On the Relationship Between Body Perception and Eating Disorders in Adolescents and Young Adults

Zoé van Dyck und Annika P. C. Lutz

1 Eating Disorders

During the last decades, eating disorders have been a frequent topic in the media. Images of emaciated models and Hollywood stars have made the news and the fashion industry has been criticised for its encouragement of extreme dieting behaviours. Western societies' ideals for female and male bodies have become increasingly slender and toned over the second half of the last century (Pope et al. 1999; Spitzer et al. 1999). The media's portrayal of these ideals has often been blamed as the culprit for body dissatisfaction, extreme dieting, and disordered eating behaviour (Levine and Murnen 2009). The introduction of Western television in Fiji in the 1990s was accompanied by the appearance of eating disorder symptoms in adolescent girls (Becker 2004). Yet, the picture is more complex. Not everyone exposed to Western media develops an eating disorder; therefore, additional factors must come into play. In addition, the relentless pursuit of thinness is not the only type of disordered eating behaviour.

The Diagnostic and Statistical Manual of Mental Disorders, fifth edition (American Psychiatric Association 2013), lists three major eating disorders: anorexia nervosa (AN), bulimia nervosa (BN), and binge eating disorder (BED). Anorexia nervosa is characterised by extreme weight-reduction behaviours, leading to underweight, as well as a disturbance in the way in which one's

Z. van Dyck (✉) · A. P. C. Lutz
Department of Behavioural and Cognitive Sciences, University of Luxembourg, Esch-sur-Alzette, Luxembourg
E-Mail: zoe.vandyck@uni.lu

A. P. C. Lutz
E-Mail: annika.lutz@uni.lu

A. Heinen et al. (Hrsg.), *Wohlbefinden und Gesundheit im Jugendalter,*
https://doi.org/10.1007/978-3-658-35744-3_15

own body is perceived. Individuals with BN engage in recurrent binge eating and compensatory behaviours, e.g. self-induced vomiting. Binge eating is defined as the consumption of large amounts of food in a discrete period of time, accompanied by a perceived loss of control over eating. It is the main characteristic of BED.

Recent prevalence data show that eating disorders are relatively common among women in Europe, with AN affecting <1–4%, BN <1–2%, BED <1–4%, and 2–3% being affected by subthreshold eating disorders (Keski-Rahkonen and Mustelin 2016). Prevalence rates in men are below 1% (Keski-Rahkonen and Mustelin 2016), resulting in a scarcity of research on eating disorders in men, which poses a particular challenge for treatment. Compared to AN and BN, however, BED is more equally distributed between the sexes, with lifetime prevalence rates of 2% for men and 3.5% for women (Hudson et al. 2007). Adolescence is a critical period, as most eating disorders develop during this time of life (Smink et al. 2012). The exact prevalence of eating disorders in Luxembourg is unknown. The only source of information are the statistics on hospitalisations in Luxembourg, which include neither outpatient treatment nor treatment in specialised hospitals abroad, therefore considerably underestimating prevalence rates. The Luxembourg Ministry of Health reported a total of 42 hospitalisations for eating disorders in 2015, with 9 hospitalisations in the age range 0–14 years and 17 hospitalisations in the age range 15–19 years (Ministère de la Santé 2018).

Eating disorders are potentially life threatening. Frequent medical complications include gastrointestinal complications, cardiovascular and pulmonary complications, hormonal disturbance, and effects on the skeletal system (Mitchell and Crow 2006). As a consequence, eating disorders have some of the highest mortality rates of all mental disorders (Harris and Barraclough 1998). Compared to the general population, mortality is almost 6 times higher in individuals with AN and almost 2 times higher in individuals with BN (Smink et al. 2012). Despite the availability of effective treatment approaches, such as cognitive behaviour therapy, outcome for eating disorders remains poor, especially for AN. In a large longitudinal study in Germany, only 40% of patients with AN showed full remission 20 years after inpatient treatment (Fichter et al. 2017). Therefore, research into the mechanisms underlying these debilitating disorders is essential, to define targets for novel approaches to intervention, and eventually improve treatment outcome.

2 Body Perception

When asked about the image of our body, which we have in our mind, most of us will think about a visual image of their body. This body image has four components: cognitive, emotional, perceptual and behavioural (Cash and Green 1986; Vocks et al. 2006). The cognitive and emotional components describe how we think and feel about our own body. Negative feelings about the body and thoughts of being too fat are hallmarks of body dissatisfaction, which is a well-established risk factor for dieting and eating disorders (Jacobi et al. 2004; Stice 2002). The perceptual component encompasses the frequently replicated phenomenon that individuals with eating disorders overestimate their body size, even in an emaciated state (Cash and Deagle 1997; Sepúlveda et al. 2002; Smeets 1997). Body size overestimation, and feelings and thoughts of being too fat may lead to extreme weight-loss behaviours, such as strict fasting, excessive exercising, self-induced vomiting, or misuse of laxatives and diuretics. These in turn may facilitate the development of binge eating. Thus, body image is at the heart of cognitive-behavioural models of eating disorders (Fairburn et al. 2003).

Yet, visual information is not the only type of information, which is integrated in the brain to form the body image. The brain constantly receives information from the body's interior, a process called *interoception.* This includes information on the position of the body and its limbs in space, and the condition of muscles, tendons, and joints, (proprioception) on the one hand, and information about the state of inner organs (viscероception) on the other hand (Birbaumer and Schmidt 2006; Schandry 2003; Vaitl 1996). In eating disorders, body perception is fundamentally altered, including distortions in the visual, as well as the interoceptive components of body image.

Adolescence is a critical developmental period. The body changes from the outside, with increasing sex characteristics, as well as from the inside, with profound changes in hormonal and central-nervous functioning. In addition, pressure to conform to societal ideals increases. Researchers have hypothesized that it might be the interaction of these combined changes in adolescence, which, together with predisposing factors such as perfectionism, lead to the development of eating disorders, especially AN (Kaye et al. 2013). Therefore, it is during adolescence that alterations in the perception of the body's shape and its internal signals play a crucial role.

In the present book chapter, a model is proposed which considers interoception as a multilevel process originating in the visceral organ, where a stimulus, for example, food in the stomach, is registered by receptors, for example, mechanoceptors in the stomach wall (Vaitl 1996). The receptor generates a signal, which is transmitted to the central nervous system. There, the signal is registered and made available for further processing. The intensity with which the visceral signal is processed in the brain can be assessed with electroencephalography (Schandry et al. 1986). Neuroimaging studies have identified several brain regions implicated in interoceptive processing. In this context, the insular cortex plays a major role (Craig 2002; Critchley et al. 2004; Pollatos et al. 2005).

Further processing of the visceral signal includes homeostatic processes occurring outside of conscious awareness, as well as conscious processes. For example, the sensation of stomach fullness triggers the release of hormones (outside of conscious awareness), and generates a sensation of satiety, which is accessible to conscious perception. The ultimate purpose of interoception is to maintain homeostatic balance, that is, to respond to internal and external stimuli in a way that maintains optimal physiological conditions. Therefore, after processing of the interoceptive signal, processes of homeostatic regulation are initiated in the brain, if required. These include non-conscious physiological processes, but also behavioural responses. For example, during meal consumption, the stretching of the stomach walls and the secretion of certain hormones is registered and eventually leads to meal termination. The motivational state generating this behaviour may be consciously perceived as satiety, but this is not necessary for the behaviour to be performed. Disordered eating behaviours may be seen as an attempt at homeostatic regulation in the short term, but which causes disruptions in interoceptive processing in the long term. For example, repeated binge eating may distend stomach walls, and alternating binge eating and vomiting causes cardio-vascular abnormalities due to electrolyte imbalance (Mitchell and Crow 2006). Thereby, the input into the interoceptive system is altered over the course of the disorder.

In summary, we construe interoceptive processing in eating disorders as a circular multilevel model, in which the visceral signal is processed in the brain (with or without conscious perception), and causes behaviours intended to maintain homeostatic balance, but causing visceral alterations and thereby disrupting interoceptive processing. For example, in an individual with BN, an elevated heartrate may be interpreted in terms of an unbearable emotion, such as anxiety. This emotion is downregulated through binge eating. Binge eating leads to uncomfortable sensations of stomach fullness and feelings of guilt. These are

downregulated through self-induced vomiting. In the long term, the dysfunctional emotion regulation behaviours "binge eating and vomiting" lead to gastric and cardiac abnormalities, which cause abnormal sensations, which, in turn, maintain disordered eating behaviour. As an example, distended stomach walls lead to a delayed perception of satiety and thereby facilitate the ingestion of large amounts of food during binge eating.

In consequence, it is necessary to assess interoceptive processing at various levels in eating disorders, that is, the visceral organ, central nervous system representation, conscious perception, motivational interpretation, and dysfunctional regulatory behaviours. In addition, different organ systems, such as the heart and the stomach, need to be taken into account. Our model calls for a more complex investigation of interoception in eating disorders and challenges the assumption of a general interoceptive deficit (Bruch 1962; Klabunde et al. 2017). In the following, we will review the extant literature on body perception, including (visual) body image and interoception, in AN, BN, and BED, while adopting a multilevel perspective.

3 Anorexia Nervosa—Body Image, Interoception, and Multi-sensory Integration

Anorexia nervosa (AN) is an eating disorder characterised by extreme weight-reduction behaviours, leading to underweight, as well as a disturbance in the way in which one's own body is perceived (American Psychiatric Association 2013). Recent epidemiological data show that 0.8% of adolescents and young adults in Germany have suffered from AN at some point (Nagl et al. 2016). Despite these low numbers, AN is associated with severe medical complications, e.g. cardiovascular problems, osteoporosis, alterations in linear growth, and structural and functional brain abnormalities (Katzman 2005). There is still insufficient evidence as to how medical complications during the critical developmental period of adolescence affect health and well-being later in life (Katzman 2005). Moreover, a recent study assessing outcome of AN 20 years after inpatient treatment reported that mortality was increased more than fivefold compared to people of similar age and sex from the general population (Fichter and Quadflieg 2016).

Cognitive behavioural models of AN describe a vicious cycle, in which dietary restriction is maintained through an enhanced experience of control over eating, weight and shape (Fairburn et al. 1999). Experimental research has shown that already in pre-adolescent girls (aged 11–12 years) watching thin-ideal

focused television shows (e.g. shows about fashion models) increases the body dissatisfaction and makes them desire a thinner body (Anschutz et al. 2011). Indeed, thin-ideal media images have often been blamed as being responsible for body image dissatisfaction and AN, but the relationship is not as direct as one might be tempted to think (Levine and Murnen 2009). Thin-ideal media exposure only leads to body dissatisfaction, if the media ideal is adopted as one's personal ideal and if a discrepancy between the actual and the ideal body shape is detected (Dittmar et al. 2009). Body dissatisfaction, in turn, is only one of many established risk factors for AN. Additional factors take effect throughout the life span, including genetic factors, pregnancy and birth problems, feeding and gastro-intestinal problems in early childhood, adverse life events, and perfectionism, to name only a few examples, culminating in the development of eating disorder symptoms during adolescence (Jacobi et al. 2004). In the light of these findings, recent numbers of body dissatisfaction in Luxembourgish adolescents give rise to concern. The 2013/2014 Health Behaviour in School-Aged Children survey (World Health Organization 2016) reported that among 15-year-old girls, 56% perceived themselves as being too fat and 29% engaged in weight-reduction behaviours. Only 15% were actually overweight or obese. Although these girls are by no means predetermined to develop AN, they are certainly at risk.

Body dissatisfaction reflects the cognitive-affective level of body image disturbance in AN (Gleaves et al. 1995). On the behavioural level, excessive weight-loss behaviours, such as strict fasting, are prominent. Another aspect, which has drawn a lot of attention in the literature, is that individuals with AN, who are underweight by definition, significantly overestimate their body dimensions (Cash and Deagle 1997). This is a striking symptom and accompanied by alterations in other aspects of body perception, namely interoception (Lutz et al. 2019). The presence of body image disturbance is a negative prognostic factor for treatment outcome (Garfinkel et al. 1977; Slade and Russell 1973), which is why research on this aspect of AN is especially important.

In our own research (Lutz et al. 2019), we were able to show that body perception is not necessarily reduced on all levels, as suggested by early theories of AN (Bruch 1962). Previous studies confirming interoceptive deficits focused mainly on the conscious perception of cardiac signals (Pollatos et al. 2008, 2016). We investigated interoception of cardiac signals in young women (mean age 25 years) from Luxembourg and inpatients with AN, based on our multilevel model of interoception in eating disorders. On a first level, we found no group

differences regarding heart rate and its variability, suggesting the signals arriving in the brain were similar in both groups. On a second level, we investigated how this information from the heart is processed in the brain. To this end, we analysed brain potentials, which occur around 500 ms after the heartbeat (as indexed by the R-peak of the electrocardiogram). These heartbeat-evoked potentials reflect brain processing of cardiac information on a pre-conscious level, i.e. they are visible even when the individual is not actively directing their attention to the heartbeat (Schandry et al. 1986). On this level, we found enhanced processing of heartbeats in the brain. When looking at conscious perception of heartbeats (third level), we found no difference between individuals with or without AN in how well they were able to count their own heartbeats or how they judged their own heartbeat-counting performance. Moving to the fourth level of interpretation of body sensations, individuals with AN reported increased problems with the perception of emotions and other body sensations, as assessed via questionnaire. This clearly shows that prominent symptoms of AN, such as difficulties perceiving and interpreting emotions, are not necessarily based on reduced interoception. Instead, our study showed that some aspects of interoception may be unaltered or even enhanced in AN. This supports our notion that different levels need to be distinguished when assessing interoception in eating disorders.

Other studies showed increased interoceptive processing in AN during meal and food stimulus anticipation (Khalsa et al. 2015; Oberndorfer et al. 2013). Meals are inherently aversive events for individuals with AN and this aversiveness could be, at least partially, maintained by increased interoception, that is, a stronger experience of the uncomfortable sensations around eating. This would explain why fasting, rather than eating, would have a positive connotation and serve as a reward in individuals with AN (Kaye et al. 2013). In conclusion, increased interoceptive processing, rather than interoceptive deficits, may be present in AN at least at some levels (central nervous system representation). The strict fasting behaviour, which is characteristic of the disorder, might help to reduce aversive body sensations, which are amplified by distorted interoceptive processing (Kaye et al. 2013). These alterations might play a particularly important role during adolescence, as during this developmental period the balance between prefrontal and limbic brain structures changes. This makes adolescents sensitive to disruptions in the balance between controlled and intuitively motivated behaviours (Kaye et al. 2013). In that sense, altered interoceptive processing might contribute to the need for cognitive control over eating behaviour, to compensate for distorted intuitive processes.

4 Interoceptive Processes in Bulimia Nervosa and Binge-Eating Disorder

As mentioned above, BN and BED are both characterised by recurrent episodes of binge eating, referring 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 2013). These episodes have been termed objective bulimic episodes (Fairburn and Cooper 1993). While BN is marked by the oscillation between objective bulimic episodes and compensatory behavior to prevent weight gain (e.g., vomiting), along with an undue influence of shape on self-evaluation, BED entails recurrent binge eating in the absence of such compensatory behaviors (American Psychiatric Association 2013). Hence, it is little surprising that BED is strongly related to obesity (Dingemans et al. 2002), and that the prevalence of BED is high among individuals who seek weight control treatment (up to 30%; de Zwaan 2001). Furthermore, obese individuals with regular binge eating episodes seem to be especially at risk for further weight gain (Yanovski 2002). With 26% of the adult population in Luxembourg being obese (World Health Organization 2018), and a recent increase in the proportion of overweight or obese adolescents (Heinz et al. 2020), a better understanding of the factors underlying binge eating is important when aiming to tackle the obesity epidemic.

Binge eating behaviours are not solely found in clinical populations, but are also very common in the general population. Recent prevalence rates suggest that worldwide more than 20% of adolescents report binge eating episodes, with even higher rates among overweight and obese youth (He et al. 2017; Van Malderen et al. 2019). Similarly, Goossens et al. (2009) found that nearly 17% of adolescents from a community sample had experienced at least one episode of loss of control over eating during the past month. Loss of control over eating, referring to an inability to stop eating once eating has started, irrespective of the amount of food consumed, can be considered the hallmark feature of binge eating (e.g., Colles et al. 2008). Research has shown that loss of control over eating is common among youth in the general population and can be a precursor to eating disorders and other psychiatric disorders (e.g., addiction, depression) (Herpertz-Dahlmann et al. 2015).

Several lines of research have suggested that interoceptive processes play an important role in the development and maintenance of binge eating behaviours (Simmons and DeVille 2017). Altered interoception has been repeatedly associated with overeating, especially with respect to the perception of hunger

and satiety and emotion processing. To date, interoceptive processes in eating disorders have primarily been investigated in relation to the awareness of emotional states. Using self-report questionnaires, a substantial body of research has provided evidence that interoceptive sensibility is reduced in individuals engaging in uncontrollable overeating and that these impairments persist even after recovery (for a meta-analysis, see Jenkinson et al. 2018).

Besides self-report measures, behavioural measures have been used to investigate conscious interoceptive accuracy, most of which have focused on people's ability to perceive their own heartbeats (Brener and Kluvitse 1988; Critchley et al. 2004; Schandry 1981; Whitehead et al. 1977). The predominant focus on cardiac interoceptive accuracy is largely due to pragmatic reasons: Heartbeats are distinct and frequent internal events that can be easily discriminated and measured (Garfinkel et al. 2015). These so-called heartbeat perception tasks are well-validated measures, as evidenced by relationships between cardiac interoceptive accuracy and activation in brain structures responsible for the mapping of internal bodily responses, in particular the right anterior insula, and the somatomotor and cingulate cortices (Critchley et al. 2004). While research on cardiac interoceptive accuracy in BED remains scarce, studies on participants with BN show either attenuated interoceptive abilities compared to healthy controls (Klabunde et al. 2013) or no differences (Eshkevari et al. 2014; Pollatos and Georgiou 2016).

This inconsistent evidence raises doubts about the use of measures of cardiac interoception as a proxy for interoception in general, which do not directly address a core aspect of interoceptive deficits in eating disorders, i.e. impaired perception of hunger and satiety cues. A major objective of our working group in recent years has therefore been the development and validation of adequate measures to assess interoceptive processes in eating disorders at multiple levels, based on our model introduced earlier. To do so, we focus on the processing of interoceptive information from two organ systems that are particularly relevant to eating behaviours, that is, the heart and the stomach. Altered processing of cardiovascular activity, as measured by heartbeat perception tasks, has frequently been linked to disturbances in cognitive and emotional processes (e.g., Craig 2009). Difficulties in the processing and regulation of emotions have also been documented in BN and BED (e.g., Harrison et al. 2010), suggesting that interoceptive deficits are indirectly linked to eating disorder symptomatology. Another organ system of relevance for eating behaviours is the gastric system, which might contribute to eating disorder symptoms via altered processing of hunger and satiety cues (Klabunde et al. 2017).

In the self-report domain, our research group has developed a multidimensional questionnaire to assess eating disorder-specific interoceptive processes in terms of the ability to perceive emotions, hunger and satiety, and to discriminate between those signals (van Dyck et al. 2017). First results using the eating disorder-specific interoceptive processes-questionnaire (EDIP-Q) are promising and show alterations on all four dimensions in individuals with an eating disorder diagnosis (van Dyck et al. 2017). More importantly, the EDIP-Q subscales were affected to a varying extent and in different directions among eating disorder types, suggesting that the processing of emotions, hunger, and satiety might be of differential relevance in different eating disorder diagnoses. More precisely, participants with BN or BED reported more difficulties perceiving satiety cues and differentiating between hunger and emotional states compared to AN and healthy controls. This finding is in line with the idea that individuals with BN or BED use binge eating as a (dysfunctional) emotion regulation strategy.

With the aim of developing a behavioural measure of interoceptive processing in the gastric system, we developed a water load test as a provocative test of gastric distention (van Dyck et al. 2016). Gastric distention during intake activates vagal and spinal mechanosensitive afferents, which transmit signals from the stomach to the brain and lead to the perception of satiation and fullness (Hellström et al. 2004). Reduced sensitivity to these signals may result in excessive food intake (Wang et al. 2008), a core feature of binge eating. Laboratory studies have shown that patients with BN or BED eat larger meals compared to controls, even under controlled circumstances (Kissileff et al. 1996). Furthermore, patients require much larger amounts of food than healthy control participants to reach similar levels of fullness (Walsh et al. 2003). These findings suggest that individuals with BN or BED process the information on gastric distention differently, which may contribute to altered sensations and physiological and behavioral responses.

Water load test protocols were initially developed to assess gastric sensation and accommodation in patients with functional digestive disorders and, therefore, needed some adaptations to measure sensitivity for eating-related sensations. We developed the water load test-II as a two-step drink test measuring the perception of eating-related satiation, in addition to the experience of maximum stomach fullness. Initial results in a non-clinical sample in Luxembourg suggest that the water load test-II is a simple, reliable test that distinguishes well between sensations of comfortable satiation and unpleasant fullness (van Dyck et al. 2016). Importantly, water volume ingested until satiation was related to bulimic

symptoms, suggesting that the development of satiation is altered in individuals who engage in binge eating. Using the water load test-II in combination with psychophysiological methods, we further found that individuals with BN or BED show a delayed response to satiation, together with abnormal gastric motility, as assessed via electrogastrography (van Dyck et al. 2020). Applying the multilevel model of interoception, gastric motility corresponds to the most basic level of gastric interoception, which refers to the rate of stomach contractions and is a central mediator of hunger and satiety (Janssen et al. 2011). Furthermore, we were able to show that the degree of normal gastric activity decreased with the number of binge eating episodes per week in the patient group, suggesting that there is a systematic relationship between the severity of the eating disorder and the extent of disturbances to gastric motor function (van Dyck et al. 2020).

5 Treatment of Interoceptive Deficits

Several implications for the treatment of eating disorders might follow from findings on interoceptive abnormalities, and interventions can occur at each level of our model. One of the best-validated treatment approaches for eating disorders is cognitive behaviour therapy (Linardon et al. 2017). This type of psychotherapy typically focuses on the normalisation of eating behaviour and the treatment of body image disturbance. Interventions targeting eating behaviour usually address maladaptive dieting patterns, such as limiting calorie intake, leaving excessive time between meals, and avoiding "forbidden foods" (Fairburn et al. 1993; Hilbert and Tuschen-Caffier 2010). A pattern of regular eating is established, which patients are required to follow until their hunger and satiety signals are re-established. This pattern of eating also aims at preventing binge eating (Latner and Wilson 2000).

When treating young patients who are living with their family of origin, it is essential to include parents or guardians in the therapeutic process and to build up a solid therapeutic relationship with both the child/adolescent and the parents (Herpertz et al. 2011). Parents can help the young patients to realize the need for treatment and ensure that the treatment is arranged and carried out. For this reason, they should be provided comprehensive information about the eating disorder and the required treatment. Furthermore, it is important to support the emotional functioning of parents in order to strengthen their ability to support their child most effectively during treatment.

Another line of interventions is derived from awareness and mindfulness-based trainings, trying to improve the patients' ability to regulate eating through heightened responsivity to internal hunger and satiety cues. However, although mindfulness-based interventions have become increasingly popular in the treatment of eating disorders (e.g., Dunne 2018), they only target some aspects of interoceptive processing (Khalsa et al. 2008).

Using biofeedback of electrogastrographic activity, Stern and colleagues showed that normal gastric myoelectrical activity can be increased in healthy individuals (Stern et al. 2004). Normal gastric myoelectrical activity corresponds to three cycles per minute and is associated with normal gastric function (Koch and Stern 2004). Hence, electrogastrographic biofeedback constitutes a promising and noninvasive intervention to improve individuals' awareness of their stomach activity and enhance gastric interoceptive processing at the most basic level (the visceral organ).

The visual aspect of body image can be altered, as well (Farrell et al. 2006), and its improvement constitutes a key factor for remission (Key et al. 2002; Vall and Wade 2015). Yet, visual information on the body's state is not processed in isolation, but integrated with interoceptive information. This is termed multisensory integration (Badoud and Tsakiris 2017). Interventions based on multisensory integration are still in the experimental phase, but show promising results. One technique, for example, uses virtual reality to integrate visual information (showing the exterior of the body) and tactile information (a sensation of touch). This technique reduces body size overestimation in AN (Keizer et al. 2016). A current project at the University of Luxembourg expands this line of research, by investigating how the addition of interoceptive (heartbeat-related) information may help to improve body image. This work is essential to improve the poor long-term outcome of AN (Fichter et al. 2017) and support clinicians and patients in Luxembourg and worldwide. As these interventions are performed in virtual reality environments, they might appear particularly appealing to adolescents. Yet, it is important to keep in mind that evidence exists that interoceptive deficits persist even after recovery from an eating disorder (Jenkinson et al. 2018; Klabunde et al. 2013). This raises the question to what extent interoceptive processes are traits that cannot be changed. Further research is needed to investigate whether alterations on interoceptive levels in the cardiac or gastric system can be modified in eating disordered patients. Moreover, we are unaware of any research investigating the long-term consequences of disruptions in interoceptive functioning during the developmentally critical period of adolescence.

6 Summary and Conclusion

In this book chapter, we presented a selective review of the role of body perception in eating disorders, with a special focus on research performed in Luxembourg. We conclude that the visual aspect of the body is perceived in a distorted and negative way in all eating disorders. The picture is much more complex when looking at the perception of signals from within the body. Therefore, we adopted a multilevel perspective on interoception, taking into account different organ systems (e.g. heart, stomach), different levels of processing (visceral organ, central nervous system representation, conscious processing, interpretation, behaviour), and their interactions. Regarding AN, we found that processing on the different levels diverges, and that processing on some levels may even be enhanced (central nervous system representation). Enhanced processing of interoceptive signals in the central nervous system, especially around meals, may directly promote fasting behaviour, as it increases the discomfort associated with eating in these individuals.

Concerning eating disorders in which binge eating is a central feature (BN and BED), we showed that interoceptive deficits exist on different levels (visceral organ, conscious processing, and behaviour) and in both the cardiac and the gastric domains. Studies investigating different levels of interoceptive processing concomitantly within the same sample of eating disordered patients are scarce, which is a gap we are currently attempting to fill in our research at the University of Luxembourg. Furthermore, additional studies are needed to examine the unique associations of binge eating, purging, and prolonged episodes of dietary restriction with interoceptive processes at multiple levels and in different organ systems.

Research on interoception has gained popularity only recently and we are just beginning to understand the complexity of interoceptive alterations in eating disorders. Yet, this area of research opens up several avenues for potential interventions, which are expected to improve current treatment programmes for eating disorders in the future. Regarding adolescents and young adults, research on the relationship between eating disorder symptoms and interoceptive processes is scarce. Few studies have investigated the development of interoceptive ability during youth and throughout the lifespan, and available evidence suggests that interoceptive perception changes with development (Failla et al. 2020). It is, however, not yet known how these age-related interoceptive changes may contribute to the development of healthy or disordered eating behaviours. Yet, it seems likely that they constitute one of the bio-psycho-social changes associated

with adolescence, which play a crucial role in the development of eating disorders (Kaye et al. 2013). Eating-disorder research is especially important in Luxembourg, where little is known about the prevalence of eating disorders or about factors contributing to their development.

References

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). American Psychiatric Publishing.

Anschutz, D. J., Spruijt-Metz, D., Van Strien, T., & Engels, R. C. M. E. (2011). The direct effect of thin ideal focused adult television on young girls' ideal body figure. *Body Image*, *8*(1), 26–33. https://doi.org/10.1016/j.bodyim.2010.11.003

Badoud, D., & Tsakiris, M. (2017). From the body's viscera to the body's image: Is there a link between interoception and body image concerns? *Neuroscience and Biobehavioral Reviews*, *77*(April), 237–246. https://doi.org/10.1016/j.neubiorev.2017.03.017

Becker, A. E. (2004). Television, Disordered Eating, and Young Women in Fiji: Negotiating Body Image and Identity during Rapid Social Change. *Culture, Medicine and Psychiatry*, *28*(4), 533–559. https://doi.org/10.1007/s11013-004-1067-5

Birbaumer, N., & Schmidt, R. F. (2006). *Biologische Psychologie* (6th ed.). Springer Medizin Verlag.

Brener, J., & Kluvitse, C. (1988). Heartbeat detection: Judgments of the simultaneity of external stimuli and heartbeats. *Psychophysiology*, *25*(5), 554–561.

Bruch, H. (1962). Perceptual and conceptual disturbances in anorexia nervosa. *Psychosomatic Medicine*, *24*(2), 187–194.

Cash, T. F., & Deagle, E. A. (1997). The nature and extent of body-image disturbances in anorexia nervosa and bulimia nervosa: A meta-analysis. *International Journal of Eating Disorders*, *22*, 107–125.

Cash, T. F., & Green, G. K. (1986). Body weight and body image among college women: Perception, cognition, and affect. *Journal of Personality Assessment*, *50*(2), 290–301.

Colles, S. L., Dixon, J. B., & O'Brien, P. E. (2008). Loss of control is central to psychological disturbance associated with binge eating disorder. *Obesity*, *16*(3), 608–614. https://doi.org/10.1038/oby.2007.99

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews. Neuroscience*, *3*(8), 655–666. https://doi.org/10.1038/nrn894

Craig, A. D. (2009). How do you feel — now? The anterior insula and human awareness. *Nature Reviews Neuroscience*, *10*(1), 59–70. https://doi.org/10.1038/nrn2555

Critchley, H. D., Wiens, S., Rotshtein, P., Ohman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience*, *7*(2), 189–195. https://doi.org/10.1038/nn1176

de Zwaan, M. (2001). Binge eating disorder and obesity. *International Journal of Obesity and Related Metabolic Disorders: Journal of the International Association for the Study of Obesity*, *25*(1), 51–55. https://doi.org/10.1038/sj.ijo.0801699

Dingemans, A. E., Bruna, M. J., & Van Furth, E. F. (2002). Binge eating disorder: A review. *Internation Journal of Obesity*, *26*(3), 299–307.

Dittmar, H., Halliwell, E., & Stirling, E. (2009). Understanding the impact of thin media models on women's body-focused affect: the roles of thin-ideal internalization and weight-related self-discrepancy activation in experimental exposure effects. *Journal of Social and Clinical Psychology*, *28*(1), 43–72. https://doi.org/10.1521/jscp.2009.28.1.43

Dunne, J. (2018). Mindfulness in Anorexia Nervosa: An Integrated Review of the Literature. *Journal of the American Psychiatric Nurses Association*, *24*(2), 109–117. https://doi.org/10.1177/1078390317711250

Eshkevari, E., Rieger, E., Musiat, P., & Treasure, J. (2014). An investigation of interoceptive sensitivity in eating disorders using a heartbeat detection task and a self-report measure. *European Eating Disorders Review*, *22*(5), 383–388. https://doi.org/10.1002/erv.2305

Failla, M. D., Bryant, L. K., Heflin, B. H., Mash, L. E., Schauder, K., Davis, S., Gerdes, M. B., Weitlauf, A., Rogers, B. P., & Cascio, C. J. (2020). Neural Correlates of Cardiac Interoceptive Focus Across Development: Implications for Social Symptoms in Autism Spectrum Disorder. *Autism Research*, *13*(6), 908–920. https://doi.org/10.1002/aur.2289

Fairburn, C. G., & Cooper, Z. (1993). The eating disorder examination. In C. G. Fairburn & G. T. Wilson (Eds.), *Binge eating: Nature, assessment, and treatment* (12th ed., pp. 317–360). Guilford Press.

Fairburn, C. G., Cooper, Z., & Shafran, R. (2003). Cognitive behaviour therapy for eating disorders: a "transdiagnostic" theory and treatment. *Behaviour Research and Therapy*, *41*(5), 509–528. https://doi.org/10.1016/S0005-7967(02)00088-8

Fairburn, C. G., Marcus, M. D., & Wilson, G. T. (1993). Cognitive-behavioral therapy for binge eating and bulimia nervosa: A comprehensive treatment manual. In C. G. Fairburn & G. T. Wilson (Eds.), *Binge eating. Nature, assessment, and treatment* (pp. 361–404). Guilford Press.

Fairburn, C. G., Shafran, R., & Cooper, Z. (1999). A cognitive behavioural theory of anorexia nervosa. *Behaviour Research and Therapy*, *37*, 1–13.

Farrell, C., Shafran, R., & Lee, M. (2006). Empirically evaluated treatments for body image disturbance: A review. *European Eating Disorders Review*, *14*(5), 289–300. https://doi.org/10.1002/erv.693

Fichter, M. M., & Quadflieg, N. (2016). Mortality in eating disorders – Results of a large prospective clinical longitudinal study. *International Journal of Eating Disorders*, *49*(4), 391–401. https://doi.org/10.1002/eat.22501

Fichter, M. M., Quadflieg, N., Crosby, R. D., & Koch, S. (2017). Long-term outcome of anorexia nervosa: Results from a large clinical longitudinal study. *International Journal of Eating Disorders*, *50*(9), 1018–1030. https://doi.org/10.1002/eat.22736

Garfinkel, P. E., Moldofsky, H., & Garner, D. M. (1977). Prognosis in anorexia nervosa as influenced by clinical features, treatment and self-perception. *Canadian Medical Association Journal*, *117*(9), 1041–1045. http://www.ncbi.nlm.nih.gov/pubmed/912628

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: Distinguishing interoceptive accuracy from interoceptive awareness. *Biological Psychology*, *104*, 65–74. https://doi.org/10.1016/j.biopsycho.2014.11.004

Gleaves, D., Williamson, D., Eberenz, K., Sebastian, S., & Barker, S. (1995). Clarifying body-image disturbance: Analysis of a multidimensional model using structural modeling. *Journal of Personality Assessment*, *64*(3), 478–493.

Goossens, L., Soenens, B., & Braet, C. (2009). Prevalence and characteristics of binge eating in an adolescent community sample. *Journal of Clinical Child and Adolescent Psychology*, *38*(3), 342–353. https://doi.org/10.1080/15374410902851697

Harris, E., & Barraclough, B. (1998). Excess mortality of mental disorder. *British Journal of Psychiatry*, *173*, 11–53.

Harrison, A., Sullivan, S., Tchanturia, K., & Treasure, J. (2010). Emotional functioning in eating disorders: attentional bias, emotion recognition and emotion regulation. *Psychological Medicine*, *40*(11), 1887–1897. https://doi.org/10.1017/S0033291710000036

He, J., Cai, Z., & Fan, X. (2017). Prevalence of binge and loss of control eating among children and adolescents with overweight and obesity: An exploratory meta-analysis. *International Journal of Eating Disorders*, *50*(2), 91–103. https://doi.org/10.1002/eat.22661

Heinz, A., van Duin, C., Kern, M. R., Catunda, C., & Willems, H. (2020). *Trends from 2006–2018 in Health Behaviour, Health Outcomes and Social Context of Adolescents in Luxembourg*. University of Luxembourg.

Hellström, P. M., Geliebter, A., Näslund, E., Schmidt, P. T., Yahav, E. K., Hashim, S. A., & Yeomans, M. R. (2004). Peripheral and central signals in the control of eating in normal, obese and binge-eating human subjects. *British Journal of Nutrition*, *92*(S1), 47–57. https://doi.org/10.1079/BJN20041142

Herpertz-Dahlmann, B., Dempfle, A., Konrad, K., Klasen, F., & Ravens-Sieberer, U. (2015). Eating disorder symptoms do not just disappear: the implications of adolescent eating-disordered behaviour for body weight and mental health in young adulthood. *European Child and Adolescent Psychiatry*, *24*(6), 675–684. https://doi.org/10.1007/s00787-014-0610-3

Herpertz, S., Hagenah, U., Vocks, S., Wietersheim, J. von, Cuntz, U., & Zeeck, A. (2011). The Diagnosis and Treatment of Eating Disorders. *Deutsches Aerzteblatt Online*, *108*(40), 678–685. https://doi.org/10.3238/arztebl.2011.0678

Hilbert, A., & Tuschen-Caffier, B. (2010). *Essanfälle und Adipositas*. Hogrefe.

Hudson, J. I., Hiripi, E., Pope, H. G., & Kessler, R. C. (2007). The prevalence and correlates of eating disorders in the National Comorbidity Survey Replication. *Biological Psychiatry*, *61*(3), 348–358. https://doi.org/10.1016/j.biopsych.2006.03.040

Jacobi, C., Hayward, C., de Zwaan, M., Kraemer, H. C., & Agras, W. S. (2004). Coming to Terms With Risk Factors for Eating Disorders: Application of Risk Terminology and Suggestions for a General Taxonomy. *Psychological Bulletin*, *130*(1), 19–65. https://doi.org/10.1037/0033-2909.130.1.19

Janssen, P., Vanden Berghe, P., Verschueren, S., Lehmann, A., Depoortere, I., & Tack, J. (2011). Review article: The role of gastric motility in the control of food intake. *Alimentary Pharmacology & Therapeutics*, *33*(8), 880–894. https://doi.org/10.1111/j.1365-2036.2011.04609.x

Jenkinson, P. M., Taylor, L., & Laws, K. R. (2018). Self-reported interoceptive deficits in eating disorders: A meta-analysis of studies using the eating disorder inventory. *Journal of Psychosomatic Research*, *110*(November 2017), 38–45. https://doi.org/10.1016/j.jpsychores.2018.04.005

Katzman, D. K. (2005). Medical complications in adolescents with anorexia nervosa: A review of the literature. *International Journal of Eating Disorders*, *37*, S52–S59. https://doi.org/10.1002/eat.20118

Kaye, W. H., Wierenga, C. E., Bailer, U. F., Simmons, A. N., & Bischoff-Grethe, A. (2013). Nothing tastes as good as skinny feels: The neurobiology of anorexia nervosa. *Trends in Neurosciences*, *36*(2), 110–120. https://doi.org/10.1016/j.tins.2013.01.003

Keizer, A., Van Elburg, A., Helms, R., & Dijkerman, H. C. (2016). A virtual reality full body illusion improves body image disturbance in anorexia nervosa. *PLoS ONE*, *11*(10), 1–21. https://doi.org/10.1371/journal.pone.0163921

Keski-Rahkonen, A., & Mustelin, L. (2016). Epidemiology of eating disorders in Europe. *Current Opinion in Psychiatry*, *29*(6), 340–345. https://doi.org/10.1097/YCO.0000000000000278

Key, A., George, C. L., Beattie, D., Stammers, K., Lacey, H., & Waller, G. (2002). Body image treatment within an inpatient program for anorexia nervosa: The role of mirror exposure in the desensitization process. *International Journal of Eating Disorders*, *31*(2), 185–190.

Khalsa, S. S., Craske, M. G., Li, W., Vangala, S., Strober, M., & Feusner, J. D. (2015). Altered interoceptive awareness in anorexia nervosa: Effects of meal anticipation, consumption and bodily arousal. *International Journal of Eating Disorders*, *1 mL*, n/a-n/a. https://doi.org/10.1002/eat.22387

Khalsa, S. S., Rudrauf, D., Damasio, A. R., Davidson, R. J., Lutz, A., & Tranel, D. (2008). Interoceptive awareness in experienced meditators. *Psychophysiology*, *45*(4), 671–677. https://doi.org/10.1111/j.1469-8986.2008.00666.x

Kissileff, H. R., Wentzlaff, T. H., Guss, J. L., Walsh, B. T., Devlin, M. J., & Thornton, J. C. (1996). A direct measure of satiety disturbance in patients with bulimia nervosa. *Physiology and Behavior*, *60*(4), 1077–1085. https://doi.org/10.1016/0031-9384(96)00086-8

Klabunde, M., Acheson, D. T., Boutelle, K. N., Matthews, S. C., & Kaye, W. H. (2013). Interoceptive sensitivity deficits in women recovered from bulimia nervosa. *Eating Behaviors*, *14*(4), 488–492. https://doi.org/10.1016/j.eatbeh.2013.08.002

Klabunde, M., Collado, D., & Bohon, C. (2017). An interoceptive model of bulimia nervosa: A neurobiological systematic review. *Journal of Psychiatric Research*, *94*, 36–46. https://doi.org/10.1016/j.jpsychires.2017.06.009

Koch, K. L., & Stern, R. M. (2004). *Handbook of electrogastrography*. Oxford University Press.

Latner, J. D., & Wilson, G. T. (2000). Cognitive-behavioral therapy and nutritional counseling in the treatment of bulimia nervosa and binge eating. *Eating Behaviors*, *1*(1), 3–21. https://doi.org/10.1016/S1471-0153(00)00008-8

Levine, M. P., & Murnen, S. K. (2009). "Everybody knows that mass media are/are not [pick one] a cause of eating disorders": A critical review of evidence for a causal link between media, negative body image, and disordered eating in females. *Journal of Social and Clinical Psychology*, *28*(1), 9–42. https://doi.org/10.1521/jscp.2009.28.1.9

Linardon, J., Wade, T. D., De La Piedad Garcia, X., & Brennan, L. (2017). The efficacy of cognitive-behavioral therapy for eating disorders: A systematic review and meta-analysis. *Journal of Consulting and Clinical Psychology*, *85*(11), 1080–1094. https://doi.org/10.1037/ccp0000245

Lutz, A. P. C., Schulz, A., Voderholzer, U., Koch, S., van Dyck, Z., & Vögele, C. (2019). Enhanced cortical processing of cardio-afferent signals in anorexia nervosa. *Clinical Neurophysiology*, *130*(9), 1620–1627. https://doi.org/10.1016/j.clinph.2019.06.009

Ministère de la Santé, . (2018). *Carte sanitaire – mise a jour 2017. Grand-Duché de Luxembourg. Fascicule 2: Motifs de recours à l'hospitalisation selon la classification internationale des maladies (ICD 10)*.

Mitchell, J. E., & Crow, S. (2006). Medical complications of anorexia nervosa and bulimia nervosa. *Current Opinion in Psychiatry*, *19*(4), 438–443. https://doi.org/10.1097/01.yco.0000228768.79097.3e

Nagl, M., Jacobi, C., Paul, M., Beesdo-Baum, K., Höfler, M., Lieb, R., & Wittchen, H. U. (2016). Prevalence, incidence, and natural course of anorexia and bulimia nervosa among adolescents and young adults. *European Child and Adolescent Psychiatry*, *25*(8), 903–918. https://doi.org/10.1007/s00787-015-0808-z

Oberndorfer, T., Simmons, A., McCurdy, D., Strigo, I., Matthews, S., Yang, T., Irvine, Z., & Kaye, W. (2013). Greater anterior insula activation during anticipation of food images in women recovered from anorexia nervosa versus controls. *Psychiatry Research*, *214*(2), 132–141. https://doi.org/10.1016/j.pscychresns.2013.06.010

Pollatos, O., & Georgiou, E. (2016). Normal interoceptive accuracy in women with bulimia nervosa. *Psychiatry Research*, *240*, 328–332. https://doi.org/10.1016/j.psychres.2016.04.072

Pollatos, O., Herbert, B. M., Berberich, G., Zaudig, M., Krauseneck, T., & Tsakiris, M. (2016). Atypical self-focus effect on interoceptive accuracy in anorexia nervosa. *Frontiers in Human Neuroscience*, *10*(484). https://doi.org/10.3389/fnhum.2016.00484

Pollatos, O., Kirsch, W., & Schandry, R. (2005). Brain structures involved in interoceptive awareness and cardioafferent signal processing: A dipole source localization study. *Human Brain Mapping*, *26*(1), 54–64. https://doi.org/10.1002/hbm.20121

Pollatos, O., Kurz, A.-L., Albrecht, J., Schreder, T., Kleemann, A. M., Schöpf, V., Kopietz, R., Wiesmann, M., & Schandry, R. (2008). Reduced perception of bodily signals in anorexia nervosa. *Eating Behaviors*, *9*(4), 381–388. https://doi.org/10.1016/j.eatbeh.2008.02.001

Pope, H. G., Olivardia, R., Gruber, A., & Borowiecki, J. (1999). Evolving ideals of male body image as seen through action toys. *The International Journal of Eating Disorders*, *26*(1), 65–72.

Schandry, R. (1981). Heart beat perception and emotional experience. *Psychophysiology*, *18*(4), 483–488. http://www.ncbi.nlm.nih.gov/pubmed/7267933

Schandry, R. (2003). *Biologische Psychologie* (1st ed.). Beltz Verlage.

Schandry, R., Sparrer, B., & Weitkunat, R. (1986). From the heart to the brain: Study of heartbeat contingent scalp potentials. *International Journal of Neuroscience*, *30*, 261–275. https://doi.org/10.3109/00207458608985677

Sepúlveda, A. R., Botella, J., & León, J. A. (2002). Body-image disturbance in eating disorders: A meta-analysis. *Psychology in Spain*, *6*(1), 83–95.

Simmons, W. K., & DeVille, D. C. (2017). Interoceptive contributions to healthy eating and obesity. *Current Opinion in Psychology*, *17*, 106–112. https://doi.org/10.1016/j.copsyc.2017.07.001

Slade, P. D., & Russell, G. F. M. (1973). Awareness of body dimensions in anorexia nervosa: Cross-sectional and longitudinal studies. *Psychological Medicine*, *3*(2), 188–199. https://doi.org/10.1017/S0033291700048510

Smeets, M. A. M. (1997). The rise and fall of size estimation research in anorexia nervosa: A review and reconceptualization. *European Eating Disorders Review*, *5*(2), 75–95.

Smink, F. R. E., van Hoeken, D., & Hoek, H. W. (2012). Epidemiology of eating disorders: Incidence, prevalence and mortality rates. *Current Psychiatry Reports*, *14*(4), 406–414. https://doi.org/10.1007/s11920-012-0282-y

Spitzer, B. L., Henderson, K. A., & Zivian, M. T. (1999). Gender differences in population versus media body sizes: A comparison over four decades. *Sex Roles*, *40*(7/8), 545–565.

Stern, R. M., Vitellaro, K., Thomas, M., Higgins, S. C., & Koch, K. L. (2004). Electrogastrographic biofeedback: a technique for enhancing normal gastric activity. *Neurogastroenterology and Motility*, *16*(6), 753–757. https://doi.org/10.1111/j.1365-2982.2004.00543.x

Stice, E. (2002). Risk and maintenance factors for eating pathology: A meta-analytic review. *Psychological Bulletin*, *128*(5), 825–848. https://doi.org/10.1037/0033-2909.128.5.825

Vaitl, D. (1996). Interoception. *Biological Psychology*, *42*(1–2), 1–27. https://doi.org/10.1016/0301-0511(95)05144-9

Vall, E., & Wade, T. D. (2015). Predictors of treatment outcome in individuals with eating disorders: A systematic review and meta-analysis. *International Journal of Eating Disorders*, *48*(7), 946–971. https://doi.org/10.1002/eat.22411

van Dyck, Z., Ortmann, J., Lutz, A. P. C., Rose, G., & Vögele, C. (2017). Development and validation of a multidimensional instrument to assess eating disorder-specific interoceptive processes. In A. Schorr (Ed.), *13. Kongress der Fachgruppe Gesundheitspsychologie der DGPs* (pp. 45–47).

van Dyck, Z., Schulz, A., Blechert, J., Herbert, B. M., Lutz, A. P. C., & Vögele, C. (2020). Gastric interoception and gastric myoelectrical activity in bulimia nervosa and binge-eating disorder. *International Journal of Eating Disorders*, *18*(S), eat.23291. https://doi.org/10.1002/eat.23291

van Dyck, Z., Vögele, C., Blechert, J., Lutz, A. P. C., Schulz, A., & Herbert, B. M. (2016). The Water Load Test As a Measure of Gastric Interoception: Development of a Two-Stage Protocol and Application to a Healthy Female Population. *PLOS ONE*, *11*(9), e0163574. https://doi.org/10.1371/journal.pone.0163574

Van Malderen, E., Goossens, L., Verbeken, S., Boelens, E., & Kemps, E. (2019). The interplay between self-regulation and affectivity in binge eating among adolescents. *European Child and Adolescent Psychiatry*, *28*(11), 1447–1460. https://doi.org/10.1007/s00787-019-01306-8

Vocks, S., Legenbauer, T., Troje, N., & Schulte, D. (2006). Körperbildtherapie bei Essstörungen. *Zeitschrift Für Klinische Psychologie Und Psychotherapie*, *35*(4), 286–295. https://doi.org/10.1026/1616-3443.35.4.286

Walsh, B. T., Zimmerli, E., Devlin, M. J., Guss, J., & Kissileff, H. R. (2003). A disturbance of gastric function in bulimia nervosa. *Biological Psychiatry*, *54*(9), 929–933. https://doi.org/10.1016/S0006-3223(03)00176-8

Wang, G. J., Tomasi, D., Backus, W., Wang, R., Telang, F., Geliebter, A., Korner, J., Bauman, A., Fowler, J. S., Thanos, P. K., & Volkow, N. D. (2008). Gastric distention activates satiety circuitry in the human brain. *NeuroImage*, *39*(4), 1824–1831. https://doi.org/10.1016/j.neuroimage.2007.11.008

Whitehead, W. E., Drescher, V. M., Heiman, P., & Blackwell, B. (1977). Relation of heart rate control to heartbeat perception. *Biofeedback and Self-Regulation*, *2*(4), 371–392. https://doi.org/10.1007/BF00998623

World Health Organization. (2016). *Growing up unequal: gender and socioeconomic differences in young people's health and well-being* (J. C. Inchley, D. B. Currie, T. Young, O. Samdal, T. Torsheim, L. Augustson, F. Mathison, A. Y. Aleman-Diaz, M. Molcho, M. Weber, & V. Barnekow (Eds.); Issue 7).

World Health Organization. (2018). *Fact sheet on obesity and overweight*. https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight

Yanovski, S. Z. (2002). Binge eating in obese persons. In *Eating disorders and obesity: A comprehensive handbook* (2nd ed., pp. 403–407). Guilford Press.