessment of interoceptive dimensions. The latter has clinical relevance, as interoceptive processes may contribute differently to cognitions, emotions, and symptom presentation (Suksasilp & Garfinkel, 2022).

The aim of the current study was, therefore, to provide a more comprehensive multidimensional assessment of interoception with regards to recurrent BEE as a transdiagnostic characteristic in individuals with recurrent BEEs. Given the close association between cardiac interoception and emotional processing (Wiens, 2005), we investigated cardiac interoceptive processes at multiple levels, including IAcc, IBe, IIn, the strength and the neural representation of cardio-afferent signals at the cortical level. Based on the prominent emotional disturbances in individuals with BE and increased negative affect in response to gastric distensions during a water load test in participants with BN and BED (van Dyck et al., 2020), we investigated emotional experience and affective state in relation to heartbeat perception, as well.

We hypothesized (I.) IAcc, IBe and IIn, derived from the heartbeat counting task (HCT; Schandry, 1981), to be unaltered in individuals with recurrent BEEs (BE group) compared to HCs (HC group). Regarding neural representation, we expected (II.) to find an attention effect in both groups, with higher HEP amplitudes during the HCT compared to the rest condition. Consistent with previous findings in BN and BED, and accounting for comorbid depressive disorders, we hypothesized (III.) that individuals with BEEs will exhibit either unaltered or reduced neural representation of cardiac signals at the cortical level, with the BE group showing similar or lower HEP amplitudes compared to the HC group. Regarding the strength of cardio-afferent signals (i.e., cardiac activation), we expected (IV.) the BE group to show decreased mean heart rate (HR) and increased high-frequency normalized unit (HF n.u.), indicating heightened parasympathetic activity compared to the HC group. Additionally, we hypothesized (V.) that the BE group would perceive the HCT as more aversive and rate their negative affective state higher while rating their positive affective state lower than the HC group.

## 4.3. Methods

**Procedure**

This study is part of a larger project approved by the Ethics Review Panel of the University of Luxembourg (ERP 22-017A2 EDIP). We aimed at recruiting women who currently reported recurrent BEEs with a minimum average frequency of once a month and a sense of loss of control over eating, regardless of the amount of food consumed or the presence of purging behavior. We also sought women without current BE behavior or ED history. Participants were recruited from the general population in Luxembourg via flyers and advertisements in local media (social media, newspapers, magazines). General exclusion criteria were: (1) being underage (< 18 years) (2) neurological disorders (e.g., epilepsy), (3) chronic diseases and/or medication affecting easting behavior (e.g., diabetes mellitus), (4) substance use disorder, (5) history of bariatric surgery, (6) cardio-vascular diseases, (7) pregnancy and/or breast-feeding, (8) uncorrected impairment of vision, and (9) conditions impeding the application of electrodes (e.g., skin diseases or allergies). A total of 151 volunteers were screened for eligibility with a custom-made telephone screening. Eligibility was then confirmed in the first session of the study.

The study involved two sessions on separate days. In the first session, participants provided written informed consent and completed a set of questionnaires administered via the survey platform SoSci Survey (https://www.soscisurvey.de/) to assess levels of ED psychopathology, general and ED-specific interoceptive perception, maladaptive eating behavior, emotion regulation difficulties, depression, and anxiety (detailed information on the questionnaires used are provided in the supplemental materials). This was followed by three interviews (1) a customized interview to collect socio-demographic and health-related data, (2) the Diagnostic Short-Interview for Mental Disorders (Mini-DIPS Open Access – extended version; Margraf & Cwik, 2017) to assess lifetime diagnoses, and (3) the Eating Disorder Examination (Hilbert et al., 2004) to assess current ED psychopathology and to classify BEEs into objective (eating 'large' amounts of food with loss of control) and subjective BEEs (eating normal amounts perceived as excessive by the participant, with loss of control). Lifetime diagnoses were coded according to DSM-5 criteria (APA, 2013). Participants' height and weight were measured at the end of the session.

In the second session, the psychophysiological assessment was carried out. Participants were instructed not to eat for three hours and not to drink for two hours before the session. They were seated in a comfortable chair. After preparing the EEG and ECG electrodes, a five-minute resting-state measurement was conducted and followed by three distinct behavioral tasks aimed at assessing interoceptive processes in the cardiovascular and gastrointestinal organ systems. This article presents the results for the HCT (Schandry, 1981), while the results for the other tasks will be reported elsewhere. Stimulus presentation and response collection were run with E-Prime 3.0 (Psychology Soft- ware Tools, Sharpsburg, PA). Participants received a gift voucher worth €60 as reimbursement for their participation.

**Participants**

The BE group comprised twenty-eight individuals who reported recurrent BEEs ($n$ = 14 BED, $n$ = 5 BN, $n$ = 1 AN-BP, $n$ = 3 Other Specified Feeding or Eating Disorder (OSFED), $n$ = 2 partially remitted BED, $n$ = 3 partially remitted BN). The HC group included twenty-eight participants, matched with the BE group according to age, sociodemographic status, and, when possible, body mass index (BMI), with none reporting BEEs. While the groups were comparable in age and education ($ps > .05$; see Table 2), the BE group participants had a higher BMI ($p$ = .005). In addition, the BE group reported significantly more severe ED psychopathology (drive for thinness, bulimic tendencies, body dissatisfaction), poorer general and ED-specific interoceptive perception, greater endorsement of maladaptive eating styles (restrained, emotional, and external eating), greater emotion regulation difficulties, and higher levels of depression and anxiety compared to HCs (all $ps < .05$; see Table 2).

Sociodemographic sample characteristics, differences in trait questionnaires and lifetime diagnoses for the BE group and HC group are presented in Table 2.

**Table 2**
*Sociodemographic Characteristics and Lifetime Diagnoses*

| | BE group | | HC group | | Between-groups test | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* = 28 | | *n* = 28 | | | | | |
| **Demographics** | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *d* |
| Age | 35.2 | 16.5 | 32.9 | 14.1 | 0.558 | 54 | .579 | .15 |
| BMI | 29.2 | 8.0 | 24.2 | 4.2 | 2.950 | 40.97 | .005 | .79 |
| | *Mean Rank* | | *Mean Rank* | | *U* | | *p* | *r* |
| Education level* | 26.68 | | 30.32 | | 443 | | .371 | -0.12 |
| **Questionnaires** | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *d* |
| EDI-2 | | | | | | | | |
| Drive for Thinness | 32.1 | 6.4 | 18.3 | 6.7 | 7.84 | 54 | <.001 | 2.10 |
| Bulimic tendencies | 25.3 | 6.7 | 11.2 | 3.7 | 9.68 | 41.70 | <.001 | 2.59 |
| Body dissatisfaction | 41.2 | 10.4 | 28.8 | 10.8 | 4.37 | 54 | <.001 | 1.17 |
| EDIP-Q | | | | | | | | |
| Total score | 3.8 | 0.8 | 5.5 | 0.6 | -8.84 | 54 | <.001 | -2.36 |
| Emotions | 4.4 | 1.2 | 5.7 | 0.7 | -4.83 | 41.44 | <.001 | -1.29 |
| Hunger | 4.4 | 1.2 | 5.8 | 0.8 | -4.96 | 48.42 | <.001 | -1.32 |
| Satiety | 2.7 | 1.1 | 4.8 | 1.1 | -7.20 | 54 | <.001 | -1.93 |
| Discrimination | 4.0 | 1.3 | 5.9 | 0.8 | -6.47 | 46.4 | <.001 | 1.09 |
| MAIA | | | | | | | | |
| Noticing | 4.0 | 0.8 | 4.3 | 0.8 | -.90 | 54 | .371 | -.24 |
| Not distracting | 2.6 | 0.8 | 3.3 | 0.9 | -3.24 | 54 | .002 | -.87 |
| Not worrying | 2.7 | 1.0 | 3.5 | 1.0 | -2.83 | 54 | .006 | -.76 |
| Attention regulation | 3.3 | 0.9 | 4.0 | 0.8 | -3.28 | 54 | .002 | -.88 |
| Emotional awareness | 4.2 | 1.1 | 4.5 | 0.8 | -1.15 | 54 | .256 | -.31 |
| Self-regulation | 3.1 | 1.1 | 3.9 | 1.0 | -3.01 | 54 | .004 | -.81 |
| Body listening | 2.8 | 1.3 | 3.9 | 1.1 | -3.22 | 54 | .002 | -.86 |
| Trusting | 3.1 | 1.3 | 4.8 | 1.0 | -5.48 | 54 | <.001 | -.86 |
| DEBQ | | | | | | | | -1.46 |
| Restrained Eating | 3.3 | 0.9 | 2.3 | 0.7 | 4.57 | 54 | <.001 | 1.22 |
| Emotional Eating | 3.7 | 0.8 | 2.2 | 0.8 | 7.22 | 54 | <.001 | 1.93 |
| External Eating | 3.5 | 0.4 | 3.1 | 0.5 | 3.70 | 54 | .001 | 0.99 |
| DERS | | | | | | | | |
| Mean Score | 2.9 | 0.7 | 1.9 | 0.5 | 6.09 | 54 | <.001 | 1.63 |
| Nonacceptance | 2.9 | 1.2 | 1.8 | 0.6 | 4.40 | 41.83 | <.001 | 1.18 |
| Goals | 3.4 | 0.9 | 2.4 | 0.9 | 4.08 | 54 | <.001 | 1.09 |
| Impulse | 2.8 | 0.8 | 1.8 | 0.6 | 5.55 | 54 | <.001 | 1.48 |
| Awareness | 2.9 | 0.9 | 2.2 | 0.8 | 3.00 | 54 | .004 | 0.80 |
| Strategies | 3.1 | 0.9 | 1.8 | 0.6 | 6.08 | 47.69 | <.001 | 1.63 |
| Clarity | 2.5 | 0.9 | 1.9 | 0.6 | 2.86 | 46.95 | .006 | 0.76 |
| PHQ-9 | 10.4 | 5.3 | 5.3 | 4.2 | 4.03 | 54 | <.001 | 1.08 |
| GAD-7 | 9.2 | 5.1 | 4.7 | 3.6 | 3.82 | 48.33 | <.001 | 1.02 |
| **Current comorbid diagnoses** | *n* | *%* | *n* | *%* | | | | |
| Depressive disorders | 7 | 25 | 0 | 0 | | | | |
| Anxiety Disorders | 12 | 42.9 | 1 | 3.6 | | | | |
| Obsessive-compulsive and related disorders | 1 | 3.6 | 0 | 0 | | | | |
| Trauma- and stressor related disorders | 0 | 0 | 0 | 0 | | | | |
| Somatic symptom and related disorder | 1 | 3.6 | 0 | 0 | | | | |
| Sleep-wake disorders | 2 | 7.1 | 0 | 0 | | | | |

| **Current comorbid diagnoses** | *n* | % | *n* | % |
|---|---|---|---|---|
| Substance-related and addictive disorders | 0 | 0 | 0 | 0 |
| **Past diagnoses** | *n* | % | *n* | % |
| Depressive disorders | 15 | 53.6 | 4 | 14.3 |
| Anxiety Disorders | 2 | 7.1 | 2 | 7.1 |
| Obsessive-compulsive and related disorders | 0 | 0 | 0 | 0 |
| Trauma- and stressor related disorders | 9 | 32.1 | 1 | 3.6 |
| Somatic symptom and related disorder | 0 | 0 | 0 | 0 |
| Sleep-wake disorders | 1 | 3.6 | 0 | 0 |
| Substance-related and addictive disorders | 3 | 10.7 | 0 | 0 |

*Note.* Group differences for metric variables were calculated with *t*-tests and for ordinal variables with the Mann-Whitney-*U* test. BE group = binge eating group, HC group = Healthy control group, BMI = Body Mass Index, EDI-2 = Eating Disorder Inventory-2, * education level was coded according to the International Standard Classification of Education (ISCED2012), EDIP-Q = Eating Disorder-specific Interoceptive Perception-Questionnaire, DEBQ = Dutch Eating Behavior Questionnaire, DERS = Difficulties in Emotion Regulation Scale, Nonacceptance = Nonacceptance of Emotional Responses, Goals = Difficulties Engaging in Goal-Directed Behavior, Impulse = Impulse Control Difficulties, Awareness = Lack of Emotional Awareness, Strategies = Limited Access to Emotion Regulation Strategies, Clarity = Lack of Emotional Clarity, PHQ-9 = Patient Health Questionnaire-9, GAD-7 = Generalized Anxiety Disorder-7.

**Heartbeat Counting Task**

In the HCT (Schandry, 1981), participants focused on and silently counted their own heartbeats during fixed and randomized time intervals (25s, 35s, 45s, and 55s), without feeling their pulse or using other aids. A 25s practice trial preceded the experiment. Time intervals were indicated on screen by a fixation cross. After each trial, participants reported the number of counted heartbeats and rated their confidence in their accuracy on a 9-point Likert scale ranging from 0 (not sure at all) to 8 (absolutely sure). Further instructions required counting only the heartbeats they actually perceived, not estimating the number, and indicating 'zero' if none were perceived ('strict' instructions: e.g., Desmedt et al., 2018). No feedback was provided on their performance. Indices of cardiac interoception were derived as follows:

IAcc scores were computed using the formula below.

$$\frac{1}{4} \sum [1 - \frac{(|counted\ heartbeats - recorded\ heartbeats|)}{recorded\ heartbeats}]$$

IBe scores were derived from averaged confidence ratings.

IIn scores were calculated using the "percent of maximum possible" (POMP) scoring method, as previously applied by Weineck et al. (2019). First, IAcc and IBe scores were transformed into POMP scores using the formula below (Cohen et al., 1999).

$$\text{POMP} = \frac{x{-}variable\ mininum\ score}{maximum{-}minium\ score} * 100$$

The absolute difference between these POMP scores was then calculated and subtracted from 100 to obtain more intuitive IIn scores, with higher values indicating greater IIn.

**Emotional Experience**

After completing the HCT, participants rated their emotional experience of perceiving their heartbeat using three different 9-point SAM scales (Bradley & Lang, 1994) with the anchors “negative” and “positive” for Valence, “calm” and “excited” for Arousal, and “nor anxious at all” and “very anxious” for Anxiety.

In addition, the Positive and Negative Affect Schedule (PANAS) was used to assess positive and negative affective states pre- and post-task. Responses were given on a 5-point Likert scale ranging from 1 (very slightly or not at all) to 5 (extremely). Mean scores were calculated for each subscale, with higher scores reflecting higher levels of positive affect (PA) and negative affect (NA), respectively. For positive affect (PA), Cronbach’s α in the current sample was .81 and .88 for pre- and post-task, respectively. For negative affect (NA), Cronbach’s α in the current sample was .90 and .89 for pre- and post-task, respectively.

**Physiological Data Acquisition and Processing**

Physiological data acquisition and processing were performed with BrainVision Recorder and Analyzer (Version 2.2; Brain Products, Gilching, Germany). EEG data were recorded with a 32-channel actiCAP electrode system (Ag/AgCl electrodes, 10-20 system, reference FCz, impedances < 20 kΩ) with BrainAmp amplifiers (Brain Products, Gilching, Germany). Bipolar horizontal EOG electrodes were placed next to the outer canthi of both eyes. ECG electrodes (Ag/AgCl; Medi-Trace 200, MT200) were placed according to the Einthoven lead II configuration. Data were sampled at 1000 Hz and high-pass filtered at 0.016 Hz.

Offline, EEG data were resampled at 250 Hz, re-referenced to mathematically linked mastoids (TP9, TP10) and bandpass filtered at 0.1 – 35 Hz (half power cutoff, 24 db/octave slope). A 50 Hz notch filter was applied to reduce line noise. R-waves were automatically detected, visually inspected, and corrected if necessary. A semi-automatic raw data inspection was conducted to identify major artefacts (e.g., muscle movements). Ocular artefacts were not included in the raw data inspection but removed subsequently with the Restricted Infomax Independent

Component Analysis (ICA) algorithm with Fp1 as vEOG channel. EEG data were then segmented into epochs ranging from -250 ms to 1000 ms after the R-wave and baseline corrected (-250 ms to -50 ms). Since only major artefacts were marked during raw data inspection, an additional semi-automatic artefact rejection was applied to segmented data. Segments containing artifacts, such as muscle activity, drifts, or non-physiological glitches, were removed. Participants were included in further analysis if they met the a priori defined threshold of 50% or more valid segments (Luck, 2014). All participants met this criterion, with an average of 167.5 (*SD* = 10.47) valid HEP segments for the resting condition, and 166.18 (SD = 23.61) for the HCT. HEP amplitudes were computed as mean amplitudes in the time window of 455 to 595 ms after the R-wave, where the impact of the electro-cardiac field is considered minimal (Dirlich et al., 1997). To examine gross effects of laterality and scalp location, electrodes were pooled into 3 × 3 scalp sectors (e.g., Lutz et al., 2019; Müller et al., 2015; Schulz et al., 2020; Schulz, Ferreira de Sá, et al., 2015): anterior left (Fp1, F3, F7, FC1, FC5), anterior central (Fz, FCz), anterior right (Fp2, F4, F8, FC2, FC6), central left (C3, T7), central (Cz), central right (C4, T8), posterior left (CP1, CP5, P3, P7, PO9, O1), posterior central (Pz, Oz), and posterior right (CP2, CP6, P4, P8, PO10, O2).

ECG data from the five-minute resting state were subjected to further analysis of HR and HRV using the ARTiiFACT software (Kaufmann et al., 2011). Artifacts in the interbeat-interval data were corrected through cubic spline interpolation. Spectral analysis of the RR interval series was performed using fast Fourier transform (FFT), and mean HR and high-frequency normalized units (HF n.u.) were calculated as an indicator of bodily signal strength/cardiac activation.

**Statistical Analyses**

Statistical analyses were performed using IBM SPSS Statistics (Version 27), with the critical alpha level set to .05. Group differences in IAcc, IBe, IIn, and cardiac activation were examined using independent-samples *t*-tests. HEP amplitudes were evaluated using a 2 × 3 × 3 × 2 mixed-design ANOVA with the repeated-measurement factor Condition (rest vs. HCT), Lobe (anterior, central, posterior), and Laterality (left, central, right), and the factor Group (BE vs. HC group). To control for potential artifacts in the recorded EEG data that originate from the cardiac activity (i.e., cardiac field artifact, CFA), equivalent analyses to those performed on the HEP amplitudes were conducted on the ECG data as control analyses using a 2 × 2 mixed-design ANOVA with the repeated-measurement factor Condition (rest vs. HCT), and the factor Group (BE vs. HC group). Differences in the emotional experience of perceiving the heartbeat were assessed using independent-samples *t*-tests. Affective states were evaluated using a 2 × 2 mixed-design ANOVA with the repeated-measurement factor Time (pre vs. post HCT), and the factor Group (BE vs. HC group). Significant main and interaction effects were further analyzed with Bonferroni-corrected post hoc independent and paired samples *t*-tests. Effect sizes are reported as partial eta squared for ANOVAs ($\eta p^2 = .01$ "small", $\eta p^2 = .06$ "medium", and $\eta p^2 = .14$ "large") and Cohen's *d* for t-tests (*d* = 0.2 "small", *d* = 0.5 "medium", and *d* = 0.8 "large") (Cohen, 1988).

## 4.4. Results

**Interoceptive Accuracy, Interoceptive Beliefs, Interoceptive Insight, and Cardiac Activation**

Means and *SDs* for IAcc, IBe, IIn, and indices of cardiac activation are presented in Table 3. There were no group differences for IAcc, IBe, and IIn (*ps* > .05). The groups differed, however, in bodily signal strength (*ps* < .05), with the BE group showing lower mean HR and higher HF n.u. compared to HCs.

**Table 3**
*Mean scores (M) and standard deviations (SD) for interoceptive processing in the cardiac domain, including interoceptive accuracy, sensibility, insight, and physiological state.*

| | BE group $n = 28$ | | HC group $n = 28$ | | Between-groups test | | | |
|---|---|---|---|---|---|---|---|---|
| **Interoceptive processing** | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *d* |
| Interoceptive accuracy | 0.46 | 0.36 | 0.51 | 0.32 | -0.48 | 54 | .635 | -0.13 |
| Interoceptive sensibility | 5.62 | 1.82 | 4.80 | 2.13 | 1.53 | 54 | .131 | 0.41 |
| Interoceptive insight | 65.48 | 32.22 | 65.49 | 26.54 | -0.00 | 54 | .999 | .00 |
| Physiological state | | | | | | | | |
| Mean heart rate | 51.27 | 23.10 | 54.26 | 8.50 | 2.25 | 54 | .029 | .60 |
| HF n.u. | 65.28 | 10.80 | 38.77 | 18.21 | 4.24 | 54 | < .001 | 1.13 |

*Note.* Group differences were calculated using independent samples *t*-tests. BE group = binge eating group, HC group = Healthy control group, HF n.u. = high-frequency normalized units

## Neural Representation: HEPs

There was a significant interaction effect between Lobe and Laterality, $F(2.55, 137.48) = 9.95$, $p < .001$, $\eta p^2 = .16$. HEP amplitudes were highest at central electrode sites and differed significantly from both anterior central ($t(55) = -3.66$, $p = .001$, $d = -0.49$) and posterior central electrode sites ($t(55) = 4.10$, $p < .001$, $d = -0.52$). No significant difference in HEP amplitudes was found between anterior central and posterior central electrodes ($t(55) = 1.43$, $p = .157$, $d = -0.19$). An overview of the results concerning the post hoc paired-samples *t*-tests is provided in the supplemental materials (Supplementary Table 1).

The groups showed no differences in general HEP amplitudes, $F\ (1.00, 54.00) = 0.001$, $p = .98$, $\eta p^2 < 0.01$. Groups, however, differed in their response depending on task (interaction Condition × Group: $F\ (1.00, 54.00) = 4.98$, $p = .030$, $\eta p^2 = .08$; see Figures 1 and 2): HEP amplitudes in the HC group increased significantly from the resting state to the HCT condition, with a medium effect size ($0.05 \pm 0.44$ vs. $0.22 \pm 0.53$, $t(27) = -2.63$, $p = .026$, $d = -0.45$). This effect was not found in the BE group, as there was no significant difference in HEP amplitudes between resting state and task condition (0.22 ± 0.50 vs. 0.09 ± 0.77, $t(27) = 1.38$, $p = .182$, $d = 0.26$). No other higher-order interactions were significant ($p > .05$).

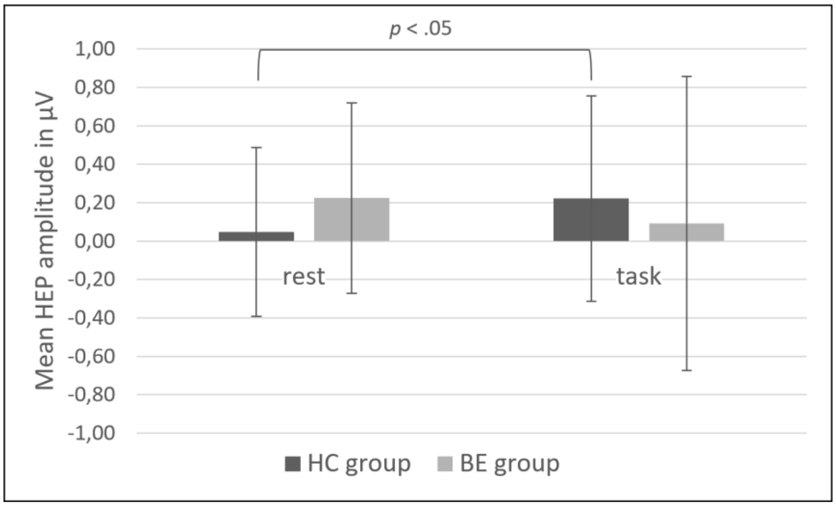


**Figure 1.** Bar chart represents the heartbeat-evoked potential (HEP) amplitudes separately for conditions and groups. Statistical differences were determined using independent and dependent samples *t*-tests. HC group = healthy control group, BE group = binge eating group.

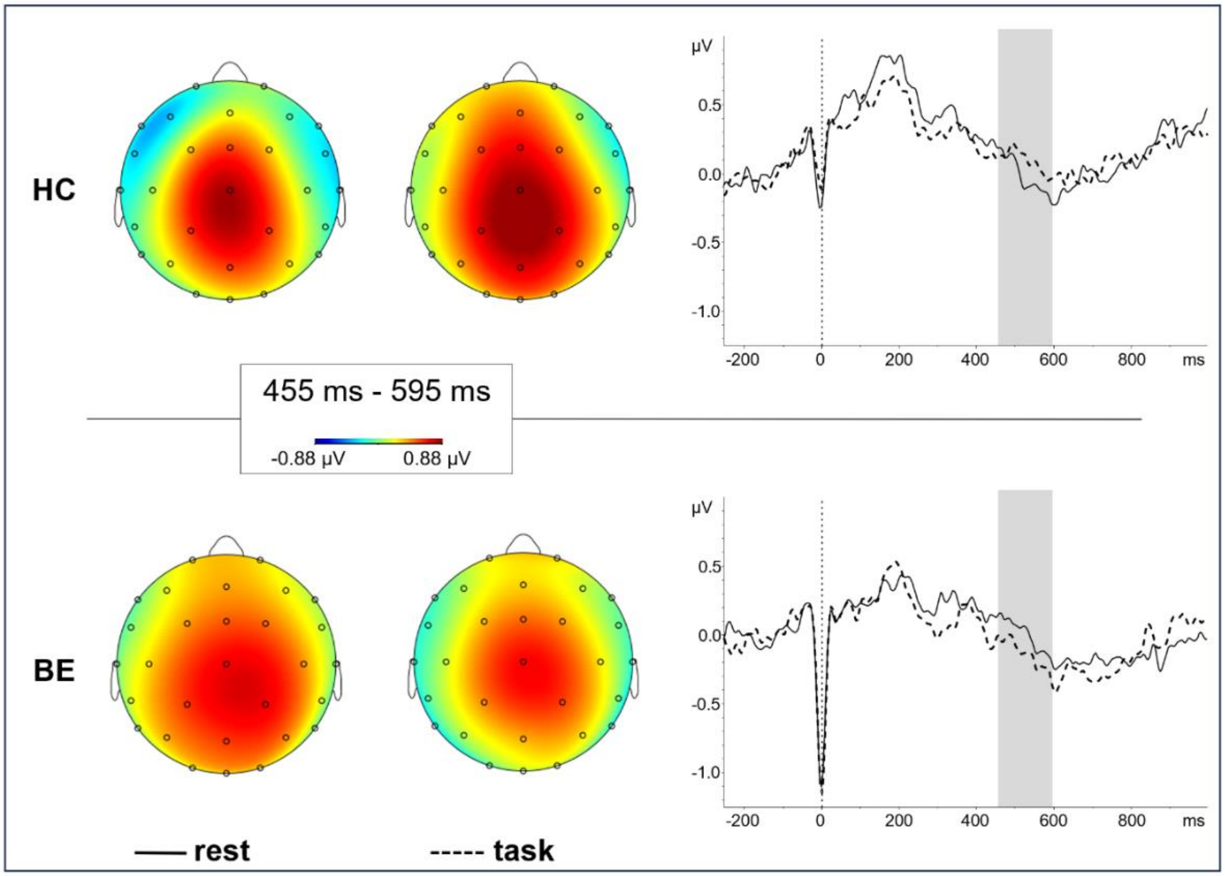


**Figure 2.** Scalp topographies and average waveforms of heartbeat-evoked potentials (HEPs) are presented separately for conditions and groups. The healthy control (HC) group is shown on the top, the binge eating (BE) group on the bottom. For the waveform, the signal was pooled across all electrodes. The R-peak of the ECG occurred at 0 ms. The HEP time window is indicated by a grey bar (455-595 ms).

## CFA Control Analysis

CFA control analysis revealed that average ECG amplitude neither differed between groups ($F(1, 54) = 0.25$, $p = .617$, $\eta p^2 = .01$), nor between conditions ($F(1, 54) = 2.49$, $p = .120$, $\eta p^2 = .04$), nor between groups across conditions (interaction Condition × Group: $F(1, 54) = 0.003$, $p = .959$, $\eta p^2 < .001$).

**Exploratory Correlational Analyses**

Pearson correlation analyses were conducted to explore the relationships between the change in HEP amplitude from rest to task (ΔHEP) with BMI and trait questionnaire scores. An overview of the results is provided in the supplementary materials (Supplementary Table 2). BMI was unrelated to ΔHEP ($r = .07$, $p > .05$). For ED psychopathology, we found negative relationships ranging from small to moderate; however, only the relationship with Bulimic Tendencies was significant ($r = -0.42$, $p < .01$), while the relationships with Drive for Thinness and Body Dissatisfaction were small and non-significant (*rs* = -.20 and -.15, respectively, *ps* > .05). Regarding general interoceptive perception, correlations with MAIA subscales were small and non-significant (*rs* = 0.02 - 0.22, *ps* > .05). For ED-specific interoceptive perception, significant correlations ranged from small to moderate (*rs* = 0.26 - 0.34, *ps* < .05), except for the Discrimination subscale ($r = 0.18$, $p > .05$). For maladaptive eating styles, we found negative relationships ranging from small to moderate; however, only the relationship with Restraint Eating was significant ($r = -0.36$, $p < .01$), while the relationships with Emotional or External Eating were not significant (*rs* = -.23 and -.24, respectively, *ps* > .05). Regarding emotion regulation difficulties, there were no significant relationships with the DERS subscales, except for a small negative relationship with Impulse Control Difficulties ($r = -.27$, $p < .05$). Additionally, ΔHEP was not related to levels of depression or anxiety (*ps* > .05).

**Emotional Experience**

Participants rated their emotional experience of perceiving their heartbeats. No group differences were found for Valence (5.75 ± 2.05 vs. 6.14 ± 1.82, $t(54) = -0.76$, $p = .451$, $d = -0.20$), Arousal (3.89 ± 2.30 vs. 3.32 ± 2.00, $t(54) = -0.99$, $p = .326$, $d = -0.26$), or Anxiety (3.29 ± 2.36 vs. 2.43 ± 1.77, $t(54) = 1.54$, $p = .130$, $d = -0.41$).

Affective states were assessed before and after the HCT. For PA, there was a significant main effect for Time ($F(1, 54) = 54.46$, $p < .001$, $\eta p^2 = .50$) but not for Group ($F(1, 54) = 2.41$, $p = .481$, $\eta p^2 = .04$). PA ratings decreased significantly from pre to post in both groups ($2.91 \pm 0.69$ vs. $2.37 \pm 0.69$, $t(55) = 7.28$, $p < .001$, $d = 0.97$).

For NA, significant main effects were found for Time ($F(1, 54) = 12.56$, $p = .001$, $\eta p^2 = .19$) and Group ($F(1, 54) = 6.50$, $p = .014$, $\eta p^2 = .11$). The interaction effect between Time and Group reached trend level significance ($F(1, 54) = 3.45$, $p = .069$, $\eta p^2 = .06$). NA ratings increased significantly from pre to post in both groups ($1.25 \pm 0.32$ vs. $1.47 \pm 0.59$, $t(55) = -3.47$, $p = .001$, $d = -0.46$). While NA ratings did not differ between the groups at pre ($1.32 \pm 0.37$ vs. $1.18 \pm 0.25$, $t(54) = 1.74$, $p = .07$, $d = -0.47$), differences were significant at post, with the BE group reporting higher NA compared to the HC group ($1.66 \pm 0.68$ vs. $1.28 \pm 0.40$, $t(43.88) = 2.55$, $p = .014$, $d = -0.68$).

## 4.5. Discussion

The first objective of this study was to assess cardiac interoceptive processes at multiple levels with regards to recurrent BEE as a transdiagnostic characteristic in individuals with recurrent BEEs.

The groups did not differ in overall electrocortical activity. An attention effect was anticipated in both groups, with higher HEP amplitudes during the HCT compared to rest. This attention effect was observed in the HC group, but not in the BE group (partially supporting hypothesis II), indicating altered cortical processing of cardiac signals in individuals with BEEs (supporting hypothesis III). This finding contrasts with previous research on unaltered neural representation in individuals with BN and BED (Lutz et al., 2023; Lutz, van Dyck, et al., 2019). Interestingly, similar patterns of altered cortical processing of cardiac signals were reported in patients with depersonalization disorder (Schulz, Köster, et al., 2015), suggesting a potential link to disengagement from bodily sensations and dissociative tendencies. From a clinical perspective, individuals with recurrent BEEs often describe these episodes as a dissociative experience, aligning with the escape theory, which posits that BE "arises as part of motivated attempt to escape from self-awareness'(Heatherton & Baumeister, 1991; p. 88). ED patients tend to exhibit higher levels of dissociation compared to HCs, with BE severity closely related to the level of dissociation (La Mela et al., 2010). This dissociation may allow individuals with BEEs to engage in BE as a mechanism to reduce self-awareness and alleviate NA. Since ECG activity did not differ between groups and conditions (see CFA control analysis), we assume that the observed differences in HEP amplitudes are most likely due to differences in cardiac signal processing at the cortical level.

We examined relationships between changes in HEP amplitude from rest to task (ΔHEP) with BMI and trait questionnaire scores. While individuals with BEEs had a higher BMI and reported greater emotional regulation difficulties and elevated levels of depression and anxiety compared to HCs, these factors did not significantly correlate with ΔHEP. Instead, more severe ED psychopathology and greater endorsement of maladaptive eating behaviors—particularly bulimic tendencies and restrictive eating—were both associated with smaller increases in ΔHEP. Additionally, although individuals with BEEs reported greater difficulties in both general and ED-specific interoceptive perception, only the latter was associated with a smaller increase in ΔHEP. These findings suggest that alterations in the neural representation of cardiac signals in the BE group are specifically linked to ED-related psychopathology and interoceptive perception, rather than broader psychopathological factors, such as depressive symptoms.

Regarding cardiac activation, individuals with recurrent BEEs had a lower resting mean HR and higher HF n.u. compared to HCs, reflecting a shift towards heightened parasympathetic activity and reduced sympathetic activity (supporting hypothesis IV). HR and HRV are sensitive indicators of autonomic nervous system (ANS) activity (Shaffer & Ginsberg, 2017). Specifically, HRV is generally associated with parasympathetic vagal activity, while lower HRV suggests reduced vagal tone and/or increased sympathetic activity (Malik et al., 1996). Although Christensen et al., (2023) found no ANS alterations in individuals with BED, our findings on ANS alterations in the BE group are in line with meta-analytic findings indicating higher parasympathetic activity at rest in individuals with BN (Peschel et al., 2016), BED and subthreshold EDs (Watford et al., 2020).

Although the groups differed in cardiac signal properties and cortical processing, these differences did not affect IAcc, IBe, and IIn scores (supporting hypothesis I). Thus, our results are consistent with the majority of studies that report no alterations at these levels (Eshkevari et al., 2014; Lutz et al., 2023; Pollatos & Georgiou, 2016), but contrast with one study that reports interoceptive deficits in individuals recovered from BN (Klabunde et al., 2013). One reason for non-significant findings might be that differences at the peripheral and central level were not substantial enough to affect IAcc, IBe, and IIn scores. Another plausible explanation is that individuals with BEEs used cognitive strategies to compensate for difficulties in focusing on their bodily sensations, such as estimating heartbeats based on their knowledge of HR. This cognitive reliance is also evident in disordered eating behaviors. For instance, individuals with EDs often manage their eating habits through self-monitoring techniques such as tracking portion sizes (Dörsam et al., 2020) and counting calories (Simpson & Mazzeo, 2017), rather than relying on internal hunger and satiety cues. This behavior may stem from a lack of trust in bodily sensations, which affects how individuals perceive the utility of bodily awareness in health and decisionmaking. Body mistrust is a significant factor linking interoceptive processes with ED symptoms (Brown et al., 2020).

Further supporting this notion, difficulties in perceiving and interpreting internal body states in individuals with BEEs are also reflected at the self-report level in our study. The BE group scored lower on the MAIA and EDIP-Q subscales compared to HCs, indicating greater difficulties in general and ED-specific interoceptive perception, respectively. Particularly, participants with BEEs scored significantly lower on EDIP-Q Discrimination compared to HCs, indicating greater difficulties in discriminating between emotional states and feelings of hunger. This finding aligns with previous research showing that individuals with self-reported BN and BED struggle more with this discrimination than those with AN and HCs (Ortmann et al., 2024). Thus, impaired perception and difficulty in discriminating between visceral signals are crucial factors in the etiology of BE behavior.

The second objective of the current study was to explore cardiac interoceptive evaluation and to investigate whether the attention to cardiac signals affected the affective state of participants. Groups did not differ in their retrospective ratings of valence, arousal, and anxiety during the HCT, but showed differences in their affective state from pre- to post-task (partially supporting hypothesis IV). We observed a decrease in PA ratings and an increase in NA ratings, the latter being particularly pronounced in the BE group and differing significantly from the HC group. Furthermore, NA ratings were also generally higher in the BE than in the HC group. These results suggest that the HCT induced an increase in NA, especially in individuals with recurrent BEEs. Based on the etiological models and these results, we can propose the following two explanations:

(1) Participants with BEEs had greater difficulties in performing the HCT due to their stronger sympathetic activation (potentially making it more difficult to discriminate cardiac signals from background noise) and weaker cortical representation, leading to increased NA. This assumption is supported by our findings on altered cortical processing of cardio-afferent signals and self-reported difficulties in general and ED-specific interoceptive perception (as measured by the MAIA and EDIP-Q) in the BE group compared to HCs. According to the escape theory of BE (Heatherton & Baumeister, 1991), individuals with BEEs exhibit higher levels of self-perception, self-criticism, and negative evaluation due to high expectations of themselves and their strong need to be perceived favorably by others. This aversive self-perception leads to emotional stress. It is, therefore, plausible to assume that the increased level of difficulty of the HCT, combined with the high standards for task performance, contributed to the increase in NA in participants with BEEs.

(2) Focusing attention on the heartbeat was perceived as unpleasant and aversive by both groups. Given the self-reported greater emotion regulation difficulties (measured by the DERS) in the BE group compared to the HC group, it is plausible that participants with BEEs coped less efficiently with this negative experience than HCs, thereby sustaining their NA. According to the affect regulation model (Polivy & Herman, 1993), individuals with BEEs have limited access to emotion regulation strategies, leading them to rely on maladaptive strategies such as BE to cope with emotional distress. Several lines of research provide evidence that deficits in emotion regulation constitute a transdiagnostic feature across the ED spectrum (Brockmeyer et al., 2014; Mallorquí-Bagué et al., 2018; Monell et al., 2018), and that NA often precedes BEEs (Meule et al., 2021; Schaefer et al., 2020).

The two explanations are not mutually exclusive. Instead, they might complement each other and align with the pattern of results in the present study. Further research is warranted to investigate the complexity of the relationship between interoceptive processing and emotional experience in individuals with BEEs.

**Limitations**

To form the BE group, women were recruited from the general population who reported at least one BEE per month over a three-month period. This inclusive approach, which involved individuals with both full syndrome and subthreshold EDs, was based on evidence showing (1) that BE behavior occurs in the general population (e.g., Duarte et al., 2015; Goldschmidt et al., 2015; Sonneville et al., 2013), and (2) that subthreshold EDs present similar psychopathology and distress (Chapa et al., 2018; Johnson et al., 2021; Striegel-Moore et al., 2000). Although this approach led to a certain degree of heterogeneity within the group, it also enhanced representativeness, thereby increasing ecological validity and generalizability of study results.

Thus, participants within the BE group shared one commonality, that is, recurrent BEEs, which were categorized into OBE and SBE. Despite this distinction, our BE group lacked sufficient diversity for further subgroup analyses, such as in Brownstone et al. (2013). In addition, it remains unclear whether the observed profile of altered interoceptive processes, particularly the altered neural representation of cardiac signals, is specific to BE-related EDs or EDs in general. For example, Lutz et al. (2019) found enhanced cortical processing of cardiac signals in AN patients. These contradictory findings highlight the diverse profiles of altered interoceptive processes across different ED types (Ortmann et al., 2024), contributing to the heterogeneous clinical picture of EDs, ranging from severe restrictive eating to uncontrolled overeating. Further comparative research on interoceptive processes across multiple dimensions between EDs and along the ED spectrum, such as in Lutz et al. (2023), is warranted to refine treatment approaches. This important direction of research should extend beyond the cardiovascular system to include the gastrointestinal system, which is directly associated with eating behavior. Emerging evidence suggests that altered perception of gastrointestinal sensations, such as hunger and satiety, plays a significant role in the etiology of EDs (Ortmann et al., 2024; Poovey & Rancourt, 2024; van Dyck et al., 2020), and therefore represents a potential target for intervention.

BMI has been associated with greater interoceptive deficits in previous research (Robinson et al., 2021). We, therefore, aimed to match HC participants with BE group participants based on BMI as well. Perfect BMI matching was not feasible in all cases, leading to significant group differences, with the BE group exhibiting a higher BMI. BMI was, however, unrelated to ΔHEP. This suggests that the differences in neural representation of cardiac signals observed in the BE group are not attributable to BMI variations. Instead, these alterations are more likely related to differences in ED psychopathology and ED-specific interoceptive perception as discussed above.

The ambiguity in our results, as well as the broader inconsistency in the literature on interoceptive deficits in EDs, may be attributed to the susceptibility of the HCT to non-interoceptive influences, such as prior knowledge of HR and response bias (e.g., Desmedt et al., 2020; Murphy et al., 2018). While in the current study we used the HCT due its compatibility with the assessment of HEPs (e.g., Lutz et al., 2019; Pollatos & Schandry, 2004; Schulz, Köster, et al., 2015) and mitigated the potential impact of non-interoceptive factors by using 'strict' instructions (Desmedt et al., 2018; Ehlers et al., 1995), it cannot be ruled out that also response biases contributed to IAcc scores, and, hence, also to IIn scores.

**Conclusion**

This is the first study to examine cardiac interoception at multiple levels in individuals with recurrent BEEs across a spectrum. The results suggest a profile of specific interoceptive alterations in individuals with BE behavior, with heightened sympathetic cardiac activity and altered neural central-nervous representation of cardio-afferent signals at the cortical level, while the dimensions of IAcc, IBe, and IIn remain unaltered. Similar patterns of altered neural representation have been reported in individuals with depersonalization disorder. These findings suggest that altered neural representation of cardiac signals reflect disengagement from bodily sensations. This disengagement could impair emotion processing and regulation, potentially contributing to BE behavior in individuals with BEEs. It remains an open question whether the observed changes in interoceptive processing are specific to BE-related EDs or EDs in general.

Future research should explore interoceptive processes at multiple levels in relation to disordered eating behaviors and examine other organ systems, such as the gastrointestinal system, to provide deeper insights. Understanding the underlying mechanisms of altered interoceptive processing is crucial for developing more targeted and effective treatment approaches for disordered eating behaviors.

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## 4.7. Supplemental Materials

*Eating Disorder Inventory-2.* The EDI-2 (Paul & Thiel, 2005) is a 91-item self-report measure of ED psychopathology. In the present study, the first three subscales Drive for Thinness (DT; 7 items), Bulimia/Bulimic Tendencies (BU; 7 items), and Body Dissatisfaction (BD; 9 items) were used to assess core ED psychopathology. Responses were given on a 6-point Likert scale ranging from 1 (never) to 6 (always). Sum scores were calculated for each subscale, with higher scores indicating greater severity of ED symptoms. Cronbach's α in the current sample was .91, .93 and .94 for DT, BU and BD, respectively.

*Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q).* The EDIP-Q (Ortmann et al., 2024) is a 25-item self-report measure designed to assess eating disorder-specific interoceptive perception, which involves the ability to perceive and distinguish between emotions, hunger, and satiety. It consists of four subscales: Emotions, Hunger, Satiety, and Discrimination. Responses were given on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Total score (TS) and mean scores for each subscale were calculated, with higher scores indicating better EDIP. Cronbach's α in the current sample was .92 for Emotions, .78 for Hunger, .94 for Satiety, .85 for Discrimination, and .94 for the TS.

*Multidimensional Assessment of Interoceptive Awareness (MAIA).* The MAIA (Mehling et al., 2012) is a 32-item self-report measure designed to assess multiple facets of interoceptive abilities. It consists of eight subscales: Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. Responses were given on a 5-point Likert scale ranging from 1 (never) to 5 (always), with higher scores indicating better interoceptive awareness. Cronbach's α in the current sample was .59, .62, .69, .85, .85., 88, .92, and .92 for Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting, respectively.

*Dutch Eating Behavior Questionnaire.* The DEBQ (Nagl et al., 2016) is a 33-item self-report measure to assess restrained, emotional, and external eating behavior. Responses were given on a 5-point Likert scale, ranging from 1 (never) to 5 (very often). Sum scores were calculated for each subscale, with higher scores indicating more frequent endorsement of maladaptive eating behaviors. Cronbach's α in the current sample was .94, .97, and .66 for Restrained, Emotional, and External Eating, respectively.

*Difficulties in Emotion Regulation Questionnaire (DERS).* The DERS (Ehring et al., 2013)is a 36-item self-report measure designed to assess difficulties in emotion regulation. It consists of six subscales: Nonacceptance of Emotional Responses (Nonacceptance), Difficulties Engaging in Goal-Directed Behavior (Goals), Impulse Control Difficulties (Impulse), Lack of Emotional Awareness (Awareness), Limited Access to Emotion Regulation Strategies (Strategies), and Lack of Emotional Clarity (Clarity). Responses were given on a 5-point Likert scale, ranging from 1 (almost never) to 5 (almost always). Mean Score (DERS-MS) and sum scores for each subscale were calculated, with higher scores indicating greater emotion dysregulation. Cronbach's α in the current sample was .93 for Nonacceptance, .92 for Goals, .87 for Impulse, 89 for Awareness, .93 for Strategies, .93 for Clarity, and .96 for the DERS-MS.

*Patient Health Questionnaire-9 (PHQ-9).* The PHQ-9 (Kroenke et al., 2001) is a 9-item measure designed to assess depressive symptoms depressive symptoms experienced over the past last two weeks. Responses were given on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Higher sum scores indicate more severe depressive symptoms. Cronbach's α in the current sample was .87.

*Generalized Anxiety Disorder-7 (GAD-7).* The GAD-7 (Spitzer et al., 2006) is a 7-item self-report measure designed to assess generalized anxiety disorder symptoms experienced over the past two weeks. Responses were given on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Higher sum scores indicate more severe anxiety symptoms. Cronbach's α in the current sample was .89.

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**Supplementary Table 1**

*Means and SDs of HEP amplitudes at the clusters, i.e., anterior left, anterior central, anterior right, central left, central, central right, posterior left, posterior central, and posterior right electrode sites.*

| Pair of clusters | | HEP Amplitude | | Between-groups test | | | |
|---|---|---|---|---|---|---|---|
| | | *M* | *SD* | *t* | *df* | *p* | *d* |
| **Pair 1** | Anterior Left | 0.11 | 0.76 | -5.03 | 55 | < .001 | -0.67 |
| | Anterior Central | 0.47 | 0.88 | | | | |
| Pair 2 | Anterior Left | 0.11 | 0.76 | -0.14 | 55 | .891 | -0.02 |
| | Anterior Right | 0.12 | 0.67 | | | | |
| Pair 3 | Anterior Left | 0.11 | 0.76 | 0.55 | 55 | .584 | 0.07 |
| | Central Left | 0.06 | 0.78 | | | | |
| **Pair 4** | Anterior Left | 0.11 | 0.76 | -5.07 | 55 | < .001 | -0.68 |
| | Central | 0.81 | 1.09 | | | | |
| Pair 5 | Anterior Left | 0.11 | 0.76 | 1.19 | 55 | .239 | 0.16 |
| | Central Right | 0.01 | 0.64 | | | | |
| Pair 6 | Anterior Left | 0.11 | 0.76 | 0.67 | 55 | .505 | 0.09 |
| | Posterior Left | 0.05 | 0.50 | | | | |
| **Pair 7** | Anterior Left | 0.11 | 0.76 | -2.36 | 55 | .022 | -0.32 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| Pair 8 | Anterior Left | 0.11 | 0.76 | -0.08 | 55 | .935 | -0.01 |
| | Posterior Right | 0.12 | 0.43 | | | | |
| **Pair 9** | Anterior Central | 0.47 | 0.88 | 5.34 | 55 | < .001 | 0.71 |
| | Anterior Right | 0.12 | 0.67 | | | | |
| **Pair 10** | Anterior Central | 0.47 | 0.88 | 4.13 | 55 | < .001 | 0.55 |
| | Central Left | 0.06 | 0.78 | | | | |
| **Pair 11** | Anterior Central | 0.47 | 0.88 | -3.67 | 55 | .001 | -0.49 |
| | Central | 0.81 | 1.09 | | | | |
| **Pair 12** | Anterior Central | 0.47 | 0.88 | 4.84 | 55 | < .001 | 0.65 |
| | Central Right | 0.01 | 0.64 | | | | |
| **Pair 13** | Anterior Central | 0.47 | 0.88 | 4.79 | 55 | < .001 | 0.64 |
| | Posterior Left | 0.05 | 0.50 | | | | |
| Pair 14 | Anterior Central | 0.47 | 0.88 | 1.43 | 55 | .157 | 0.19 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| **Pair 15** | Anterior Central | 0.47 | 0.88 | 3.35 | 55 | .001 | 0.45 |
| | Posterior Right | 0.12 | 0.43 | | | | |
| Pair 16 | Anterior Right | 0.12 | 0.67 | 0.58 | 55 | .566 | 0.08 |
| | Central Left | 0.06 | 0.78 | | | | |
| **Pair 17** | Anterior Right | 0.12 | 0.67 | -5.95 | 55 | < .001 | -0.80 |
| | Central | 0.81 | 1.09 | | | | |
| Pair 18 | Anterior Right | 0.12 | 0.67 | 1.71 | 55 | 0.092 | 0.23 |
| | Central Right | 0.01 | 0.64 | | | | |
| Pair 19 | Anterior Right | 0.12 | 0.67 | 0.87 | 55 | 0.386 | 0.12 |
| | Posterior Left | 0.05 | 0.50 | | | | |
| **Pair 20** | Anterior Right | 0.12 | 0.67 | -2.55 | 55 | .014 | -0.34 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| Pair 21 | Anterior Right | 0.12 | 0.67 | 0.01 | 55 | .992 | 0.00 |
| | Posterior Left | 0.12 | 0.43 | | | | |
| **Pair 22** | Central Left | 0.06 | 0.78 | -5.46 | 55 | < .001 | -0.73 |
| | Central | 0.81 | 1.09 | | | | |
| Pair 23 | Central Left | 0.06 | 0.78 | 0.59 | 55 | .559 | 0.08 |
| | Central Right | 0.01 | 0.64 | | | | |
| Pair 24 | Central Left | 0.06 | 0.78 | 0.14 | 55 | .893 | 0.02 |
| | Posterior Left | 0.05 | 0.50 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Pair 25** | Central Left | 0.06 | 0.78 | -3.16 | 55 | .003 | -0.42 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| Pair 26 | Central Left | 0.06 | 0.78 | -0.58 | 55 | .563 | -0.08 |
| | Posterior Right | 0.12 | 0.43 | | | | |
| **Pair 27** | Central | 0.81 | 1.09 | 5.79 | 55 | < .001 | 0.77 |
| | Central Right | 0.01 | 0.64 | | | | |
| **Pair 28** | Central | 0.81 | 1.09 | 6.27 | 55 | < .001 | 0.84 |
| | Posterior Left | 0.05 | 0.50 | | | | |
| **Pair 29** | Central | 0.81 | 1.09 | 4.10 | 55 | < .001 | 0.55 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| **Pair 30** | Central | 0.81 | 1.09 | 5.39 | 55 | < .001 | 0.72 |
| | Posterior Right | 0.12 | 0.43 | | | | |
| Pair 31 | Central Right | 0.01 | 0.64 | -0-60 | 55 | .549 | -0.08 |
| | Posterior Left | 0.05 | 0.50 | | | | |
| **Pair 32** | Central Right | 0.01 | 0.64 | -3.91 | 55 | < .001 | -0.52 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| Pair 33 | Central Right | 0.01 | 0.64 | -1.68 | 55 | .098 | -0.23 |
| | Posterior Right | 0.12 | 0.43 | | | | |
| **Pair 34** | Posterior Left | 0.05 | 0.50 | -4.23 | 55 | < .001 | -0.56 |
| | Posterior Central | 0.34 | 0.73 | | | | |
| Pair 35 | Posterior Left | 0.05 | 0.50 | -1.11 | 55 | .272 | -0.15 |
| | Posterior Right | 0.12 | 0.43 | | | | |
| **Pair 36** | Posterior Central | 0.34 | 0.73 | 3.50 | 55 | .001 | 0.47 |
| | Posterior Right | 0.12 | 0.43 | | | | |

*Note.* Differences between clusters were calculated using paired samples *t*-tests. HEP = heartbeat evoked potential. Bonferroni-corrected $\alpha = 0.0014$. Significant pairs are highlighted in bold.

**Supplementary Table 2**

*Relationships between the change in HEP amplitude from rest to task (ΔHEP) with BMI and trait questionnaire scores*

| | ΔHEP | |
|---|---|---|
| Measured Variables | *r* | *p* |
| BMI | .07 | .632 |
| EDI-2 | | |
| Drive for Thinness | -.20 | .133 |
| **Bulimic tendencies** | **-.42** | **.001** |
| Body dissatisfaction | -.15 | .267 |
| EDIP-Q | | |
| **Total score** | **.34** | **.010** |
| **Emotions** | **.31** | **.022** |
| **Hunger** | **.26** | **.049** |
| **Satiety** | **.34** | **.009** |
| Discrimination | .18 | .186 |
| MAIA | | |
| Noticing | .02 | .911 |
| Not distracting | .17 | .213 |
| Not worrying | .10 | .485 |
| Attention regulation | .10 | .468 |
| Emotional awareness | .03 | .822 |
| Self-regulation | .10 | .466 |
| Body listening | .17 | .211 |
| Trusting | .22 | .112 |
| DEBQ | | |
| **Restrained Eating** | **-.35** | **.008** |
| Emotional Eating | -.23 | .091 |
| External Eating | -.25 | .064 |
| DERS | | |
| Mean Score | -.35 | .084 |
| Nonacceptance | -.16 | .248 |
| Goals | -.02 | .886 |
| **Impulse** | **-.27** | **.044** |
| Awareness | -.26 | .057 |
| Strategies | -.23 | .093 |
| Clarity | -.24 | .069 |
| PHQ-9 | -.23 | .084 |
| GAD-7 | -.19 | .157 |

*Note*. Pearson correlation analyses were conducted to explore the relationships between the change in heartbeat evoked potential (HEP) amplitude from rest to task (ΔHEP) with BMI and trait questionnaire scores, EDIP-Q = Eating Disorder-specific Interoceptive Perception-Questionnaire, DEBQ = Dutch Eating Behavior Questionnaire, DERS = Difficulties in Emotion Regulation Scale, Nonacceptance = Nonacceptance of Emotional Responses, Goals = Difficulties Engaging in Goal-Directed Behavior, Impulse = Impulse Control Difficulties, Awareness = Lack of Emotional Awareness, Strategies = Limited Access to Emotion Regulation Strategies, Clarity = Lack of Emotional Clarity, PHQ-9 = Patient Health Questionnaire-9, GAD-7 = Generalized Anxiety Disorder-7, significant relationships are highlighted in bold.

# 5. Gastric Interoceptive Processing in Individuals with and without Binge Eating Behavior (Study 5)

Ortmann, J., Lutz, A. P. C., Schulz, A., Wolpert, N., van Dyck, Z. & Vögele, C. (2024). *Gastric Interoceptive Processing in Individuals with and without Binge Eating Behavior* [Manuscript in preparation]. Department of Behavioural and Cognitive Sciences, University of Luxembourg.

## 5.1. Abstract

**Objective**: This study aimed at investigating gastric interoceptive processing at multiple levels in individuals with binge eating (BE) behavior. **Methods**: Participants (n = 28 BE group, n = 28 healthy control [HC] group) underwent the two-step water load test (WLT-II), which involves the intake of non-caloric water until satiety (step 1) and fullness (step 2). Electroencephalography (EEG) and electrogastrography (EGG) were recorded during a 10-minute resting period before water ingestion ($t_0$), and after each drinking phase ($t_1$ and $t_2$). Indices of interoceptive sensitivity (ISen), interoceptive beliefs (IBe), attribution of interoceptive sensations (AIS), and interoceptive insight (IIn) were computed. We assessed percentage distribution of EGG cycle durations across frequency bands (properties of afferent signals) and the degree of gastric-alpha phase-amplitude coupling (PAC; neural representation of gastric activity) at $t_0$, $t_1$, and $t_2$. Relationships between gastric-alpha PAC and other variables were explored. **Results**: The BE group consumed significantly more water to feel satiated, indicating altered ISen. Gastric-alpha PAC was observed over central-parietal and occipital regions at $t_0$, but not at $t_1$ and $t_2$, without group differences. Within the BE group, gastric-alpha PAC was moderately associated with self-reported eating disorder-specific interoceptive perception, as well as the ability to discriminate between emotional states and hunger. **Conclusion**: Enhanced stomach-brain communication may facilitate the perception and discrimination of interoceptive signals relevant to the regulation of eating behavior, while impaired communication may contribute to disordered eating patterns such as BE. Normalizing gastric ISen may be targeted in future intervention eating disorders intervention.

*Key words:* Gastric interoception, gastric-alpha phase-amplitude coupling, binge eating, eating disorders

## 5.2. Introduction

Binge eating (BE) refers to the uncontrolled consumption of large amounts of food within a discrete period of time. Frequent BE episodes (BEEs) are a shared symptom across eating disorders (EDs; American Psychiatric Association [APA], 2013). Notably, BE occurs also in non-clinical populations and is of clinical relevance due to its association with impaired mental health and well-being (e.g., Duarte et al., 2015; Goldschmidt et al., 2015; Sonneville et al., 2013). Despite the availability of empirically supported interventions, relapse and mortality rates for EDs remain high in the long term (Fichter et al., 2017; Fichter & Quadflieg, 2016; Quadflieg & Fichter, 2019). Research into etiological mechanisms is, therefore, essential to define new targets for novel interventions, and eventually improve treatment outcomes. Altered interoceptive processes have been proposed as a key transdiagnostic feature among the spectrum of EDs (Martin et al., 2019). Altered perception of gastrointestinal sensations, such as hunger and satiety, plays a significant role in the etiology of EDs (Ortmann, Lutz, et al., 2024; Poovey & Rancourt, 2024; van Dyck et al., 2020), representing a potential target for intervention. Despite the multidimensional nature of interoception, studies typically focus on investigating a single interoceptive dimension (e.g., interoceptive accuracy). The aim of the present study is to extend previous research by providing a comprehensive assessment of gastric interoception across dimensions in individuals with recurrent BEEs, as interoceptive dysfunctions underlying EDs may result from inter-relationships between dimensions, such as previously demonstrated for somatic symptoms (Schulz et al., 2020).

Interoception refers to the process by which the nervous system perceives, interprets and integrates signals from multiple organ systems involved in bodily homeostasis, such as the cardiovascular, pulmonary and gastrointestinal systems (Khalsa et al., 2018). Current conceptualizations distinguish interoceptive dimensions based on the level of processing in the peripheral and central nervous systems and the assessment approach, including psychophysiological, behavioral and self-report measures (Forkmann et al., 2016; Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2019; Suksasilp & Garfinkel, 2022).

The current selection of interoceptive dimensions is based on the multidimensional model proposed by Suksasilp & Garfinkel (2022). *Properties of afferent signals* from visceral organs (Schulz & Vögele, 2023; formerly referred to as *physiological state*; Forkmann et al., 2016), such as the heart or the stomach, represents the most basic level of interoceptive processing. *Neural representation* includes cortical processing of afferent signals from visceral organs, e.g., coupling of central nervous system activity with afferent physiological signals. *Interoceptive accuracy* (IAcc) is a behavioral index of interoception, which is typically assessed in the cardiac or respiratory domain and refers to the precision with which individuals monitor and report interoceptive sensations. When investigating the gastric domain, a typical indicator of behavioral interoception is *interoceptive sensitivity* (ISen), the minimal threshold of interoceptive signal changes to be perceived (Schulz & Vögele, in press; van Dyck et al., 2016). *Self-report and interoceptive beliefs* (IBe, Suksasilp & Garfinkel, 2022; formerly referred to as *interoceptive sensibility* [ISe], Garfinkel et al., 2015) encompass self-reported experiences and beliefs about internal sensations, typically assessed through questionnaire-based scales or confidence ratings in interoceptive task performance. *Interoceptive insight* (IIn, Suksasilp & Garfinkel, 2022; formerly referred to as *interoceptive awareness* [IAw], Garfinkel et al., 2015) pertains to the metacognitive evaluation of one's experience or performance during an interoceptive task, indexed by the correspondence between IAcc/ISe and IBe. *Attribution of interoceptive sensations* refers to how individuals interpret the nature, intensity, and causes of sensations related to the visceral organ, also assessed using self-reports (Suksasilp & Garfinkel, 2022). Each dimension contributes differently to cognitions, emotions, and symptom presentation (Suksasilp & Garfinkel, 2022).

Altered interoceptive processes have been found in eating and weight disorders (Martin et al., 2019). Recent findings of Ortmann and collegues (2024) highlight the differential contribution of emotions, hunger and satiety to the heterogeneity of ED symptoms using the novel Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q). Participants with EDs reported overall greater difficulties in ED-specific interoceptive perception (EDIP) compared to healthy controls (HCs). While individuals with EDs reported similar difficulties in perceiving emotions, those with bulimia nervosa (BN) or binge-eating disorder (BED) reported lower sensitivity to satiety cues, higher sensitivity to hunger cues, and greater difficulty distinguishing hunger from emotional states. In contrast, participants with anorexia nervosa (AN) exhibited the opposite pattern. These variations in hunger and satiety perception across ED types suggest that these factors play distinct and significant roles in disordered eating behaviors, such as BE.

An organ system directly associated with the regulation of eating behavior is the gastrointestinal system. Two mechanisms underlying satiety perception during food intake are gastric distension and gastric motility (Janssen et al., 2011). Gastric distension activates spinal mechanosensitive afferents, providing feedback on the body's state of satiety and fullness. Furthermore, the stomach contracts approximately three times per minute to process food. Interstitial cells of Cajal (ICC), located in the stomach wall, serve as electrical pacemakers and generate constant gastric slow waves. The normal frequency of ICC pacemaker activity in healthy humans is around 0.05 Hz, or three cycles per minute (cpm), corresponding to one cycle every 20 seconds (Kenneth L Koch & Stern, 2004). A non-invasive method for evaluating gastric motor activity is electrogastrography (EGG). It assesses myoelectrical activity of gastric smooth muscles using cutaneous electrodes placed on the abdominal wall. Thus, the EGG frequency reflects a combination of gastric slow waves and transient smooth muscle activity responsible for stomach contractions (Wolpert et al., 2020). Normal gastric myoelectrical activity (GMA; normogastria) increases after both food intake (e.g., Friesen et al., 2006) and water loads (e.g., Herbert et al., 2012; Koch et al., 2000; van Dyck et al., 2020). In contrast, gastric dysrhythmias (bradygastria, tachygastria) have been associated with symptoms such as nausea, vomiting, and abdominal discomfort or pain (e.g., Carson et al., 2022; Gharibans et al., 2019).

Only a few studies have assessed GMA in patients with EDs. Findings indicate abnormal GMA in these patients, characterized by lower normogastric activity but higher bradygastric or tachygastric activity compared to HCs, both before and after water intake (Alyami et al., 2023; Koch et al., 1998; Ogawa et al., 2004). Using the standardized protocol of the two-step Water Load Test (WLT-II; van Dyck et al., 2016), which involves two consecutive drinking phases, van Dyck and collegues (2020) found abnormal GMA in individuals with BN and BED, paired with lower sensitivity to gastric distention and delayed onset of satiety.

A crucial processing step between the physiological state of a particular organ system and its perception is the neural representation and processing of signals at the cortical level. Recent studies have explored stomach-brain interactions by combining EGG with encephalographic techniques in healthy participants during resting states. Using magnetoencephalography (MEG), Richter and collegues (2017) found significant phase-amplitude coupling (PAC) in parieto-occipital regions and anterior insula, wherein the phase of gastric slow waves modulated the amplitude of the cortical alpha rhythm (10-11 Hz). This gastric-alpha PAC was found to explain 8% of the variance in alpha rhythm amplitude fluctuations. In another study, Todd and collegues (2021) investigated the relationship between gastric-alpha PAC and body image using electroencephalography (EEG) and EGG, finding evidence that reduced gastric-alpha PAC is associated with higher levels of body shame and weight preoccupation. These symptoms are commonly linked to disordered eating behaviors, including binge eating (Mitchison et al., 2017; O'Loghlen et al., 2022; Sharpe et al., 2018). Despite suggestions that the degree of gastric-alpha PAC could offer insights into individual differences in the central processing of gastroafferent signals (Suksasilp & Garfinkel, 2022), the direct relationship between gastric-alpha PAC and eating behavior in both healthy individuals and those with disordered eating behavior has not yet been investigated.

Although previous studies suggest altered processing of gastric signals at self-report, psychophysiological, and behavioral levels in individuals with EDs (Ortmann, Lutz, et al., 2024; Poovey et al., 2022; van Dyck et al., 2020), studies investigating interoceptive processes in conjunction are scarce. A comprehensive assessment of interoceptive processing is, however, essential to develop more targeted interventions, especially because mental disorders show certain profiles of alterations at some, but not all interoceptive levels (e.g., Garfinkel et al., 2016; Jakubczyk et al., 2019; Lutz et al., 2019; Schulz et al., 2022).

To address these important gaps in the literature, we investigated multiple levels of gastric interoceptive processing in individuals with recurrent BEEs. Participants underwent the two-stage Water Load Test (WLT-II; van Dyck et al., 2016) while EEG and EGG were recorded concurrently, allowing for the comprehensive investigation of interoceptive processing in the gastric domain. In line with previous studies demonstrating gastric interoceptive deficits in BN and BED (van Dyck et al., 2020), we hypothesized (I.) that individuals with recurrent BEEs (BE group) exhibit lower levels of ISen, (II.) IBe and (III.) IIn, and (IV.) more negative AIS compared to healthy control participants (HC group). Moreover, we expected (V.) that the BE group would show more gastric arrhythmia and less normogastric activity (GMA), and (VI.) alterations in the cortical representation of gastric signals. Specifically, we predicted that the BE group would demonstrate lower gastric-alpha phase-amplitude coupling (PAC) throughout the WLT-II compared to the HC group.

## 5.3. Methods

### Procedure

Study procedures were approved by the Ethics Review Panel of the University of Luxembourg (ERP 22-017A2 EDIP). Study participation included two sessions on separate days. Adult female participants were recruited from the general population in Luxembourg through flyers and advertisements in various media outlets, including social media, newspapers, magazines. Eligibility was initially assessed with a custom-made telephone screening and confirmed in the first session of the study. Inclusion criteria for the groups under investigation differed. For the BE group, participants were required to report recurrent BEEs (minimum average frequency of once a month over a three-month period), characterized by a sense of loss of control over eating, regardless of the amount of food consumed, with or without purging behavior. For the HC group, participants were required *not* to report recurrent BEEs or ED history. General exclusion criteria included neurological disorders (e.g., epilepsy), chronic diseases and/or medication affecting eating behavior (e.g., diabetes mellitus), current substance use disorder, history of bariatric surgery, cardiovascular diseases, pregnancy and/or breast-feeding, uncorrected impairment of vision, and conditions impeding the application of electrodes (e.g., skin diseases or allergies).

Prior to data collection, participants provided written informed consent. In the first session, eligibility for study participation and group allocation were verified. For this purpose, three interviews were conducted: (1) A customized interview to collect sociodemographic and health-related data, (2) a modified version of the Diagnostic Short-Interview for Mental Disorders (Mini-DIPS Open Access; Margraf & Cwik, 2017) to assess lifetime diagnoses, and (3) the Eating Disorder Examination (Hilbert et al., 2004) to assess current ED psychopathology and to classify BEEs into objective BEEs (eating 'large' amounts of food with loss of control) and subjective BEEs (eating normal amounts perceived as excessive by the participant, with loss of control). Lifetime diagnoses were coded according to DSM-5 criteria (APA, 2013). Furthermore, participants completed trait questionnaires administered via the survey platform SoSci Survey (https://www.soscisurvey.de/) to assess levels of ED psychopathology, ED-specific interoceptive perception, maladaptive eating behavior, emotion regulation difficulties, depression, and anxiety (detailed information on the questionnaires used are provided in the supplemental materials). At the end of the first session, participant's height and weight were measured.

The second session included the implementation of different paradigms and the simultaneous measurement of physiological signals to investigate interoceptive processes in the cardiovascular and gastrointestinal system. Participants were instructed to fast for a minimum of three hours and to refrain from drinking for two hours before the session. Compliance with the instructions was checked through a face-to-face interview regarding the last meal and drink consumed prior to the session. Participants were then prepared for psychophysiological measurements and positioned in a semi-reclined sitting position (45 degrees). After a five-minute resting period, two heartbeat perception tasks and the two-step Water Load Test (van Dyck et al., 2016) were performed. Stimulus presentation and response collection were run with E-Prime 3.0 (Psychology Soft- ware Tools, Sharpsburg, PA). Participants received a gift voucher worth €60.00

as reimbursement for their participation. As the current dataset was part of an extended study setup, data on cardiac interoception concerns separate research questions and are thus reported elsewhere.

**Participants**

The BE group consisted of twenty-eight individuals reporting recurrent BEEs ($n$ = 14 full-syndrome BED, $n$ = 5 full-syndrome BN, $n$ = 1 AN binge/purging type, $n$ = 3 Other specified feeding or eating disorder (OSFED), $n$ = 2 partially remitted BED, $n$ = 3 partially remitted BN). All participants in the BE group reported recurrent BEEs of at least once a month over a three-month-period. HC participants ($n$ = 28) were selected to match the participants of the BE group in terms of age, body mass index (BMI; $kg/m^2$), and educational level coded according to the International Standard Classification of Education (ISCED 2011; 2012). None of them reported objective or subjective BEEs.

Groups did not differ in age and educational level but differed significantly in BMI. Compared to HCs, the BE group reported significantly more severe ED psychopathology, including a stronger drive for thinness, more pronounced bulimic tendencies, and greater body dissatisfaction. They also exhibited poorer general and ED-specific interoceptive perception, a higher endorsement of maladaptive eating styles (restrained, emotional, and external eating), greater difficulties with emotion regulation, and higher levels of depression and anxiety compared to the HCs. Observed differences had medium to large effect sizes (all $p$s < .05). Sociodemographic characteristics, trait questionnaire differences, and lifetime diagnoses for the BE and HC groups are presented in Table 1.

**Table 1**
*Sociodemographic Characteristics and Lifetime Diagnoses*

| | BE group | | HC group | | Between-groups test | | | |
|---|---|---|---|---|---|---|---|---|
| | *n* = 28 | | *n* = 28 | | | | | |
| **Demographics** | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *d* |
| Age | 35.2 | 16.5 | 32.9 | 14.1 | 0.558 | 54 | .579 | .15 |
| BMI | 29.2 | 8.0 | 24.2 | 4.2 | 2.950 | 40.97 | .005 | .79 |
| | *Mean Rank* | | *Mean Rank* | | *U* | | *p* | *r* |
| Education level* | 26.68 | | 30.32 | | 443 | | .371 | -0.12 |
| **Questionnaires** | *M* | *SD* | *M* | *SD* | *t* | *df* | *p* | *d* |
| EDI-2 | | | | | | | | |
| Drive for Thinness | 32.1 | 6.4 | 18.3 | 6.7 | 7.84 | 54 | <.001 | 2.10 |
| Bulimic tendencies | 25.3 | 6.7 | 11.2 | 3.7 | 9.68 | 41.70 | <.001 | 2.59 |
| Body dissatisfaction | 41.2 | 10.4 | 28.8 | 10.8 | 4.37 | 54 | <.001 | 1.17 |
| EDIP-Q | | | | | | | | |
| Total score | 3.8 | 0.8 | 5.5 | 0.6 | -8.84 | 54 | <.001 | -2.36 |
| Emotions | 4.4 | 1.2 | 5.7 | 0.7 | -4.83 | 41.44 | <.001 | -1.29 |
| Hunger | 4.4 | 1.2 | 5.8 | 0.8 | -4.96 | 48.42 | <.001 | -1.32 |
| Satiety | 2.7 | 1.1 | 4.8 | 1.1 | -7.20 | 54 | <.001 | -1.93 |
| Discrimination | 4.0 | 1.3 | 5.9 | 0.8 | -6.47 | 46.4 | <.001 | 1.09 |
| MAIA | | | | | | | | |
| Noticing | 4.0 | 0.8 | 4.3 | 0.8 | -.90 | 54 | .371 | -.24 |
| Not distracting | 2.6 | 0.8 | 3.3 | 0.9 | -3.24 | 54 | .002 | -.87 |
| Not worrying | 2.7 | 1.0 | 3.5 | 1.0 | -2.83 | 54 | .006 | -.76 |
| Attention regulation | 3.3 | 0.9 | 4.0 | 0.8 | -3.28 | 54 | .002 | -.88 |
| Emotional awareness | 4.2 | 1.1 | 4.5 | 0.8 | -1.15 | 54 | .256 | -.31 |
| Self-regulation | 3.1 | 1.1 | 3.9 | 1.0 | -3.01 | 54 | .004 | -.81 |
| Body listening | 2.8 | 1.3 | 3.9 | 1.1 | -3.22 | 54 | .002 | -.86 |
| Trusting | 3.1 | 1.3 | 4.8 | 1.0 | -5.48 | 54 | <.001 | -.86 |
| DEBQ | | | | | | | | -1.46 |
| Restrained Eating | 3.3 | 0.9 | 2.3 | 0.7 | 4.57 | 54 | <.001 | 1.22 |
| Emotional Eating | 3.7 | 0.8 | 2.2 | 0.8 | 7.22 | 54 | <.001 | 1.93 |
| External Eating | 3.5 | 0.4 | 3.1 | 0.5 | 3.70 | 54 | .001 | 0.99 |
| DERS | | | | | | | | |
| Mean Score | 2.9 | 0.7 | 1.9 | 0.5 | 6.09 | 54 | <.001 | 1.63 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nonacceptance | 2.9 | 1.2 | 1.8 | 0.6 | 4.40 | 41.83 | <.001 | 1.18 |
| Goals | 3.4 | 0.9 | 2.4 | 0.9 | 4.08 | 54 | <.001 | 1.09 |
| Impulse | 2.8 | 0.8 | 1.8 | 0.6 | 5.55 | 54 | <.001 | 1.48 |
| Awareness | 2.9 | 0.9 | 2.2 | 0.8 | 3.00 | 54 | .004 | 0.80 |
| Strategies | 3.1 | 0.9 | 1.8 | 0.6 | 6.08 | 47.69 | <.001 | 1.63 |
| Clarity | 2.5 | 0.9 | 1.9 | 0.6 | 2.86 | 46.95 | .006 | 0.76 |
| PHQ-9 | 10.4 | 5.3 | 5.3 | 4.2 | 4.03 | 54 | <.001 | 1.08 |
| GAD-7 | 9.2 | 5.1 | 4.7 | 3.6 | 3.82 | 48.33 | <.001 | 1.02 |
| **Current comorbid diagnoses** | *n* | % | *n* | % | | | | |
| Depressive disorders | 7 | 25 | 0 | 0 | | | | |
| Anxiety Disorders | 12 | 42.9 | 1 | 3.6 | | | | |
| Obsessive-compulsive and related disorders | 1 | 3.6 | 0 | 0 | | | | |
| Trauma- and stressor related disorders | 0 | 0 | 0 | 0 | | | | |
| Somatic symptom and related disorder | 1 | 3.6 | 0 | 0 | | | | |
| Sleep-wake disorders | 2 | 7.1 | 0 | 0 | | | | |
| Substance-related and addictive disorders | 0 | 0 | 0 | 0 | | | | |
| **Past diagnoses** | *n* | % | *n* | % | | | | |
| Depressive disorders | 15 | 53.6 | 4 | 14.3 | | | | |
| Anxiety Disorders | 2 | 7.1 | 2 | 7.1 | | | | |
| Obsessive-compulsive and related disorders | 0 | 0 | 0 | 0 | | | | |
| Trauma- and stressor related disorders | 9 | 32.1 | 1 | 3.6 | | | | |
| Somatic symptom and related disorder | 0 | 0 | 0 | 0 | | | | |
| Sleep-wake disorders | 1 | 3.6 | 0 | 0 | | | | |
| Substance-related and addictive disorders | 3 | 10.7 | 0 | 0 | | | | |

*Note.* From *Cardiac Interoceptive Processing and Emotional Experience in Individuals with and without Binge Eating Behavior* by J. Ortmann, A. Schulz, A. P. C. Lutz, Z. van Dyck, C. Vögele, 2024, *Manuscript submitted for publication*, Department of Behavioural and Cognitive Sciences, University of Luxembourg. Group differences for metric variables were calculated with *t*-tests and for ordinal variables with the Mann-Whitney-*U* test. BE group = binge eating group, HC group = Healthy control group, BMI = Body Mass Index, EDI-2 = Eating Disorder Inventory-2, * education level was coded according to the International Standard Classification of Education (ISCED2012), EDIP-Q = Eating Disorder-specific Interoceptive Perception-Questionnaire, DEBQ = Dutch Eating Behavior Questionnaire, DERS = Difficulties in Emotion Regulation Scale, Nonacceptance = Nonacceptance of Emotional Responses, Goals = Difficulties Engaging in Goal-Directed Behavior, Impulse = Impulse Control Difficulties, Awareness = Lack of Emotional Awareness, Strategies = Limited Access to Emotion

Regulation Strategies, Clarity = Lack of Emotional Clarity, PHQ-9 = Patient Health Questionnaire-9, GAD-7 = Generalized Anxiety Disorder-7.

## Gastric Interoception

### *Interoceptive Sensitivity (ISen): the two-step Water Load Test-II (WLT-II)*

The WLT-II was performed according to the protocol described by van Dyck et al. (2016) depicted in Fig. 1. Participants were instructed to ingest non-carbonated water at room temperature over two successive 5-min phases at their own discretion. In the first phase, they were instructed to drink water until they perceived the first sign of satiation, indicating meal termination. In the second phase, participants were instructed to continue drinking water until they reached maximum stomach fullness. Three 10-minute resting measurements of physiological signals (incl. EEG and EGG) were taken, one before the first water load (baseline measurement, $t_0$) and the last two after the first and second drinking phase ($t_1$ and $t_2$, respectively). During this time, participants were instructed to relax and minimize movement.

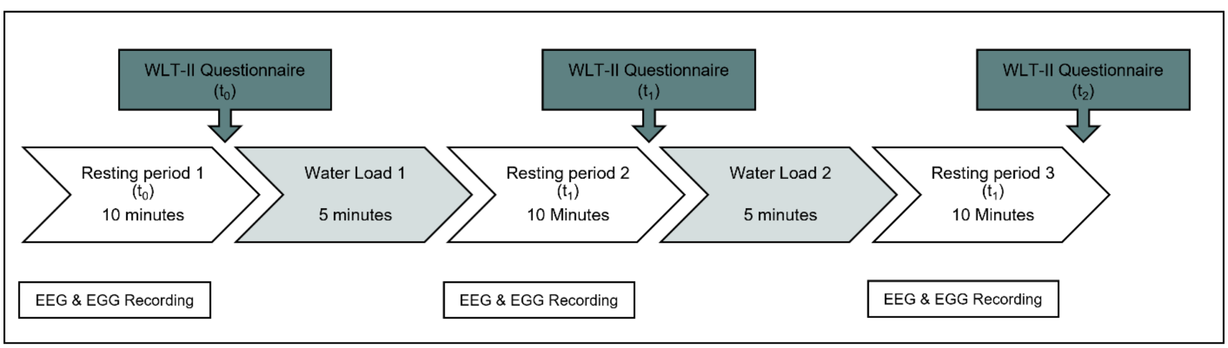


**Figure 1.** Time sequence of the Two-Step Water Load Test (WLT-II; van Dyck et al. 2016)

Water was administered in a 6-liter stainless steel container filled with 1.5 liters, from which participants drank through a 70 cm straw to control for swallowing sizes. This procedure ensured both safety and blinding of participants to the amount of water consumed, providing the impression of an unlimited water supply.

The following WLT-II indices were calculated as means of interoceptive accuracy: (1) ingested water volume (ml) until satiety (sat_ml); (2) additional water volume until maximum stomach fullness (Δfull_ml); (3) total ingested water volume (total_ml), and (4) percentage of satiation to total volume (sat_%).

***Interoceptive beliefs (IBe) and Attribution of Interoceptive Sensations (AIS): The WLT-II questionnaire***

At the end of each resting period (see Fig. 1), participants filled in the WLT-II questionnaire. They were instructed to focus on their current abdominal sensations and rate their momentary feelings of satiety and fullness (IBe), as well as their negative affect (NA), which serves as an index for AIS. Ratings were given on a 7-point Likert scale ranging from 1 (no sensation/not at all) to 7 (extremely).

***Interoceptive Insight (IIn): Correspondence between ISen and IBe***

To operationalize IIn, sat_% (ISen) and satiety rating (IBe) at $t_1$ (i.e., after water intake to the point of satiety) were transformed into "Percent of maximum possible" (POMP)-scores using the formula below (Cohen et al., 1999). Their absolute difference was calculated and subtracted from 100 to obtain more intuitive IIn scores, with higher scores corresponding to greater IIn.

$$\text{POMP} = \frac{x - variable\ mininum\ score}{maximum - minium\ score} * 100$$

***Physiological state: Distribution of EGG cycle durations across frequency bands***

EGG data were recorded during the three 10-minute resting periods of the WLT-II. For each resting period, power spectral density was computed for specific frequency bands (Koch & Stern, 2004): *bradygastria* (1.0 – 2.5 cpm; 0.017 – 0.043 Hz; cycle duration between 24 s to 60 s), *normogastria* (2.5 – 3.75 cpm; 0.043 – 0.062 Hz; cycle duration between 16 to 24 s), and *tachygastria* (3.75 – 10.0 cpm; 0.063 – 0.167 Hz; cycle duration between 6s to 16 s). Subsequently, the distribution of EGG cycle durations across frequency bands was calculated. Further details of EGG data processing are described in the corresponding subsection of "Physiological data processing and analysis".

***Neural representation: Gastric-alpha Phase Amplitude Coupling (PAC)***

Gastric-alpha PAC refers to the coupling between the phase of gastric slow waves and the amplitude of the cortical alpha rhythm (Richter et al., 2017). To quantify the degree of PAC during the three resting periods ($t_0$, $t_1$, and $t_2$), we computed the modulation index (MI; Tort et al., 2010) for each resting period. MI values range from 0 (no PAC) to 1 (maximum coupling). Details on PAC estimation and statistical determination of significant clusters are provided in the corresponding subsection "Physiological data processing and analysis".

**Physiological data acquisition**

Data acquisition was performed with BrainVision recorder (Version 2.2) and BrainAmp amplifiers (BrainAmp DC/BrainAmp ExG: Brain Products, Gilching, Germany) at a sampling rate of 1000 Hz. EEG data were recorded with a 32-channel actiCAP electrode system (Ag/AgCL electrodes, 10-20 system, reference FCz, impedances < 20 kΩ), and high-pass filtered at 0.016 Hz. Horizontal EOG electrodes were placed next to the outer canthi of both eyes. EGG data were recorded using three electrodes (Conmed Cleartrace), with two active electrodes positioned over the region of the antrum of the stomach, as described by Koch & Stern (2004), with no high-pass filter (DC recording). Specifically, one active electrode was positioned midway between the xiphoid notch and umbilicus, along the abdominal midline. The second active electrode was placed approximately 6 cm to the left of the first active electrode. The ground electrode was positioned approximately 10 cm to the right of the abdominal midline. Before attaching the EOG and EGG electrodes, the skin at the respective electrode sites was prepared by gently abrading and cleaning with alcohol.

**Physiological data processing and analysis**

First preprocessing steps were conducted using BrainVision Analyzer (version 2.2; Brain Products, Gilching, Germany). EEG data were resampled at 250 Hz and low-pass filtered below 35 Hz (half power cutoff, 24 db/octave slope). A 50 Hz notch filter was applied to reduce line noise. EEG data were re-referenced to mathematically linked mastoids. A semi-automatic raw data inspection was conducted to identify major artifacts (e.g., muscle movements, non-physiological glitches). Data was then subjected to Restricted Infomax Independent Component Analysis (ICA) to identify and remove components reflecting ocular and cardiac field artefacts. The entire data set was used to train the ICA algorithm. Channels with excessive noise were not included in ICA but were subsequently replaced using topographical interpolation (spherical splines). The data were then segmented into the resting periods ($t_0$, $t_1$, and $t_2$) and exported for further analysis with MATLAB (MathWorks, Natick, Massachusetts, USA, version R2023b) and the Fieldtrip Toolbox (Oostenveld et al., 2011).

Preprocessed EEG data were filtered using a Butterworth zero-phase shift bandpass filter (8-13 Hz, order 3) to isolate the alpha band using the Fieldtrip toolbox. A Hann tapered window was applied to temper the signal and reduce edge effects (Richter et al., 2017). Raw EGG data were filtered using an infinite impulse response filter (MATLAB: FIR2) with a ±0.015 Hz bandwidth around each participant's gastric peak frequency. This range was chosen to effectively capture physiological fluctuations in the gastric cycle duration while excluding harmonics of the gastric rhythm (Wolpert et al., 2020). Subsequently, the filtered data were Hilbert transformed to extract both the alpha band power of the EEG signal and the instantaneous phase of the gastric rhythm.

***Percentage Distribution of EGG cycle durations across frequency bands***

The distribution of EGG cycle durations across frequency bands of interest (i.e., bradygastria, normogastria, and tachygastria; Koch & Stern, 2004) was estimated from the gastric phase. We adapted a MATLAB code originally developed by Wolpert and collegues (2020) to align with the threshold proposed by Koch & Stern (2004) to analyze the cycle durations for the frequency bands of interest. The standard deviation of cycle duration was computed for each frequency band. Cycles falling within the defined range for each frequency band were categorized as representative instances of that activity type, while cycles outside the range were considered non-representative. The proportion of each frequency band was calculated by dividing the count of cycles within the defined range by the total number of cycles, then multiplying by 100 to obtain a percentage.

***Phase amplitude coupling (PAC) estimation and statistical determination of significant clusters***

For each 10-minute resting measurement, EGG phases were divided into 18 bins of 20 degrees each, and the corresponding EEG power in the alpha frequency band was averaged for each phase bin. To quantify the deviation of the PAC profile from a uniform distribution, we calculated the Modulation Index (MI; Tort et al., 2010). For the statistical determination of significant PAC clusters, we followed the two-step process outlined by Richter and colleagues

(2017). In the first step, we estimated chance-level PAC for each participant and channel by generating 1000 surrogate data sets to build a distribution of surrogate MI values. The chance-level MI for each participant and channel was then defined as the median of these surrogate MI values. In the second step, we evaluated whether the empirical MI significantly differed from the chance-level MI at the group level using a cluster-based permutation procedure (Maris & Oostenveld, 2007) as implemented in FieldTrip (Oostenveld et al., 2011). In this procedure, the empirical MI value is compared with the corresponding chance-level MI value across all participants using a *t* test for each channel, with intrinsic correction for multiple comparisons. Clusters were defined based on spatial adjacency, where channels exceeded the first-level *t*-threshold ($p < .05$, two-sided) and were connected to at least two neighboring channels that also exceeded this threshold. Each candidate cluster was evaluated based on the sum of *t*-values across its constituent channels to determine if this sum was likely to have occurred. This assessment was performed by shuffling labels ('empirical' and 'chance') 10,000 times and retaining the largest positive and negative clusters from each permutation to control for multiple comparisons. The resulting clusters were characterized by their summary statistics (sum of *t*-values per channel) and their Monte Carlo *p*-values, indicating their significance at the cluster level after correction for multiple comparisons across channels.

**Statistical Analysis**

Statistical analyses were performed using IBM SPSS Statistics (Version 27), with the critical alpha level set to .05. Group differences in demographic characteristics and trait questionnaires were examined using either independent samples *t* tests or Mann-Whitney *U* tests, depending on the scale and distribution of the variables. Between-group comparisons on ISen and IIn were performed using independent samples *t* tests. To evaluate the effect of water ingestion on subjective ratings on satiety, fullness and negative affect (NA), we calculated three separate 3 × 2 mixed-design ANOVAs with the repeated-measurement factor Time ($t_0$, $t_1$, $t_2$) and the group factor Group (BE vs. HC group). To assess changes in EGG activity due to water ingestion, we conducted four separate 3 × 2 mixed-design ANOVAs with Time (t0, t1, t2) as the repeated-measurement factor and the factor Group (BE vs. HC group), using the relative EGG power of frequency bands as dependent variables. Significant main and interaction effects were further analyzed with post hoc independent and paired samples *t* tests, which were Bonferroni-corrected in case of three or more comparisons. When Mauchly's Sphericity Test indicated a violation of sphericity ($p < .05$), the Greenhouse-Geisser correction was applied. For gastric-alpha PAC, between-group comparisons on identified significant clusters per time point were performed using independent samples t tests. If the same clusters were identified across all time points ($t_0$, $t_1$, $t_2$), we planned to conduct additional 3 × 2 mixed-design ANOVAs, with Time ($t_0$, $t_1$, $t_2$) as the within-group variable and Group (BE vs. HC group) as the between-group variable, using the significant clusters as dependent variables to evaluate the effect of water ingestion on gastric-alpha PAC. Effect sizes reported are in terms of partial eta squared for ANOVAs ($\eta p^2 = .01$ "small", $\eta p^2 = .06$ "medium", and $\eta p^2 = .14$ "large"), and Cohen's *d* for *t* tests ($d = 0.2$ "small", $d = 0.5$ "medium", and $d = 0.8$ "large") (Cohen, 1988). Pearson correlations were calculated to test the relationships between indices of interoceptive processing and trait questionnaire data.

## 5.4. Results

**Interoceptive Sensitivity (ISen)**

Compared to the HCs, participants with BEEs ingested significantly higher volumes until satiated (sat_ml: 456.6 ± 171.7 vs. 343.6 ± 148.2, $t(54) = 2.64$, $p = .011$, $d = 0.71$) and in total (total_ml: 919.0 ± 305.4 vs. 763.5 ± 235.1, $t(54) = 2.605$, $p = .045$, $d = 0.55$), but not until perceived maximum stomach fullness (Δfull_ml: 456.3 ± 219.4 vs. 419.9 ± 142.0, $t(54) = 0.74$, $p = .464$, $d = 0.20$). Moreover, there was a non-significant trend of medium effect sizes toward higher percentages of satiation to total volume in the BE group compared to the HC group (sat_%: 50.8 ± 12.0 vs. 44.6 ± 12.2, $t(54) = 1.91$, $p = .062$, $d = 0.51$).

**Interoceptive Beliefs (IBe) and Attribution of Interoceptive Sensations (AIS)**

Figure 2 depicts ratings for satiety, fullness, and NA before the water load ($t_0$), after the first ($t_1$), and after second drinking period ($t_2$). There were no statistically significant interactions between time and group for satiety ($F(1.627, 87.646) = 2.669$, $p = .086$, $\eta_p^2 = .08$), fullness ($F(2, 108) = 2.36$, $p = .099$, $\eta_p^2 = .04$), and NA ($F(2, 108) = 0.34$, $p = .687$, $\eta_p^2 = .08$), indicating that ratings did not differ over time between the groups.

Satiety ratings significantly increased over time (main effect: $F(1.627, 87.646) = 80.67$, $p < .001$, $\eta_p^2 = .60$), with significant increases from $t_0$ to $t_1$ (2.57 ± 1.68 vs. 4.18 ± 1.61, $t(55) = -7.02$, $p < .001$, $d = -0.94$) and from $t_1$ to $t_2$ (4.18 ± 1.61 to 5.02 ± 1.73, $t(55) = -5.94$, $p < .001$, $d = -.79$). No group differences in satiety ratings were observed ($F(1, 54) = 1.63$, $p = .207$, $\eta_p^2 = .03$).

Fullness ratings significantly increased over time (main effect: $F(2, 108) = 113.88$, $p < .001$, $\eta_p^2 = .68$), with significant increase from $t_0$ to $t_1$ (1.64 ± 1.02 vs. 3.61 ± 1.76, $t(55) = -8.57$, $p < .001$, $d = -1.72$) and from $t_1$ to $t_2$ (3.61 ± 1.76 to 5.05 ± 1.75, $t(55) = -6.51$, $p < .001$, $d = -1.15$). No group differences in fullness ratings were observed ($F(1, 54) = 2.41$, $p = .127$, $\eta_p^2 = .04$

NA ratings changed over time (main effect: $F(2, 108) = 10.29$, $p < .001$, $\eta_p^2 = .16$), with a significant decrease from $t_0$ to $t_1$ (3.28 ± 1.01 vs. 2.79 ± 1.08, $t(55) = 5.05$, $p < .001$, $d = 0.68$) and significant increase from $t_1$ to $t_2$ (2.79 ± 1.08 to 3.16 ± 1.18, $t(55) = -3.22$, $p = .002$, $d = -0.43$). NA ratings differed between the groups (main effect: $F(1, 54) = 15.21$, $p < .001$, $\eta_p^2 = .22$), with the BE group reporting significantly higher NA than the HC group for $t_0$ (3.69 ± 0.97 vs. 2.87 ± 0.88, *t*(54) = 3.31, *p* = .002, *d* = 0.89), $t_1$ (3.22 ± 1.15 vs. 2.34 ± 0.80, *t*(48.10) = 3.37, *p* = .002, *d* =90) and $t_2$ (3.66 ± 1.18 vs. 2.65 ± 0.96, *t*(54) = 3.52, *p* = .001, *d* = 0.94).

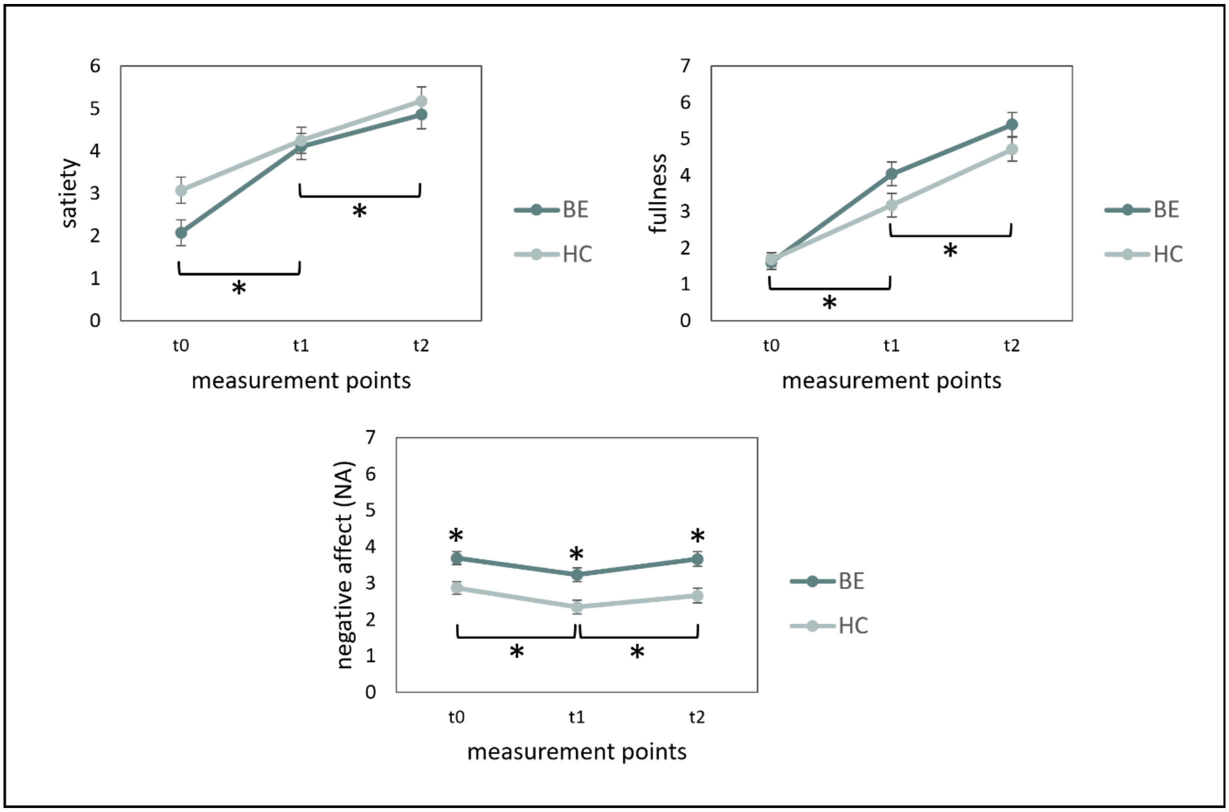


**Figure 2.** Ratings for satiety, fullness, and negative affect at three time points: before water ingestion ($t_0$), after the first drinking phase ($t_1$), and after the second drinking period ($t_2$). Data are presented separately for the binge eating (BE) group and the healthy control (HC) group. Figures represent group means, with error bars indicating standard errors (*SE*). * = significant group difference at $p < .01$, * with bracket = significant difference between measurement points at $p < .01$.

## Interoceptive Insight (IIn)

IIn scores did not differ between the BE and HC groups (69.7 ± 14.2 vs. 65.9 ± 21.8, *t*(46.42) = 0.77, *p* = .448, *d* = 0.20).

**Percentage Distribution of EGG cycle durations across frequency bands**

Two participants from the BE group were excluded from EGG analysis due to poor signal quality. Figure 3 depicts the mean percentage distribution of EGG power across the three frequency bands, comparing BE ($n$ = 26) and HC groups ($n$ = 28). We found no significant interactions between time and group for bradygastria ($F(2, 104) = 0.14$, $p = .867$, $\eta_p^2 = .003$), normogastria ($F(2, 104) = 0.34$, $p = .709$, $\eta_p^2 = .01$), and tachygastria ($F(2, 104) = 1.26$, $p = .289$, $\eta_p^2 = .02$), indicating that relative EEG power in three frequency bands did not differ over time between the groups.

Regarding bradygastria, there was a trend toward changes in relative EGG power in response to water loads ($F(2, 104) = 2.76$, $p = .068$, $\eta_p^2 = .05$), although none of the post-hoc tests reached statistical significance. Activity in the bradygastric frequency range did not differ between the groups ($F(1, 52) = 1.15$, $p = .288$, $\eta_p^2 = .02$).

Regarding normogastria, a significant main effect was found for time ($F(2, 104) = 3.16$, $p = .047$, $\eta_p^2 = .06$), indicating changes in EGG power in response to water loads, although none of the post-hoc tests reached statistical significance. Activity in the normogastric frequency range did not differ between the groups ($F(1, 52) = 0.25$, $p = .618$, $\eta_p^2 = .01$).

Activity in the tachygastric frequency range remained consistent in response to water loads ($F(1.66, 86.46) = 2.76$, $p = .289$, $\eta_p^2 = .02$), and did not differ between the groups ($F(1, 52) = 0.57$, $p = .455$, $\eta_p^2 = .01$).

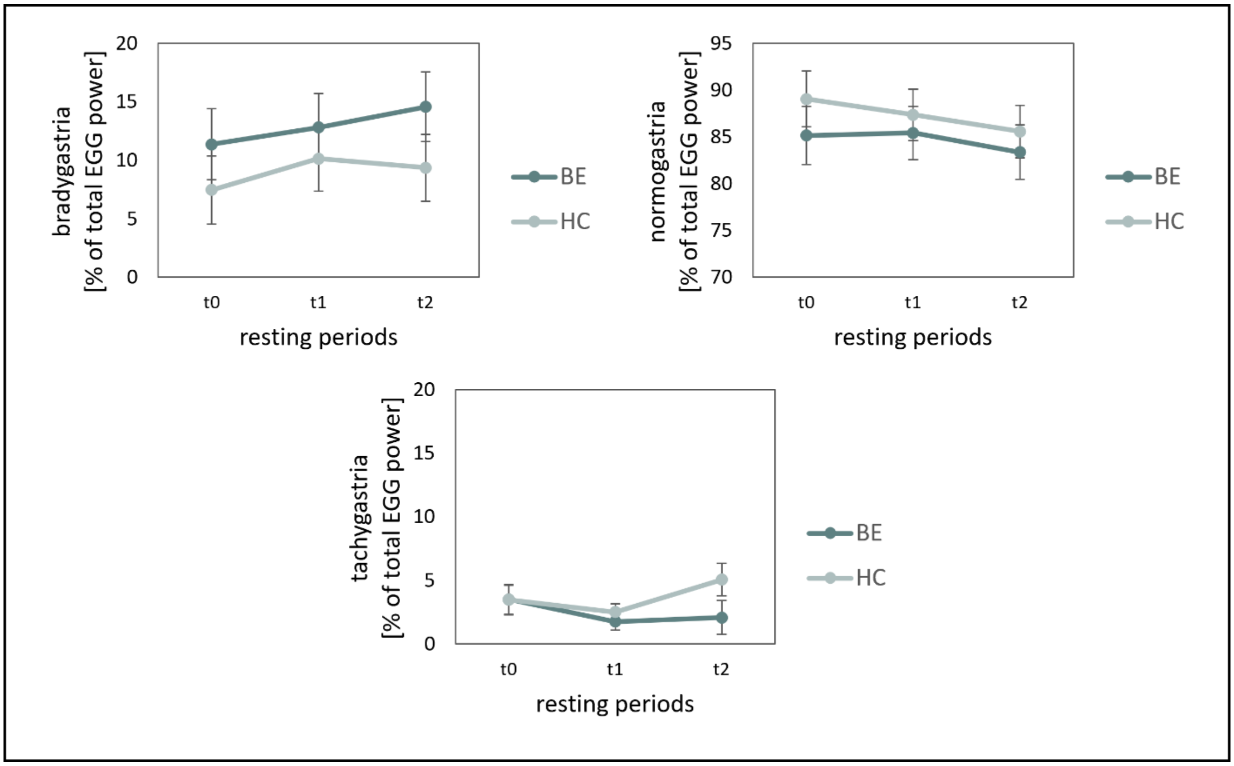


**Figure 3.** Percentages of total EGG power in four frequency bands during the resting periods ($t_0$, $t_1$, $t_2$) for the binge eating (BE) group and the healthy control (HC) group. Figures represent group means, with error bars indicating standard errors (*SE*).

## Gastric-alpha PAC

Cluster-based permutation analysis revealed a significant gastric-alpha PAC cluster over the central-parietal and occipital regions (CP1, CP5, P3, Oz, O1, O2) during the first resting period (baseline, $t_0$) (sum($t$) = 18.07, Monte Carlo $p$ = 0.0001, corrected for multiple comparisons). Gastric-alpha PAC observed in the BE group did not differ significantly from that of the HCs at baseline (0.0015 ± 0.0007 vs. 0.0014 ± 0.0006, $t(53) = 0.32$, $p = .753$, $d = 0.09$). For the subsequent resting periods ($t_1$ and $t_2$), no significant clusters were identified. Statistical maps of gastric-alpha PAC for each measurement point are shown in Figure 4, highlighting the significant cluster at $t_0$.

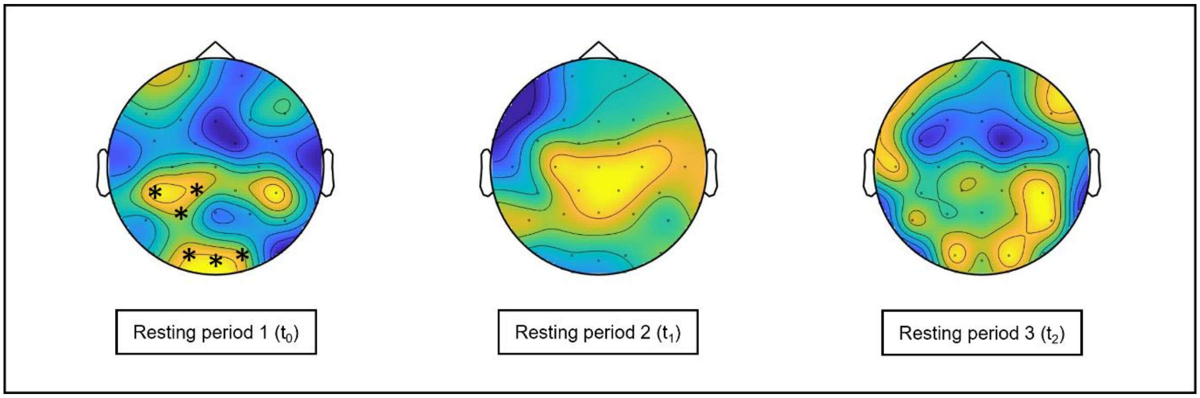


**Figure 4.** Statistical maps of gastric alpha phase-amplitude coupling (PAC) during the three resting periods of the Two-Step Water Load Test (WLT-II; van Dyck et al., 2016) across the entire study sample. Electrodes showing significant gastric alpha PAC are marked with an asterisk (*).

## Exploratory analyses

Additional analyses were conducted to explore the association of baseline gastric-alpha PAC with interoceptive dimensions and trait questionnaires. Across the whole sample, there were no significant correlations between gastric-alpha PAC and either interoceptive dimensions or trait questionnaires (*p*s > .05). In the BE group, significant moderate correlations were found between gastric-alpha PAC and the EDIP-Q total score ($r$ = .43, $p$ = .026), reflecting ED-specific interoceptive perception, and the EDIP-Q Discrimination subscale score ($r$ = .42, $p$ = .028), reflecting self-reported ability to perceive and discriminate between emotional states and hunger. In comparison (see Figure 5), no such associations were found in the HC group between gastric-alpha PAC and the EDIP-Q total score ($r$ = -.11, $p$ = .567) and Discrimination score ($r$ = -.01, $p$ = .947).

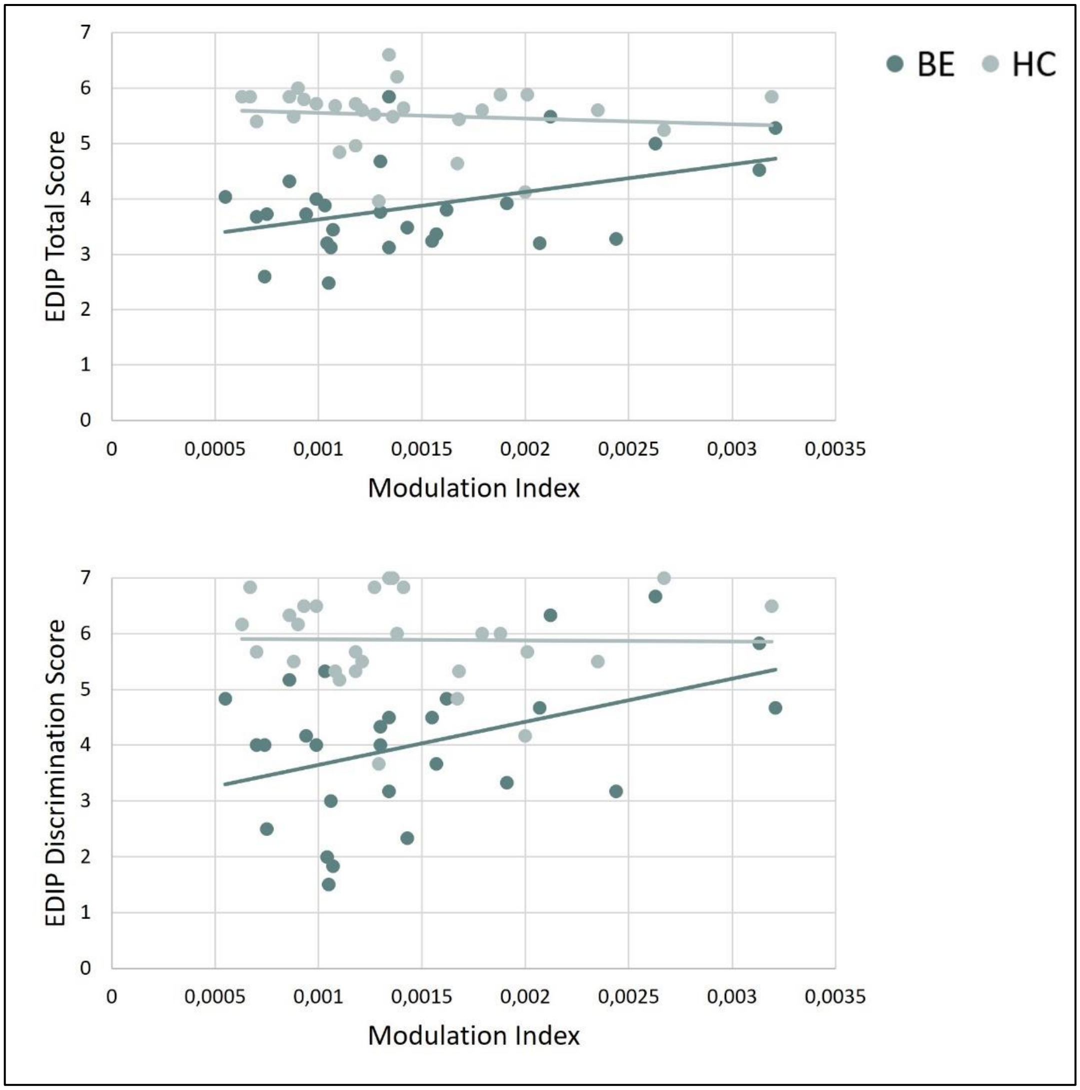


**Figure 5.** Association between Gastric-Alpha Phase-Amplitude Coupling (PAC), as indexed by the Modulation Index, and EDIP Total and Discrimination Scores. BE = Binge Eating Group, HC = Healthy Control Group.

## 5.5. Discussion

The aim of the current study was to investigate gastric interoceptive processes at multiple levels in individuals with recurrent BEEs. We found a significant group difference in ISen (supporting hypothesis I), with individuals with BEEs ingesting higher volumes of water to reach the same level of satiety as HCs. Ratings in NA related to interoceptive sensations were higher in individuals with BEEs compared to HCs (supporting hypothesis IV). Other levels of interoceptive processing were comparable between the BE and HC group (in contrast to hypotheses II, III, and VI). Exploratory analyses revealed moderate associations between the strength of stomach-brain coupling and self-reported ED-specific interoceptive perception, as well as the self-reported ability to perceive and differentiate between emotional states and hunger, but these associations were observed only in the BE group.

The WLT-II (van Dyck et al., 2016) was performed, from which indices for ISen, IBe, IIn, and AIS were derived. The satiety threshold, corresponding to the point of meal termination, was higher in the BE group, as individuals with BEEs ingested significantly higher volumes of water to reach the same level of satiety as HCs. This higher threshold is also reflected by a trend toward higher percentages of satiation relative to total volume in the BE group compared to the HC group. Notably, groups did not differ in their self-reported levels of satiety and fullness at baseline and after each drinking phase, indicating unaltered IBe in individuals with BEEs. These findings are consistent with several previous studies showing higher satiety thresholds in individuals with fully-manifested BED and BN (Sysko et al., 2007; van Dyck et al., 2020). The current study extends the literature by showing that individuals with recurrent BEEs, including full-syndrome and subthreshold EDs, have a higher satiety threshold and therefore require more intake to achieve the same level of satiety as HCs.

Supporting the notion of a higher satiety threshold in individuals with BEEs than HCs, the groups did not differ in IIn, suggesting that the metacognitive evaluation (i.e., perceived ISen in satiety perception) of the BE group was comparable to that of the HC group. This indicates that individuals with BEEs had the same level of metacognitive insight into their satiety perception as HCs, even though they consumed larger amounts of water to reach the same level of self-reported satiety. Overall, these results suggest a higher satiety threshold rather than impaired satiety perception in individuals with BEEs. A possible intervention target could, therefore, be to lower the satiety threshold. No conclusions yet can be drawn concerning a causal relationship between BE and a higher satiety threshold in individuals with BEEs. Future research should investigate whether the satiety thresholds lower in patients during recovery.

Regarding NA ratings, both groups reported a significant decrease after drinking water until satiated and a significant increase after drinking until fullness. These results suggest that satiety is experienced as a positive and comfortable state, whereas fullness is perceived as unpleasant. This also confirms that the WLT-II was effective, as participants clearly differentiated between the two drinking phases, i.e. drinking water until the first sign of satiation (phase 1), and until reaching maximum stomach fullness (phase 2). The BE group, however, consistently reported higher levels of NA compared to the HC group across all measurement points. Gastrointestinal symptoms (e.g., nausea, bloating, postprandial discomfort) are common among ED patients (Salvioli et al., 2013; Sato & Fukudo, 2015), which may account for the higher NA ratings during the water load test. Van Dyck et al. (2020) also found higher NA post-ingestion in individuals with BN and BED, supporting the idea of disturbed sensory responses to food intake in those with recurrent BEEs.

Gastric motility has been proposed as central mediator of hunger and satiety (Janssen et al., 2011). The strength and variations of afferent signals can have an impact on the processing levels of interoception (Suksasilp & Garfinkel, 2022). We, therefore, measured GMA to track the frequency and amplitude of gastric muscle contractions. Previous results suggest that individuals with BN and BED exhibit abnormal GMA (Alyami et al., 2023; Koch et al., 1998; Ogawa et al., 2004), lower sensitivity to gastric distention and delayed onset of satiety (van Dyck et al., 2020). Furthermore, there is evidence for a negative association between BE frequency and the percentage of normogastria in response to water loads, suggesting that more frequent BE is linked to lower normogastric activity (van Dyck et al., 2020). In the present study, however, we found no group differences in GMA as reflected by the distribution of EGG cycle durations across frequency bands, neither at baseline nor in response to water loads. This suggests that individuals with BEEs have similar GMA patterns and no alterations at the most basic level of interoceptive processing. Altered GMA may be a pattern specific to fully manifested BN or BED, while in subthreshold forms of these conditions, this characteristic may not yet be fully developed. Future research is warranted to explore the relationship between GMA and BE behavior across a continuum and to determine whether abnormal GMA is a clinical manifestation of BE or a consequence thereof. Longitudinal studies, experimental designs, and advanced statistical techniques will be essential for clarifying these causal relationships and uncovering the underlying mechanisms.

Since it is unlikely that GMA accounted for the differences in ISen scores between groups in our study, it is reasonable to assume that differences in gastric signal processing occur at a higher level, e.g., the neural representation of gastric signals. Stomach-brain coupling has been investigated in only a few studies (Rebollo et al., 2018; Richter et al., 2017; Todd et al., 2021), all conducted in healthy individuals at rest and without gastric stimulation. Building on this research, we investigated gastric-alpha PAC in individuals with BEEs and HCs at baseline and after each drinking phase to better understand whether and to what extent water loads modulate stomach-brain coupling. At baseline, we observed gastric-alpha PAC in the central-parietal and occipital scalp regions (CP1, CP5, P3, Oz, O1, O2). Our findings in the occipital regions align with the MEG results reported by Richter et al. (2017), while our central-parietal findings align with Todd et al.'s (2021) observations in the left central-parietal area. These findings provide robust support for similar topographical localizations of gastric-alpha PAC. The spatial resolution of EEG is, however, limited, as electrical signals detected on the scalp are a summation of various underlying neural activities, complicating the precise localization of sources (Cohen, 2014). Functional Magnetic Resonance Imaging (fMRI) identified the gastric network (Rebollo et al., 2018), an extensive network encompassing somatosensory, motor, visual, and auditory regions phase synchronized with the gastric cycle. Some of these regions, including the insula, somatosensory cortices, and cingulate motor regions, are also involved in interoceptive processing and autonomic functions (Rebollo & Tallon-Baudry, 2022). Given the novelty of this research area, the functional role of the gastric network—particularly the involvement of occipital regions, which are primarily associated with visual processing—remains largely unexplored. Rebollo et al. (2021) suggest that the occipital cortex may contribute to maintaining homeostasis by increasing visual attention for food-related cues, thus guiding eating behavior. At this stage, our understanding is still speculative. Further research is, therefore, warranted to determine which brain regions contribute to gastric interoceptive processing and (disturbed) eating behavior.

Interestingly, we found no significant clusters of gastric-alpha PAC in subsequent measurements, indicating that water loads might disrupt or alter the stomach-brain interaction. This result is in line with the findings of Balasubramani et al. (2022), who found higher levels of gastric-alpha PAC in participants after fasting for at least 8 hours compared to when they were satiated. One possible explanation for the apparent absence of gastric-alpha PAC following water loads is that parieto-occipital regions, which are involved in alpha rhythm generation (Salmelin & Hari, 1994), become deactivated in response to gastric distention (Van Oudenhove et al., 2009) caused by water ingestion. Integrating our findings with previous research suggests that the strength of the gastric alpha rhythm may vary with hunger and satiety states. Further research is needed to experimentally investigate this hypothesis.

Contrary to our expectations, there were no group differences in gastric-alpha PAC, suggesting unaltered neural representation of gastric signals in individuals with BEEs. Exploratory analyses revealed, however, a moderate association between gastric-alpha PAC and self-reported ED-specific interoceptive perception (EDIP total score), as well as the ability to differentiate between emotional states and hunger (EDIP Discrimination score), but this was observed only in the BE group. This suggests a potential link between the neural representation of gastric signals and the ability to perceive and discriminate between interoceptive signals relevant to the regulation of eating behavior in individuals with BEEs.

Individuals with BN and BED report greater difficulty in perceiving hunger and distinguishing between emotional states and hunger (Ortmann et al. 2024). Since negative emotions are commonly associated with and often precede BEEs (Meule et al., 2021; Schaefer et al., 2020), it is plausible that individuals with BEEs may confound emotional states with feelings of hunger (Bruch, 1964). Enhancing stomach-brain coupling could potentially help affected individuals better perceive and differentiate interoceptive signals, which is crucial for regulating eating behavior. Given the novelty of research on stomach-brain coupling, these hypotheses need to be tested experimentally. For instance, exploring the effects of electrical vagus nerve stimulation

(VNS)—a technique known to influence the brain's processing of visceral signals (Paciorek & Skora, 2020)—could provide insights into the role of stomach-brain coupling in interoceptive processing and eating behavior. A recent study demonstrated that VNS increased stomach-brain coupling and its relationship to self-reported hunger (Müller et al., 2022). VNS has also been found to enhance IAcc, IBe (Villani et al., 2019), and the neural representation of cardiac signals (Richter et al., 2021). Future research should investigate the effects of strengthening stomach-brain coupling on gastric interoceptive processing and eating behavior in both healthy individuals and those with EDs.

**Limitations**

Participants in the BE group shared the criterion of experiencing at least one BEE per week over a three-month period. We chose not to limit the study to only individuals with full-syndrome EDs, because (1) BE behavior is prevalent in the general population (e.g., Duarte et al., 2015; Goldschmidt et al., 2015; Sonneville et al., 2013), and (2) individuals with subthreshold EDs exhibit similar psychopathology and distress as those with full syndrome EDs (Chapa et al., 2018; Johnson et al., 2021; Striegel-Moore et al., 2000). While this inclusion criterion introduced some heterogeneity within the BE group, it increased representativeness, thereby enhancing the ecological validity and generalizability of our results. Furthermore, the transdiagnostic approach of including individuals across a spectrum of symptom severity strengthens the applicability of our findings to a broader range of BE behaviors.

While EEG offers high temporal resolution, its spatial resolution is limited (Cohen, 2014). This methodological constraint may account for the lack of observed group differences in the neural representation of gastric signals and the absence of significant clusters of gastric-alpha PAC in measurements taken after drinking phases. Moreover, we found no other significant correlations between stomach-brain coupling and self-report data on maladaptive eating styles or ED symptoms. Future research should employ brain imaging techniques with higher spatial resolution, such as fMRI, to explore stomach-brain coupling in subcortical regions, offering complementary insights into the gastric network's role in gastric interoceptive processing and regulating eating behavior.

**Conclusions**

This study provides the first comprehensive assessment of gastric interoception across multiple dimensions in individuals with recurrent BEEs. Our findings indicate that individuals with BEEs have a higher satiety threshold, which could either predispose them to BE behavior or result from their frequent BEEs. Gastric signal properties and their cortical representation appear intact. We identified a distinct link between stomach-brain coupling and the ability to perceive and differentiate between emotional states and hunger, an association observed exclusively in individuals with BEEs. This suggests that enhanced communication between the stomach and brain may facilitate the perception and differentiation of interoceptive signals crucial for regulating eating behavior. Conversely, impaired stomach-brain communication may contribute to disordered eating patterns, such as BE. These conclusions, however, are preliminary and speculative due to the early stage of this research. Further studies are needed to validate these findings and explore their implications for targeted interventions. Replication of this study using brain imaging techniques with higher spatial resolution is essential to further explore stomach-brain communication and its contribution to gastric interoceptive processing and eating behavior, in order to refine therapeutic approaches.

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## 5.7. Supplemental Materials

*Eating Disorder Inventory-2.* The EDI-2 (Paul & Thiel, 2005) is a 91-item self-report measure of ED psychopathology. In the present study, the first three subscales Drive for Thinness (DT; 7 items), Bulimia/Bulimic Tendencies (BU; 7 items), and Body Dissatisfaction (BD; 9 items) were used to assess core ED psychopathology. Responses were given on a 6-point Likert scale ranging from 1 (never) to 6 (always). Sum scores were calculated for each subscale, with higher scores indicating greater severity of ED symptoms. Cronbach's α in the current sample was .91, .93 and .94 for DT, BU and BD, respectively.

*Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q).* The EDIP-Q (Ortmann et al., 2024) is a 25-item self-report measure designed to assess eating disorder-specific interoceptive perception, which involves the ability to perceive and distinguish between emotions, hunger, and satiety. It consists of four subscales: Emotions, Hunger, Satiety, and Discrimination. Responses were given on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Total score (TS) and mean scores for each subscale were calculated, with higher scores indicating better EDIP. Cronbach's α in the current sample was .92 for Emotions, .78 for Hunger, .94 for Satiety, .85 for Discrimination, and .94 for the TS.

*Multidimensional Assessment of Interoceptive Awareness (MAIA).* The MAIA (Mehling et al., 2012) is a 32-item self-report measure designed to assess multiple facets of interoceptive abilities. It consists of eight subscales: Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. Responses were given on a 5-point Likert scale ranging from 1 (never) to 5 (always), with higher scores indicating better interoceptive awareness. Cronbach's α in the current sample was .59, .62, .69, .85, .85., 88, .92, and .92 for Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting, respectively.

*Dutch Eating Behavior Questionnaire.* The DEBQ (Nagl et al., 2016) is a 33-item self-report measure to assess restrained, emotional, and external eating behavior. Responses were given on a 5-point Likert scale, ranging from 1 (never) to 5 (very often). Sum scores were calculated for each subscale, with higher scores indicating more frequent endorsement of maladaptive eating behaviors. Cronbach's α in the current sample was .94, .97, and .66 for Restrained, Emotional, and External Eating, respectively.

*Difficulties in Emotion Regulation Questionnaire (DERS).* The DERS (Ehring et al., 2013)is a 36-item self-report measure designed to assess difficulties in emotion regulation. It consists of six subscales: Nonacceptance of Emotional Responses (Nonacceptance), Difficulties Engaging in Goal-Directed Behavior (Goals), Impulse Control Difficulties (Impulse), Lack of Emotional Awareness (Awareness), Limited Access to Emotion Regulation Strategies (Strategies), and Lack of Emotional Clarity (Clarity). Responses were given on a 5-point Likert scale, ranging from 1 (almost never) to 5 (almost always). Mean Score (DERS-MS) and sum scores for each subscale were calculated, with higher scores indicating greater emotion dysregulation. Cronbach's α in the current sample was .93 for Nonacceptance, .92 for Goals, .87 for Impulse, 89 for Awareness, .93 for Strategies, .93 for Clarity, and .96 for the DERS-MS.

*Patient Health Questionnaire-9 (PHQ-9).* The PHQ-9 (Kroenke et al., 2001) is a 9-item measure designed to assess depressive symptoms depressive symptoms experienced over the past last two weeks. Responses were given on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Higher sum scores indicate more severe depressive symptoms. Cronbach's α in the current sample was .87.

*Generalized Anxiety Disorder-7 (GAD-7).* The GAD-7 (Spitzer et al., 2006) is a 7-item self-report measure designed to assess generalized anxiety disorder symptoms experienced over the past two weeks. Responses were given on a 4-point Likert scale ranging from 0 (not at all) to 3 (nearly every day). Higher sum scores indicate more severe anxiety symptoms. Cronbach's α in the current sample was .89.

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# 6. GENERAL DISCUSSION

The main objectives of this research project were to address the gaps in the literature by (1) developing and validating a new self-report measure to assess ED-specific interoceptive perception (EDIP) and (2) providing a more comprehensive assessment of interoceptive processes in two organ systems of relevance for eating behavior, i.e. the cardiovascular and gastrointestinal systems.

## 6.1. Summary of Findings

### 6.1.1. Development and (Multilingual) Validation of the Eating Disorder-specific Interoceptive Perception Questionnaire (Studies 1-3)

Studies 1-3 focused on the development and initial validation of the Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) and its language versions. The EDIP-Q is a multidimensional self-report measure designed to assess ED-specific interoceptive perception (EDIP), defined as 'the ability to perceive emotions, hunger, and satiety and to discriminate between these physiological states'.

In Studies 1 and 2, the factor structure of the German EDIP-Q was examined in two independent samples of individuals with and without self-reported EDs. Factor analyses revealed a four-factor solution for the original scale, with a higher order EDIP factor. This led to the specification of a 25-item instrument with four subscales: *Emotions* (assessing the ability to perceive emotions), *Hunger* (assessing the ability to perceive hunger cues), *Satiety* (assessing the ability to perceive satiety cues), and *Discrimination* (assessing the ability to discriminate between emotional states and hunger). Both subscale scores and a total score can be calculated, with lower scores indicating partial or general deficits in EDIP, respectively.

Study 3 validated the English and French versions of the EDIP-Q, confirming the factor structure and demonstrating measurement invariance (i.e., configural, metric, scalar) across German-, English-, and French-speaking samples. The language versions of the EDIP-Q demonstrated sound psychometric properties across Studies 1-3. Supporting convergent validity, lower EDIP-Q TS and subscale scores were associated with more severe ED psychopathology, greater endorsement of maladaptive eating behaviors, impaired interoception, and higher levels of depression and anxiety. For divergent validity, EDIP-Q TS and subscale scores were unrelated to self-report measures of empathetic concern and perspective taking. Supporting incremental validity, EDIP-Q subscales improve predictive accuracy for ED psychopathology and maladaptive eating behaviors beyond that offered by existing self-report instruments on interoception (i.e., MAIA), with a substantial increase in explained variance ranging from 8% to 23%.

The EDIP-Q also differentiated individuals with current and past EDs from healthy controls, with the lowest scores observed in those with current EDs. Descriptive EDIP profiles were established for AN, BN, and BED. While individuals with current EDs reported similar difficulties in emotion perception, they differed on the other EDIP-Q subscales. Those with AN showed lower sensibility to hunger, higher sensibility to satiety, and fewer difficulties distinguishing between emotional states and hunger, whereas those with BN and BED showed the opposite pattern. Not all differences in EDIP between ED types reached statistical significance across Studies 1–3, which may be attributed to a certain degree of heterogeneity within the groups, as group allocation was based on self-report.

In summary, these studies provide initial support for the validity of the EDIP-Q language versions and highlight distinct interoceptive deficits in AN, BN, and BED, underscoring the need for more targeted, individualized treatment approaches.

### 6.1.2. Cardiac Interoceptive Processing and Emotional Experience in Individuals with and without Binge Eating Behavior (Study 4)

Study 4 aimed to investigate cardiac interoceptive processing at multiple levels in individuals with BE behavior, as well as their emotional experience and affective state related to heartbeat perception. Individuals with recurrent BEEs showed a profile of interoceptive alterations characterized by heightened parasympathetic cardiac activity and altered cortical processing of cardiac signals, while the dimensions of IAcc, IBe, and IAw remained unaltered. A smaller increase in HEP amplitudes from rest to HCT was associated with greater difficulties in EDIP, more severe ED psychopathology, and greater endorsement of maladaptive eating behaviors. Retrospective ratings of valence, arousal, and anxiety did not differ between groups. Affective states changed from pre- to post-task, with both groups showing a decrease in PA and an increase in NA. The BE group differed from the HC group only after the HCT, reporting higher levels of NA.

### 6.1.3. Gastric Interoceptive Processing in Individuals with Binge Eating Behavior (Study 5)

Study 5 aimed to investigate gastric interoceptive processing at multiple levels in individuals with BE behavior. Compared to HCs, individuals with recurrent BEEs ingested more water until satiated and showed a trend toward higher percentages of satiation relative to maximum fullness, indicating altered ISen. While IIn and IBe scores did not differ between the groups, individuals with recurrent BEEs rated NA higher, suggesting an aversive attribution to gastric interoceptive sensations. Contrary to previous research (van Dyck et al., 2020), no group differences were found in the distribution of EGG cycle durations across frequency bands, indicating normal gastric motor activity in individuals with recurrent BEEs. Gastric-alpha PAC was observed over central and parietal scalp regions before, but not after water ingestion. The strength of gastric-alpha PAC was associated with higher EDIP total and Discrimination scores in individuals with BEEs, indicating greater EDIP and a self-reported ability to perceive and discriminate between emotional states and hunger.

## 6.2. Integrative Discussion

The findings of this project contribute to a better understanding of the relationship between interoceptive processes and disordered eating behaviors and EDs. Previous research has highlighted the differential contribution of emotions, hunger, and satiety to ED symptoms (e.g., Brown et al., 2010; Poovey et al., 2022; van Dyck et al., 2016). However, there has been a lack of appropriate self-report measures that distinguish between the perception of these visceral signals. To address this gap, we developed and validated different language versions of the EDIP-Q (Studies 1-3), providing a comprehensive assessment of EDIP in German-, English-, and French-speaking populations. Psychometric properties (e.g., factor structure, construct validity, internal consistencies, measurement invariance, and incremental validity) were examined and empirically supported across three independent samples of individuals with and without self-reported EDs. The findings on the incremental validity of the EDIP-Q are of particular importance, as they demonstrate that the EDIP-Q add greater predictive power than existing measures of interoception (i.e., MAIA; Mehling et al., 2012) in relation to ED psychopathology and disordered eating.

Our findings reveal that deficits in EDIP are significant in individuals with self-reported EDs and may improve with recovery, potentially reaching levels comparable to healthy individuals. These results align with recent meta-analytic findings (Jenkinson et al., 2018) supporting the role of interoceptive deficits in the etiology and maintenance of EDs. Furthermore, the components of EDIP were impaired to varying degrees among different ED types. Based on the results of Studies 1-3, we established descriptive profiles of EDIP for AN, BN and BED.

*EDIP profile for AN:* Individuals with AN show similar difficulties in emotion perception to those with BN and BED, consistent with meta-analytic findings of elevated alexithymia across the ED spectrum (Westwood et al., 2017). However, compared to BN and BED, those with AN report lower sensibility hunger, higher sensibility satiety, and fewer difficulties in discriminating between emotional states and hunger. This pattern reflect the clinical picture of AN, which is characterized by severe restriction of food intake to prevent weight gain or promoting weight loss (APA, 2013). From clinical experience, patients with AN often report gastrointestinal discomfort after meals, including feelings of fullness and bloating (Norris et al., 2015), leading to partial or complete refusal to eat. Studies have shown that, after consuming a standardized meal, individuals with AN experience earlier satiety and greater postprandial fullness compared to HC (Garfinkel et al., 1978; Garfinkel, 1974; Garfinkel et al., 1979; Klastrup et al., 2020).

*EDIP profile for BN and BED:* As previously outlined, individuals with BN and BED exhibit similar difficulties in emotion perception as those with AN. However, compared to AN, those with BN and BED report higher sensibility to hunger, lower sensibility to satiety, and greater difficulty in discriminating between emotional states and hunger. This profile aligns with research indicating that individuals with BN and BED have a delayed response to satiety (van Dyck et al., 2020), require larger amounts of food to reach a similar level of fullness (Kissileff et al., 1996; Sysko et al., 2007), and engage in BE in response to negative emotions more frequently (e.g., Meule et al., 2021; Schaefer et al., 2020).

Beyond the EDIP profiles for AN, BN and BED, we identified alterations in interoceptive processes at different levels in both the cardiac and gastric domains, linked to BE behavior. In the *cardiac domain,* the most important finding concerns the altered neural representation of cardio-afferent signals at the cortical level in individuals with recurrent BEEs. Contrary to our expectations, the attention effect (i.e., increase in HEP amplitudes from rest to task) was not observed in individuals with recurrent BEEs. This pattern of neural representation of cardiac signals is similar as the pattern reported in patients with depersonalization disorder (Schulz et al., 2015) and may reflect a shared inclination toward disengagement from bodily sensations and dissociative tendencies. Episodes of BE are often described as dissociative experience, and individuals with recurrent BEEs show higher levels of dissociation than HCs, with the severity of BE closely linked to the degree of dissociation (La Mela et al., 2010). Dissociation may allow individuals to engage in BE as means to reduce self-awareness and alleviate NA, which aligns with the escape theory (Heatherton & Baumeister, 1991). Since dissociative symptoms were not directly assessed in Study 4, future research should include such measures (e.g., Dissociative Experiences Scale; Carlson & Putnam, 1993) and investigate the relationship of dissociative symptoms with interoception and ED psychopathology.

Another key finding concerns the association between smaller ΔHEP (i.e., changes in HEP amplitudes from rest to task) with greater difficulties in EDIP, more severe ED symptoms, and more frequent engagement in maladaptive eating patterns. These associations suggest that the observed alterations in the neural representation of cardiac signals are specifically linked to ED psychopathology, rather than general psychopathological factors.

We also observed significant group differences in changes in affective states from pre to post HCT. Our results suggest that the attention to the heartbeat increased NA. This increase in NA was particularly pronounced in those with recurrent BEEs and may stem from heightened negative self-awareness and emotional distress caused by the HCT, greater difficulties with emotion regulation (assessed via self-report), or a combination of both.

In the *gastric domain*, we found altered interoceptive processes in individuals with BEEs as well. Building on and expanding previous research (Kissileff et al., 1996; Sysko et al., 2007; van Dyck et al., 2020), our results indicate that individuals with BEEs have a higher satiety threshold (i.e., require higher volumes to achieve the same level of satiety) but have the same level of insight into their satiety perception as HCs. Supporting the notion of disturbed sensory responses to food intake (van Dyck et al., 2020), individuals with recurrent BEEs report generally higher NA in response to stomach distension than HCs, indicating an aversive attribution to gastric interoceptive sensations. While previous studies reported abnormal GMA in individuals with BN and BED (Alyami et al., 2023; Koch et al., 1998; Ogawa et al., 2004; van Dyck et al., 2020), our findings point toward normal gastric motor function in individuals with recurrent BEEs. This discrepancy highlights the need for further research to explore the relationship between GMA and BE behavior and to determine whether abnormal gastric motor function is a clinical manifestation of BE or a consequence thereof.

An important contribution of Study 5 concerns the first-time investigation of stomach-brain coupling in individuals with recurrent BEEs, both at rest and following gastric distention. In line with previous findings, we observed gastric-alpha PAC in the central-parietal (Todd et al., 2021) and occipital regions (Richter et al., 2017) at baseline, but not after water intake. These results suggest that gastric distention may disrupt or alter stomach-brain interactions. Contrary to our hypothesis, individuals with recurrent BEEs did not differ from HCs in their neural representation of gastric signals. We found, however, a potential link between greater stomach-brain coupling and better EDIP, particularly in the ability to perceive and discriminate between emotional states and hunger. This association was only observed in individuals with recurrent BEEs.

In summary, the outcomes of Studies 1-3 emphasize that deficits in EDIP represent a key transdiagnostic feature and should be assessed in a differentiated manner, as they may contribute differently to ED psychopathology. The EDIP-Q is a promising assessment tool for advancing ED research and its clinical application. Studies 4 and 5 provide a more comprehensive assessment of interoceptive processes within the cardiac and gastric systems. While alterations were identified in both domains, they occurred at different processing levels. For example, cardiac IAcc remained intact, whereas gastric ISen was altered in individuals with BEEs compared to HCs. These findings underscore the importance of assessing interoceptive processes across multiple levels and modalities concurrently, as they contribute differently to cognitions, emotions, and symptomatology (Suksasilp & Garfinkel, 2022).

## 6.3. Clinical Implications

Research findings have important implications for the treatment of EDs in general, and BE behavior in particular. Results from Studies 1-3 suggest that individuals with EDs experience varying degrees of difficulty in perceiving visceral sensations related to emotions, hunger and satiety, which may represent important targets for intervention. Assessing these deficits on an individual basis is essential for tailoring treatments to the specific needs of each patient. The EDIP-Q offers a valuable tool for the differentiated assessment of the perception and discrimination of emotions, hunger, and satiety.

Interventions should focus on improving patients' awareness and acceptance of emotions and physical cues related to hunger and satiety. This heightened awareness enables individuals to better recognize and respond to internal needs, while reducing their reactivity to external triggers. Cognitive Behavioral Therapy (CBT) is the treatment of choice for ED patients (Linardon, Wade, et al., 2017). However, long-term relapse and mortality rates remain high (Fichter et al., 2008; Fichter et al., 2017; Fichter & Quadflieg, 2016; Quadflieg & Fichter, 2019), highlighting the need for more effective therapeutic strategies. There is growing interest in 'third-wave' therapies, which incorporate mindfulness, acceptance, and emotion regulation strategies, which have shown potential in reducing ED symptoms (Linardon, Fairburn, et al., 2017).

For example, Mindfulness-Based Eating Awareness Training (MB-EAT) was developed to address core issues in BED (Kristeller et al., 2006), such as impaired emotional and appetite awareness. This approach has demonstrated positive effects on BE frequency, eating-related self-control, and depressive symptoms (Kristeller et al., 2014; Kristeller & Wolever, 2011). Even short-term interventions, such as a body scan, have been shown to increase the perception of hunger in healthy individuals (Palascha et al., 2021). However, most research evaluating the efficacy of mindfulness-based interventions for EDs has focused on BED. Only one study compared the effectiveness of a mindful eating group between different ED types (i.e., AN, BN, BED, and EDNOS), finding no group differences in outcomes (Hepworth, 2010). However, since participants were undergoing concurrent long-term treatments like CBT and narrative therapy, it remains unclear whether the observed progress was due to the mindfulness-based intervention, ongoing treatments, or the combination thereof. Future research should examine the effects of mindfulness-based interventions on the perception of emotions, hunger, and satiety, and determine whether increased awareness reduces ED symptoms.

As shown in Study 5, individuals with recurrent BEEs experience gastric sensations as aversive. Similarly, patients with AN report gastrointestinal discomfort during or after eating (Norris et al., 2015). These findings suggest that gastric sensations are associated with distress and unpleasant emotions. The experience of negative emotions plays a central role in third-wave psychotherapies (Hayes & Hofmann, 2017). For individuals who respond to these emotions by disengaging or shifting to a lower level of consciousness, as shown in Study 4, this may increase resistance to treatment. A potential technique to address this is ‘interoceptive exposure’, which involves repeatedly invoking unpleasant bodily sensations (e.g., gastric distention) to build tolerance. This approach, traditionally used for anxiety disorders, could also be beneficial for ED patients as it addresses the negative evaluation of interoceptive cues (Boswell et al., 2015).

Studies 4 and 5 also suggest a potential link between the neural representation of cardiac and gastric signals at the cortical level and ED symptoms. A key finding concerns the relationship between the strength of stomach-brain coupling, overall ability of EDIP, and the ability to discriminate between emotional states and hunger, which was specific to individuals with recurrent BEEs. As discussed in Study 5, enhancing stomach-brain coupling, potentially through vagus nerve stimulation (VNS), could improve the perception and differentiation of emotions, hunger, and satiety. This hypothesis remains to be tested in future studies.

VNS has shown efficacy in treating mood and other mental disorders, including schizophrenia, somatoform disorders, and post-traumatic stress disorder (Cimpianu et al., 2017). However, its effects on ED patients have yet to be explored (Duriez et al., 2020). Animal research has found an association between VNS and reduced food intake and weight loss (McClelland et al., 2013), supporting the mediating role of vagal stimulation in the perception of satiety. A recent study found that VNS enhanced stomach-brain coupling and its relationship to self-reported hunger (Müller et al., 2022). Additionally, VNS has been shown to improve IAcc, IBe (Villani et al., 2019), and the neural representation of cardiac signals (Richter et al., 2021). These findings suggest that VNS may modulate interoceptive processes, potentially alleviating ED symptoms.

Future research is warranted to investigate the effects of VNS on interoceptive processes and ED symptoms.

## 6.4. Strengths and Limitations

A key strength of this research project lies in its dual approach to investigating interoceptive processes. Studies 1-3 employed a categorical design, examining group differences in EDIP across ED types, providing valuable insights into disorder-specific patterns and establishing descriptive EDIP profiles for AN, BN, and BED. In contrast, Studies 4 and 5 followed a dimensional approach, investigating cardiac and gastric interoceptive processes along the BE spectrum. This approach aligns with the Research Domain Criteria (RDoC; Insel et al., 2010), which encourages the inclusion of individuals who do not meet full diagnostic criteria for EDs (Wildes & Marcus, 2015). Another key strength of the project concerns the investigation of interoceptive processes across dimensions and modalities, using diverse methodological approaches, including psychophysiological, behavioral, and self-report measures. This combination of approaches offered a more comprehensive understanding of interoceptive processes across distinct and continuous presentations of disordered eating.

While this research has notable strengths, certain limitations also need to be acknowledged. A notable limitation of this research project is its reliance on cross-sectional studies, which restricts the ability to draw causal conclusions about the relationship between interoceptive processes and disordered eating behavior. Longitudinal studies could provide valuable insights by tracking how interoceptive processes and eating behaviors change over time, particularly during treatment. Such studies would clarify the directionality of these relationships and how these processes influence one another. Furthermore, as discussed in the previous chapter on clinical implications, it is of great interest to explore how interventions aimed at improving interoceptive processing affect interoceptive dimensions, disordered eating behaviors, and other ED-related symptoms.

Another constraint to acknowledge is that Studies 4 and 5 focused on interoceptive processes related to BE as proxy of disordered eating behavior. It remains unclear whether the observed alterations in interoceptive processes—across both cardiac and gastric domains—are specific to the BE spectrum or extend to other disordered eating behaviors, such as restrictive eating. This uncertainty becomes more evident when comparing our findings with those of Lutz et al. (2019) who reported increased HEP amplitudes in patients with AN, contrasting with the altered cortical responses observed in individuals with recurrent BEEs in our study. Further comparative research on interoceptive processes across multiple dimensions between EDs, such as in Lutz et al. (2023), and along the ED spectrum, is warranted.

In addition to the need for comparative research, it is also important to note that interoceptive processes were investigated only in female participants. In Studies 1-3, the unequal gender distribution necessitated focusing solely on women for the comparison of EDIP across different ED types. Similarly, Studies 4 and 5 included only female participants. Future research is encouraged to specifically recruit sex- and gender-diverse individuals to ensure an adequate representation of these populations (Breton et al., 2023).

## 6.5. Future directions

An important contribution of this research project was the development and *initial* validation of the EDIP-Q in large samples of individuals with and without self-reported EDs. Future research should aim to further validate the EDIP-Q. A key next step involves applying the EDIP-Q in a controlled, clinical setting with ED patients whose diagnoses are confirmed by a mental health professional using a semi-structured interview (e.g., Eating Disorder Examination [EDE]; Fairburn & Cooper, 1993). Moreover, as previously discussed, implementing the EDIP-Q throughout therapy to track treatment progress would offer valuable insights into its clinical utility.

Future research should also prioritize recruiting sex- and gender-diverse individuals to ensure adequate representation of these populations (Breton et al., 2023). This approach would facilitate subgroup analyses and enable the exploration of potential sex and gender differences in the psychometric properties of the EDIP-Q, which are essential for establishing its validity and reliability across diverse populations. Moreover, establishing normative values for sex, gender, and ED types, such as AN, BN, and BED, would be an important step toward further validating the EDIP-Q.

The findings of this research, particularly the distinct profiles of interoceptive alterations that vary between ED types, and across different modalities, underscore the importance of assessing interoceptive processes across multiple levels and organ systems in relation to (disordered) eating behavior. Importantly, this approach extends beyond ED research and is relevant to a broader spectrum of mental disorders, as interoceptive processes contribute differently to emotions, cognitions, and symptoms (Suksasilp & Garfinkel, 2022).

Researchers should be encouraged to continue adopting both a transdiagnostic and dimensional approach, as recommended by RDoC (Insel et al., 2010). The transdiagnostic approach emphasizes the study of common underlying mechanisms across EDs (e.g., interoceptive deficits), while the dimensional approach focusses on understanding ED symptoms (e.g., disordered eating behaviors such as BE) along a spectrum rather than discrete categories. This integrative framework enhances our understanding of how interoceptive processes contribute to both shared and unique aspects of EDs, providing a foundation for developing more effective and individualized treatment approaches.

## 6.6. Concluding Remark

The research presented in this thesis investigated interoceptive processes as underlying mechanisms of disordered eating behavior and EDs, employing a range of methodologies including psychophysiological, behavioral, and self-report measures. Notably, we developed and validated the EDIP-Q, a self-report measure designed to assess EDIP in terms of ‘the ability to perceive emotions, hunger, and satiety, and to discriminate between these physiological states’. Using the EDIP-Q, we established descriptive profiles of EDIP for AN, BN, and BED. Additionally, we identified alterations in interoceptive processing across different levels and modalities associated with BE behavior. These findings underscore the importance of a comprehensive assessment of interoceptive processes to advance our understanding of how interoceptive processes contribute to ED symptoms. Future research should investigate how interoceptive alterations influence the development and maintenance of disordered eating behaviors and inform targeted interventions to improve treatment outcomes.

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## Appendices

Appendix A: German Version of the EDIP-Q

Appendix B: English Version of the EDIP-Q

Appendix C: French Version of the EDIP-Q

Appendix D: Instructions for Calculating Total and Subscale Scores for the EDIP-Q

## Appendix A: German Version of the EDIP-Q

Im Folgenden finden Sie eine Reihe von Aussagen über die Wahrnehmung von Emotionen, Hunger- und Sättigungsgefühlen. Wir interessieren uns für Ihr persönliches Empfinden und bitten Sie, anzugeben, inwiefern diese Aussagen **innerhalb des letzten Monats** auf Sie zutrafen.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. Meine Hungersignale bemerke ich schnell. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 2. Ich kann meine Gefühle gut erkennen. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 3. Ich spüre keinen Unterschied zwischen Hunger und Freude.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 4. Meine Sättigungssignale bemerke ich schnell. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 5. Ich spüre keinen Unterschied zwischen Hunger und Stress.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 6. Ich merke nicht, dass ich hungrig bin, bis ich extrem hungrig bin.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 7. Hunger und Emotionen fühlen sich bei mir gleich an.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 8. Die Sättigungssignale meines Körpers spüre ich nicht.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 9. Ich spüre leicht in meinem Körper, wie es mir geht. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 10. Ich merke, wenn ich den Punkt der angenehmen Sättigung erreicht habe. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 11. Auch wenn ich sehr lange nichts gegessen habe, spüre ich keinen Hunger.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 12. Ich kann gut erkennen, wenn ich fröhlich bin. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13. Ich merke nicht, dass ich satt bin, bis ich richtig vollgestopft bin.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 14. Ich spüre keinen Unterschied zwischen Hunger und Ärger.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 15. Ich nehme meine Gefühle genau wahr. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 16. Ich bemerke schnell, wenn mein Magen sich vor Hunger zusammenzieht. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 17. Ich spüre genau, wie viel ich gegessen habe. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 18. Ich spüre keinen Unterschied zwischen Hunger und Traurigkeit.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 19. Meine eigene Stimmung kann ich gut erkennen. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 20. Ich spüre, wann ich satt bin. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 21. Ich kann gut erkennen, wenn ich traurig, wütend oder ängstlich bin. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 22. Ich spüre keinen Unterschied zwischen Hunger und Nervosität.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 23. Ich kann die Emotionen Glück, Heiterkeit und Begeisterung gut unterscheiden. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 24. Ich spüre, wenn ich so viel gegessen habe, wie mein Körper braucht. | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |
| 25. Die Hungersignale meines Körpers spüre ich nicht.[R] | Trifft überhaupt nicht zu | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Trifft vollständig zu |

**Reference:**

Ortmann, J., Lutz, A. P. C., Rose, G., Happ, C., Vögele, C., Schulz, A., & van Dyck, Z. (2024). Development and initial validation of a self-report measure to assess eating disorder-specific interoceptive perception. *Psychological Assessment*, *36*(2), 162–174. https://doi.org/10.1037/pas0001283

## Appendix B: English Version of the EDIP-Q

You will find a list of statements regarding your experience of emotions, hunger, and the feeling of fullness. We are interested in your personal perception thereof, and ask you to indicate how often the following statements were applicable to you **within the last month**.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. I notice my hunger signals easily | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 2. I can recognize my emotions easily. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 3. I do not feel a difference between hunger and joy.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 4. I notice my satiety signals easily. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 5. I do not feel a difference between hunger and stress.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 6. I do not realize that I am hungry until I am extremely hungry.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 7. Hunger and emotions feel the same to me.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 8. I do not feel the satiety signals of my body.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 9. I easily feel how I am doing in my body. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 10. I notice when I reach a point of comfortable satiation. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 11. Even when I have not eaten anything for a long time, I do not feel hunger.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 12. I can easily notice when I feel joy. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13. I do not notice that I am full until I have completely stuffed myself.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 14. I do not feel a difference between hunger and anger.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 15. I accurately perceive my feelings. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 16. I easily notice when my stomach pulls itself together when I am hungry. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 17. I feel exactly how much I have eaten. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 18. I do not feel a difference between hunger and sadness.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 19. I can recognize my mood well. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 20. I feel when I am full. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 21. I can recognize when I feel sad, angry, or anxious well. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 22. I do not feel a difference between hunger and nervousness.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 23. I can differentiate between happiness, cheerfulness, and excitement well. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 24. I feel when I have eaten as much food as my body needs. | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |
| 25. I do not feel the hunger signals of my body.[R] | Does not apply at all | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Applies completely |

**Reference:**

Ortmann, J., Infanti, A., van Dyck, Z. & Vögele, C. (2024). *Multilingual Validation and Application of the Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) in English-, French-, and German-speaking samples.* Manuscript under review.

## Appendix C: French Version of the EDIP-Q

Vous trouverez, ci-dessous, toute une série d'affirmations concernant la perception d'émotions, de sensations de faim ou de satiété. Intéressés par votre ressenti personnel, nous vous saurions gré d'indiquer dans quelle mesure ces déclarations correspondent à ce que vous avez pu vivre **le mois dernier.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. Je remarque rapidement mes signaux de faim. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 2. J'arrive bien à identifier mes sentiments. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 3. Je ne sens pas la différence entre faim et joie. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 4. Je remarque rapidement mes signaux de satiété. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 5. Je ne sens pas la différence entre faim et stress. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 6. Je ne remarque pas que j'ai faim avant d'être littéralement affamé(e). [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 7. Pour moi, la faim et les émotions se ressentent de la même manière. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 8. Je ne ressens pas les signaux de satiété de mon corps. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 9. Je ressens facilement dans mon corps comment je me porte. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 10. Je remarque quand j'ai atteint le point de satiété agréable. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 11. Même après n'avoir rien mangé depuis très longtemps, je ne ressens pas la faim. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 12. Je perçois bien quand je suis joyeux(se) | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 13. Je ne réalise pas être rassasié(e) avant d'être vraiment gavé(e). [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 14. Je ne sens pas la différence entre faim et colère. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 15. Je perçois parfaitement mes sentiments. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 16. Je remarque vite quand mon estomac se contracte sous l'effet de la faim. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 17. Je sens exactement quelle quantité j'ai mangée. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 18. Je ne sens pas la différence entre faim et tristesse. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19. Je n'ai aucun mal à identifier ma propre humeur. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 20. Je sens quand je suis rassasié(e). | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 21. Je sais bien reconnaître quand j'éprouve de la tristesse, de la colère ou de l'anxiété. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 22. Je ne sens pas la différence entre faim et nervosité. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 23. Je sais bien faire la différence entre les émotions de bonheur, de gaieté ou d'enthousiasme. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 24. Je sens quand j'ai mangé la quantité dont mon corps a effectivement besoin. | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |
| 25. Je ne ressens pas les signaux de faim émis par mon corps. [R] | Pas du tout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Tout à fait |

**Reference:**

Ortmann, J., Infanti, A., van Dyck, Z. & Vögele, C. (2024). *Multilingual Validation and Application of the Eating Disorder-specific Interoceptive Perception Questionnaire (EDIP-Q) in English-, French-, and German-speaking samples.* Manuscript under review.

# Appendix D: Instructions for Calculating Total and Subscale Scores for the EDIP-Q

### *EDIP-Q Total Score*

- Calculate the total score by averaging the scores of all items of the EDIP-Q
- $^{R}$ = Reverse Coded Items
- Formula:

$$EDIP - Q\ Total\ Score = \frac{\text{Sum of All Item Scores}}{25}$$

### *EDIP-Q Subscale Scores*

- Calculate the subscale scores for each subscale by averaging the scores of the items within that subscale.
    - Emotions: 2, 9, 12, 15, 19, 21, 23
    - Hunger: 1, 6, 11, 16, 25
    - Satiety: 4, 8, 10, 13, 17, 20, 24
    - Discrimination: 3, 5, 7, 14, 18, 22
- $^{R}$ = Reverse Coded Items
- Formula:

$$Subscale\ Score = \frac{\text{Sum of Item Scores}}{\text{Number of Items in Subscale}}$$