

ANGLIA RUSKIN UNIVERSITY

FACULTY OF SCIENCE AND ENGINEERING

SCHOOL OF PSYCHOLOGY AND SPORTS SCIENCE

BODIES FROM THE INSIDE OUT: AN INVESTIGATION OF THE RELATIONSHIPS  
BETWEEN INTEROCEPTION AND BODY IMAGE

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## ABSTRACT

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Interoception refers to the processing of internal bodily stimuli, while body image refers to appearance-related perceptions, affect, and cognitions. Previous research has identified an inverse relationship between interoception and body image, with people who have lower levels of self-reported and behavioural interoceptive ability tending to report more negative body image. In the present thesis, I sought to examine whether this association is upheld across multiple components of interoception and body image, and after accounting for key demographic variables. Studies 1-4 investigated associations between facets of self-reported interoceptive awareness and body image in online samples of adults ( $N = 646$ ) and adolescents ( $N = 265$ ) from the United Kingdom (UK) and a sample of Malaysian adults ( $N = 815$ ). Study 5 investigated associations between facets of body image and a behavioural measure of gastric interoception (i.e., a two-stage water load task) in samples of UK ( $n = 91$ ) and Malaysian ( $n = 100$ ) adults. Study 6 investigated associations between facets of body image and implicit measures of cardiac and gastric interoception (i.e., heartbeat evoked potential and gastric-alpha phase-amplitude coupling) in UK adults ( $N = 35$ ). Significant associations between interoception and body image were identified in all six studies, across dimensions of body image and hierarchical levels of interoceptive processing, in several demographically distinct samples. However, the pattern of the associations was found to be dependent on the components of interoception and body image being examined: broadly, greater self-reported interoceptive awareness is associated with a more positive body image, and lower implicit and behavioural interoceptive sensitivity is associated with more negative body image. While many of the findings aligned with existing theoretical accounts of the association between interoception and body image, several of the findings also indicate that it is necessary to refine extant theoretical accounts to encompass the multidimensionality of interoception and body image.

Key words: Interoception; Body Image; Cross-national; Adolescence; Gastric interoception;  
Positive body image

## **Publications and presentations arising from the thesis**

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Todd, J., & Swami, V. (2020). Assessing the measurement invariance of two positive body image instruments in adults from Malaysia and the United Kingdom. *Body Image*, 34, 112-116. <https://doi.org/10.1016/j.bodyim.2020.05.009>

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Todd, J., Aspell, J. E., Barron, D., & Swami, V. (2019). Multiple dimensions of interoceptive awareness are associated with facets of body image in British adults. *Body Image*, 29, 6-16. <https://doi.org/10.1016/j.bodyim.2019.02.003>

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## **List of Abbreviations**

ANCOVA	Analysis of covariance
BAS-2	Body Appreciation Scale-2
BASES	Body and Appearance Self-Conscious Emotions Scale
BMI	Body mass index
CFA	Confirmatory factor analysis
DMS	Drive for Muscularity Scale
ECG	Electrocardiography
ED	Eating disorder
EEG	Electroencephalography
EFA	Exploratory factor analysis
EGG	Electrogastrography
FAS	Functionality Appreciation Scale
FDR	False discovery rate
HEP	Heartbeat evoked potential
IAcc	Interoceptive accuracy
IAw	Interoceptive awareness
IS	Interoceptive sensitivity
MAIA	Multidimensional Assessment of Interoceptive Awareness
MBSRQ-AS	Multidimensional Body-Self Relations Questionnaire-Appearance Scales
MCAR	Missing completely at random
MI	Modulation index
PAC	Phase-amplitude coupling
PFRS	Photographic Figure Rating Scale
ROI	Region of interest
SEM	Structural equation modelling
SES	Socioeconomic status
UK	United Kingdom
VAST	Visceral-afferent signal transmission
VIF	Variance Inflation Factor
WLT	Water load test

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## **1. Introduction**

Bodily awareness can be divided according to internal and external domains of the body. The term *interoception* refers to the processing of stimuli originating inside the body (Craig, 2003; Khalsa et al., 2018), while *body image* refers to the generation of external, appearance-related perceptions, affects, and cognitions (Cash, 2004; Cash & Smolak, 2012). Both constructs are essential components of personal identity and contribute to the regulation of human behaviour (Cash, 2004; Craig, 2009; Damasio, 2010). However, interactions between the two constructs are complex because they are both multidimensional (Cash & Smolak, 2012; Khalsa et al., 2018; Murphy et al., 2020; Tylka, 2018) and because several demographic variables are known to interact with each construct independently. As such, the overall aim of the studies presented in this doctoral thesis was to examine associations between interoception and body image, specifically considering: (1) whether associations are robust across different components of interoception and body image, and; (2) whether associations are robust after accounting for key demographic variables.

In the present introductory chapter, I provide an overview of the current scientific knowledge of the constructs of interoception and body image, in turn. Each of these sections includes summaries of the documented associations between demographic variables and interoception and body image, respectively, with a specific focus on cultural groups, age, and gender. I then provide an overview of the extant investigations of the associations between interoception and body image and outline the current theoretical interpretations of these associations. Finally, I highlight the gaps in the extant literature that motivated the present series of studies.

### **1.1. Interoception**

The term *interoception* refers to a collection of processes through which the physiological state of the body is communicated to the brain (Craig, 2003; Khalsa et al.,

2018). Internal organs – such as the heart, lungs, and stomach – and bodily systems (e.g., the vascular and glandular systems) produce signals that continuously indicate their present condition. This signalling occurs across both conscious and unconscious levels (Cameron, 2002); for example, through explicit bodily sensations (e.g., heartrate, dyspnoea), behavioural drivers (e.g., hunger, thirst), and implicit reflexes (e.g., baroreflex, gastrocolic reflex). The nervous system then detects, interprets, and integrates this information to generate a continuous account of the body's internal state (Craig, 2003). Thus, interoception plays a key role in homeostatic regulation: in order to maintain an internal equilibrium, internal processes have to be monitored and regulated by the autonomic nervous system (Cameron, 2002; Vaitl, 1996). Interoception has also been associated with subjective experiences, such as bodily self-consciousness (Aspell et al., 2013; Babo-Rebelo et al., 2016; Tsakiris et al., 2011), as well as a range of physical and psychiatric conditions (Khalsa et al., 2018; Quadt et al., 2018).

The neurobiology of interoceptive processing comprises several different physiological pathways (Critchley & Harrison, 2013). At the broadest level, interoceptive information reaches the brain via spinal and cranial nerves (i.e., *neural pathways*) and through chemicals carried in blood (i.e., *humoral pathways*) (Critchley & Harrison, 2013). More specifically, neural pathways rely on *visceral afferent fibres*, that is, nerve fibres that carry information toward the brain. Visceral afferent fibres can be grouped according to the type of information they carry. Behavioural drivers are carried by visceral afferent nerve fibres that travel along cranial nerves (e.g., the vagus, which is connected to the heart, liver and digestive tract) and terminate within the nucleus of the solitary tract (Critchley & Harrison, 2013), situated in the brainstem. Signals relating to temperature and pain sensations are carried by spinal visceral afferents that project to the sensory processing portion of the spinal cord (the dorsal horns) and into the spinothalamic tract, which projects information

from the spinal cord to the thalamus via spinal laminar 1 (Craig, 2003; Critchley & Harrison, 2013). Conversely, information carried by humoral pathways (e.g., glucose and insulin levels) reaches the brain directly via the circumventricular organs in the third and fourth ventricles of the brain (Critchley & Harrison, 2013), which are responsible for transferring information between blood, cerebrospinal fluid, and the brain (Johnson, 2009).

Once sensory information reaches the brainstem, it is further projected to the thalamus, hypothalamus, amygdala, and into the viscerosensory cortices (Cameron, 2001; Craig, 2002; Critchley & Harrison, 2013; Palma & Benarroch, 2014; Quadt et al., 2018). The viscerosensory cortices include the anterior cingulate cortex – which is associated with visceromotor tasks and autonomic control, such as generating changes in arousal (Critchley et al., 2003) – and the insular cortex, which is acknowledged to be a critical area for interoceptive processing (Craig, 2003, 2009; Critchley & Harrison, 2013). The insular cortex can be divided into several subregions, which have been shown to have distinct functions (for a review, see Kurth et al., 2010). The posterior insula is considered to be the primary subregion for the integration of interoceptive information (Craig, 2003, 2009) and distinct areas of the posterior insula are responsible for processing signals for different bodily domains (Craig, 2009). In the mid-insula, sensory information from the amygdala and hypothalamus is integrated. Finally, the anterior insula integrates and projects information across the other viscerosensory cortices (Craig, 2009). Research indicates that the integration of interoceptive information occurs in a specific temporal sequence that begins in the posterior insula, then moves through the mid-insula, and culminates in the anterior insula (for an overview, see Craig, 2009).

### **1.1.1. Components of interoception**

Emerging consensus suggests that interoceptive processing can be parcellated into numerous components that span both conscious and unconscious levels of processing

(Garfinkel et al., 2015; Khalsa et al., 2018; Paulus et al., 2019). While the majority of interoceptive processing occurs unconsciously, the conscious act of sensing interoceptive information has been divided into different facets. However, researchers have yet to agree upon the nomenclature for these different components of interoception (Garfinkel et al., 2015; Mehling, 2016; Murphy et al., 2020; Khalsa et al., 2018), which complicates the evaluation and synthesis of extant research. The definitions for the components of interoception described in the present doctoral thesis are presented in Table 1.

Table 1

*A taxonomy of interoception.*

Component	Definition	Example measurement techniques
Accuracy (IAcc)	The precision of interoceptive monitoring	Heartbeat perception tasks (e.g., Schandry, 1981)  Two-stage water load task (van Dyck et al., 2016)
Awareness (IAw)	The self-perceived tendency to focus on/direct attention towards interoceptive stimuli.	Questionnaire measures (e.g., Mehling et al., 2012, 2018; Porges, 1993)
Explicit	Umbrella descriptor for indicators of interoception that require conscious perception of internal bodily sensations	<i>See accuracy, magnitude, sensitivity.</i>
Implicit	Umbrella descriptor for indicators of interoception that do not necessarily require conscious perception of internal bodily sensations	Heartbeat evoked potentials (Schandry et al., 1986)  Gastric-alpha phase-amplitude coupling (Richter et al., 2017)
Magnitude	The self-reported intensity of interoceptive stimuli	Ratings of cardiac and respiratory stimuli following bolus infusions of isoproterenol (Khalsa, Rudrauf, Sandesara, et al., 2009)

		Ratings of gastric sensations during water load tasks (van Dyck et al., 2016)
Sensitivity (IS)	The presence or absence of interoceptive stimuli or a domain-specific sensation	Single-stage water load tasks (e.g., Herbert et al., 2012) Inspiratory breathing load paradigms (e.g., Paulus et al., 2012)

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There are several additional distinctions within and across the components of interoception listed in Table 1. Of particular importance is the distinction between self-reported interoceptive awareness (IAw) and behavioural measures of interoceptive accuracy (IAcc) and interoceptive sensitivity (IS). A substantial body of literature documents a lack of statistically significant associations between self-reported and objectively measured detections of interoceptive stimuli (e.g., Cali et al., 2015; Ceunen et al., 2013; Forkmann et al., 2016; Gajdos et al., 2020; Garfinkel et al., 2015; Schuette et al., 2020; Weineck et al., 2019), suggesting that self-assessments of interoception do not necessarily reflect the extent to which an individual can objectively detect interoceptive stimuli. Furthermore, IAw can also be conceptualised as a higher-order construct, encompassing several lower-order facets (Mehling et al., 2012; 2018). In particular, there is an important distinction between the basic awareness of internal stimuli and the cognitive and affective judgements of interoceptive stimuli, such as adaptive and maladaptive modes of attention, appraisal and regulation (Mehling, 2016; Mehling et al., 2009, 2012). These facets of IAw have unique associations with outcome variables (for a review, see Mehling, 2016) and there is some evidence that they reflect distinct neural processes (Baranauskas et al., 2017). For these reasons, it is important that investigations of the associations between interoception and other constructs examine multiple components of interoception, including both behavioural and self-report measures.

An equally important distinction in the interoception literature relates to the processing and perception of interoceptive stimuli across different bodily domains. Interoceptive processing can be examined across different organ systems, including the cardiac (Oppenheimer & Cechetto, 2011), gastric (Mayer et al., 2006), and respiratory systems (Kruschwitz et al., 2019) (for examples, see Table 1). However, the nature of interoceptive processing across these different organ systems is not yet fully understood, with differing accounts all plausible (Khalsa et al., 2018). For example, it is possible that interoceptive processing could be domain-specific, where the processing of signals from different organ systems occurs in specialised, discrete neural circuits (see Spunt & Adolphs, 2017). This hypothesis is supported by the topography of the posterior insula (Craig, 2009) (see Section 1.1), and by studies that have found distinctions between explicit components of interoception when measured across different bodily systems (e.g., Ferentzi, Bogdány, et al., 2018, 2019; Garfinkel et al., 2016; Harver et al., 1993; Pollatos, Herbert, Mai et al., 2016; Steptoe & Vögele, 1992). It is also possible that the processing of interoceptive stimuli could be functionally coupled, where the processing of signals from two or more different bodily systems occurs within the same brain network (e.g., cardiorespiratory; Hassanpour et al., 2018). Finally, it may be that interoception is a unitary process, where components of interoception are stable across different bodily systems. This hypothesis is supported by the fact that the transmission of interoceptive information from different bodily domains shares common neuroanatomical pathways (see Section 1.1) and by studies showing significant associations between components of interoception when measured across different bodily domains (e.g., Herbert et al., 2012; van Dyck et al., 2016; Whitehead & Drescher, 1980).

The vast majority of interoception studies to date have assumed a unitary account, with data from studies in the cardiac domain often regarded as an indicator of “general” IAcc (Tsakiris & Critchley, 2016). This is problematic for two reasons. First, a recent body of

evidence has highlighted a large number of confounding variables associated with the measurement of IAcc in the cardiac domain, including: (1) physiological factors such as age, body mass index (BMI), blood pressure, resting heart rate, and heart rate variability (Khalsa, Rudrauf & Tranel, 2009; Murphy et al., 2018a, 2018b, 2018c, Zamariola et al., 2018); (2) participants' knowledge/expectations about resting heart rate (Desmedt et al., 2020; Knapp-Kline & Kline, 2005; Murphy, Brewer, et al., 2018; Murphy, Geary et al., 2018; Murphy, Millgate, et al., 2018; Ring et al., 2015) and ability to estimate time (Ainley et al., 2014; Desmedt et al., 2020); (3) biases in the way that heartbeat perception tasks are scored (Zamariola et al., 2018; cf. Tsakiris et al., 2019), and; (4) the specific wording of task instructions and the equipment utilised during the measurement of heartbeats (Desmedt et al., 2018; Murphy, Brewer, et al., 2019; Todd, Hina et al., 2020). Second, research regarding the interrelation of indices of IAcc across different bodily systems is equivocal, as outlined above. It is, therefore, important that investigations of the associations between interoception and other constructs examine components of interoception from multiple bodily domains, because findings from one bodily domain may not generalise to another.

### **1.1.2. Investigations of interoception across national and cultural groups**

To date, very few studies have directly examined explicit components of interoception in cross-cultural samples (for a review, see Ma-Kellams, 2014). The limited literature appears to indicate a broad distinction across Western and non-Western participants. For example, East Asian and West African participants have been found to demonstrate significantly lower cardiac IAcc than North American and Western European participants (Chentsova-Dutton & Dzokoto, 2014; Ma-Kellams et al., 2012). Furthermore, observation of one's own face has been found to significantly improve cardiac IAcc for participants of Western origin, but not for participants of East Asian origin (Maister & Tsakiris, 2013), indicating differences in the integration of interoceptive and exteroceptive

stimuli across Western and non-Western cultural groups. An important caveat regarding this body of literature is that it is limited by the exclusive reliance upon cardiac paradigms, which is problematic for the reasons discussed in Section 1.1.1. For example, it is unclear whether the cultural distinctions in cardiac IAcc documented in the current body of literature can be generalised to other bodily domains.

Direct cross-cultural assessments of IAw have been impeded by the need to establish *measurement invariance* when using self-report measures. That is, a prerequisite of meaningful comparisons of latent scores across different cultural and linguistic groups is ensuring that the measures capture the same construct in both groups (Chen, 2008). To date, no such studies exist in the extant IAw literature. Nevertheless, cultural differences in IAw can be implied from differences in score dimensionality (i.e., scores for measures of IAw have been found to reduce to a different number of factors across national groups). For example, translation studies for the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) have indicated substantive differences in score dimensionality (for a full review, see Todd, Barron et al., 2020; see also Study 2). This, in turn, suggests that the MAIA taps different underlying constructs across national groups. To illustrate, MAIA scores reduce to eight subscales in samples from the United States and Western Europe (Todd, Barron et al., 2020), but the extraction of a reduced number of factors has been reported in studies with samples from Asian countries, including Malaysia, where MAIA scores reduced to only three dimensions (Todd, Barron et al., 2020; see also Study 2), and Japan, where MAIA scores reduced to six dimensions (Fujino, 2019; Shoji et al., 2018). These results suggest that local cultural contexts might shape conceptions of IAw. In particular, it is possible that people from Asia experience greater difficulty in distinguishing between multiple facets of IAw.

Some authors have suggested that cultural differences in components of interoception could be related to differences in attention styles across individualist and collectivist cultures, with cultural tendencies to prioritise attention toward either the self or the social context (Makellams, 2014), or related to cross-cultural differences in the embodied experiences of subjective affect (e.g., Immordino-Yang et al., 2016). Freedman and colleagues (2020) examined these possibilities in a recent qualitative study with bicultural Japanese Americans. Using thematic analysis, the authors identified several nuanced differences in embodied experience across Japanese and American cultures. In particular, participants reported that switching between speaking English and Japanese changed the focus of attention across internal and external bodily domains. Participants reported a greater focus on the ways they were perceived by others in Japanese society, which resulted in the adoption of a third-person perspective, where their actions are perceived from an outsider's viewpoint. This perspective was associated with difficulties in turning attention toward internal stimuli. In contrast, participants described it being easier to pay attention to the self when using English. Switching between Japanese and English was also associated with alterations in body language – with Japanese being associated with less open and expressive body postures – and somatisation, with greater use of bodily references when describing emotions in Japanese, and a lesser distinction between the body and emotions. It is important to note that these findings are specific to Japanese Americans, and, therefore, should not be generalised to other non-Western contexts.

Overall, the limited extant literature examining interoception in cross-national and cross-cultural contexts indicates that there are notable differences between Western and non-Western groups. It is, therefore, important that researchers examine associations between interoception and outcome variables in culturally diverse samples. In particular, findings from Western contexts may not generalise to non-Western contexts.

### **1.1.3. The development and stability of interoception across the lifespan**

Investigations of the developmental trajectory of interoception across the lifespan have been impeded by a paucity of reliable methods that could be utilised in a longitudinal developmental study. Most of the commonly utilised paradigms (e.g., heartbeat detection tasks, questionnaire measures) rely upon participants' verbal comprehension and reporting abilities, which precludes their use with infants and young children. As an additional complication, previous research demonstrates that numerous physiological and psychological factors associated with age – such as body composition, resting heartrate, heartrate variability, systolic blood pressure, and intelligence (Franklin et al., 1997; St-Onge, 2005; Umetani et al., 1998; Yashin et al., 2006) – are also associated with cardiac IAcc (Knapp-Kline & Kline, 2005; Rouse et al., 1988; O'Brien et al., 1998). It is, therefore, difficult to isolate the effect of developmental stage upon interoception; indeed, it may be that these factors mediate the relationship between age and interoception (Murphy, Geary, et al., 2018). Owing to these complications, components of interoception have largely been explored in infancy, childhood, adolescence, and adulthood separately (Murphy et al., 2017). This section will consider each developmental stage in turn.

A developing line of research suggests that IS emerges in infancy. For example, Maister and colleagues (2017) developed a sequential looking paradigm, in which infants aged five months were shown an animated character that performed movements in a fashion that was synchronous or asynchronous ( $\pm 10\%$  speed) with their heartbeat. Overall, infants spent longer looking at the character that was moving asynchronously than the one moving synchronously. This finding was interpreted to suggest that the infants could, firstly, discriminate their own interoceptive signals, and, secondly, integrate this information with exteroceptive stimuli to inform visual preferences.

The youngest age at which explicit interoception has been assessed is 6 years of age. Koch and Pollatos (2014a) asked 1350 children aged 6-11 years to complete a modified version of the heartbeat tracking task (Schandry, 1981). The range of cardiac IAcc scores was comparable to those found in healthy adult samples, suggesting that even in early childhood, there are marked individual differences in cardiac IAcc. In a follow-up study, Koch and Pollatos (2014b) reported modest stability of heartbeat tracking task scores over a 1-year period ( $r = .33$ ). This finding has been subsequently replicated in a study of 300 twin pairs, where heartbeat tracking task scores were moderately correlated ( $r = .35$ ) when assessed in participants aged eight years old and again two years later (Murphy, Cheesman et al., 2019). These stability estimates are relatively low in comparison to stability estimates in adult samples ( $r = .41-.89$ ; for overviews, see Ferentzi, Drew, et al., 2018; Wittkamp et al., 2018), indicating that cardiac interoception changes to a greater degree in childhood compared to adulthood. Indeed, Murphy, Cheesman and colleagues (2019) found a significant improvement in task performance across the two time points.

In contrast, functional magnetic resonance imaging (fMRI) data indicate that components of interoception may have non-linear developmental trajectories across adolescence and adulthood. For example, in a sample of 37 females aged between 10 and 20 years old, Li and colleagues (2017) found that participants in mid-adolescence (aged 15 years) showed the highest activation in the bilateral ventral anterior insula when participants focused their attention on gastric activity, with older and younger participants both exhibiting lower levels of activity. Similarly, May and colleagues (2014) used fMRI to assess the neural effects of both the anticipation and experience of a soft touch to the palm or forearm. Whilst no differences were observed at the behavioural level, adolescents (aged 15-17 years) exhibited greater activation in the bilateral posterior insula, bilateral inferior frontal gyrus,

and striatum in response to the soft touch than young adults (aged 20-28 years) and mature adults (aged 29-55 years) across all conditions and stimulus types.

In adult samples, age has been negatively associated with several components of interoception, indicating that IAcc and IAw may decline in later adulthood. For example, self-reported IAw was inversely associated with age ( $r_s = -.34$ ) in a sample of participants aged 20-89 years (Murphy, Geary et al., 2018). Associations between age and cardiac IAcc have also been observed, with age inversely predicting cardiac IAcc across two different cardiac detection paradigms (Khalsa, Rudrauf & Tranel, 2009; Murphy, Geary, et al., 2018). Murphy, Geary, and colleagues (2018) found the poor performance observed in late adulthood to be due to both a direct effect of age on IAcc and an indirect effect mediated by BMI, whereby older age was associated with increased BMI, which in turn, predicted reduced IAcc.

Overall, it appears that interoceptive processing (in particular, cardiac IAcc) does not remain stable over time and is therefore a factor that should be considered when exploring the relation between interoception and other constructs. Specifically, when considered altogether, the findings from the extant literature suggest that: (1) interoceptive processing is present in infancy (Maister et al., 2017) and cardiac IAcc improves during early childhood (Murphy, Cheesman, et al., 2019); (2) areas of the brain associated with the processing of interoceptive stimuli may be particularly active during adolescence (Li et al., 2018; May et al., 2014), which could account for the peak in IAw and IAcc in adolescence and early adulthood, and; (3) IAcc and IAw decline in older adulthood (Khalsa, Rudrauf & Tranel, 2009; May et al., 2014; Murphy, Geary, et al., 2018).

#### **1.1.4. Interoception and gender**

A substantial body of research indicates that there are gender differences in interoception. In particular, women have been found to exhibit significantly lower scores in

tests of cardiac IAcc (Grabauskaitė et al., 2017; Harver et al., 1993; Ludwick-Rosenthal & Neufeld, 1985; Suschinsky & Lalumière, 2012; Murphy, Brewer et al., 2018; Whitehead & Drescher, 1980), gastric IAcc (Whitehead & Drescher, 1980), respiratory IS (Harver et al., 1993), and the concordance between perceptions of sexual arousal and genital arousal (Suschinsky & Lalumière, 2012). One possible account for these findings is that physiological differences between women and men may make it easier for men to discern interoceptive stimuli – in particular, cardiac stimuli – with a greater level of accuracy. For example, women tend to have a higher body fat percentage, lower stroke volume, and faster resting heart rates (e.g., Agelink et al., 2001). Indeed, once body fat percentage is matched, gender differences in cardiac IAcc are no longer observed (Rouse et al., 1988).

In contrast to the IAcc and IS findings, women have been found to demonstrate higher levels of IAw (Barsky et al., 2001; Grabauskaitė et al., 2017). In a sample of 376 adults (51% male), Grabauskaitė and colleagues (2017) found that women reported a significantly greater tendency to notice interoceptive stimuli and greater emotional awareness. Grabauskaitė and colleagues (2017) also found that women were significantly less likely to trust interoceptive stimuli and significantly more likely to appraise interoceptive sensations negatively.

Considered together, it appears that women tend to exhibit higher IAw, but lower IAcc and IS. Murphy, Viding and colleagues (2019) recently labelled this pattern of behaviour as high *trait interoceptive prediction error*. That is, women may experience discrepancies between expected/reported and actual bodily states. This could result in a tendency to self-report greater monitoring of interoceptive sensations, but actually demonstrate a lower objective accuracy. Murphy, Viding and colleagues (2019) suggested that this pattern of behaviour may partly arise from the greater internal physical and hormonal changes that women experience in comparison to men – including during adolescence and across the menstrual cycle, pregnancy and menopause – which might result in sustained increases in the

discrepancies between actual and expected bodily states. Overall, gender is an important factor that needs to be considered and/or controlled for when conducting interoception research, because it will likely account for a significant proportion of the variance in interoception outcome variables, and findings may not be generalisable across women and men.

## **1.2. Body image**

The modern study of body image is thought to have originated with the work of Paul Schilder (1950, p. 11), who defined *body image* in terms of appearance-related perceptions, namely, “the picture of our own body which we form in our mind, that is to say, the way in which the body appears to ourselves”. More recently, body image has been conceptualised as a multifaceted construct, comprising body-related perceptions, affects, and cognitions (Cash, 2004; Cash & Pruzinsky, 2002; Cash & Smolak, 2012; Grogan, 2017). The perceptual component refers to the accuracy of body estimations (e.g., shape, size, appearance) relative to the body’s actual form (Grogan, 2017). The attitudinal component of body image encompasses body-related evaluations (i.e., satisfaction) and feelings, and associated behaviours (e.g., negative behaviours such as avoidance of situations where the body will be exposed and adaptive behaviours such as positive self-care; Grogan, 2017; Tylka & Wood-Barcalow, 2015a). Finally, the cognitive component refers to investment in appearance and beliefs about the body (Cash, 2002). The cognitive component also incorporates strategies for interpreting and processing body-related information, such as filtering incoming information in a body-protective manner (Tylka & Wood-Barcalow, 2015a). Most body image measures assess one or more of the body image components, at either the global or site-specific level (Grogan, 2017; Thompson et al., 2012; Webb et al., 2015).

### **1.2.1. Dimensions**

In addition to the aforementioned components of body image, a robust body of evidence supports a divergence between the dimensions of negative and positive body image (Ricciardelli et al., 2018; Tylka, 2011, 2018; Tylka & Wood-Barcalow, 2015a); the two are considered to be independent and distinct constructs, rather than opposite ends of the same spectrum (Tylka, 2018; Tylka & Piran, 2019). This is important because, whilst measures of negative and positive body image are often significantly and negatively correlated, there are also unique relationships between negative and positive body image, respectively, and other variables (Tylka & Wood-Barcalow, 2015a). For example, body dissatisfaction has been associated with negative outcomes, such as alcohol consumption, whereas positive body image is predictive of positive health-related outcomes, such as using sun-protection and seeking medical help when necessary (Andrew et al., 2016), and psychosocial well-being (Swami et al., 2018).

#### **1.2.1.1. Negative body image**

*Negative body image* refers to the negative thoughts and feelings a person has about their body (Grogan, 2017). Negative body image comprises many forms, including appearance dissatisfaction, body surveillance, body shame, drive for thinness, and drive for muscularity (Tylka, 2018), but it is commonly assessed using measures of body image dissatisfaction. *Body image dissatisfaction* specifically relates to negative evaluations of the body (e.g., dissatisfaction relating to body shape, size, muscularity, or global appearance), and can be measured as the discrepancy between perceptions of one's actual body and one's ideal body (Grogan, 2017; see also Swami et al., 2008; Swami, Steiger et al., 2012). Body image dissatisfaction is extremely prevalent, with an estimated 60-80% of women reporting body image dissatisfaction (Harris & Carr, 2001; Tiggemann & Slevec, 2012). Increasing evidence also indicates that a significant proportion of men (~15-25%) experience body

dissatisfaction (Fawcner, 2012). Accordingly, body dissatisfaction has been described as a “normative discontent” for both men and women (Rodin et al., 1984).

#### **1.2.1.2. Positive body image**

Informed by qualitative research and psychometric studies, *positive body image* refers to an “overarching love and respect for the body” (Tylka, 2018, p. 9), which is characterised by an active love and respect for the body. The construct incorporates appreciation for the body and the functions it performs, acceptance of aspects of appearance that are inconsistent with societal ideals, and interpretation of incoming information in a body-image protective manner (Tylka, 2018; Wood-Barcalow et al., 2010). As such, positive body image is neither the opposite nor the absence of negative body image (Tylka, 2018; Tylka & Wood-Barcalow, 2015a). Indeed, facets of positive body image have been uniquely associated with numerous physical and psychological outcomes over-and-above facets of negative body image (for reviews, see Daniels et al., 2018; Tylka & Piran, 2019).

Like negative body image, positive body image is a multidimensional construct, consisting of multiple lower-order dimensions with minimal conceptual overlap (Tylka & Wood-Barcalow, 2015a; Webb et al., 2015), such as body appreciation, functionality appreciation, body pride, body image flexibility, and broad conceptualisations of beauty (Webb et al., 2015). In a recent assessment of the commonality and distinguishability of several core measures of positive body image, Swami, Furnham, and colleagues (2020) found body appreciation (as measured by the Body Appreciation Scale-2; Tylka & Wood-Barcalow, 2015b) to be the core and central component of positive body image, with functionality appreciation and body pride found to be slightly more distal, but nevertheless central, components.

#### **1.2.2. Investigations of body image across national and cultural groups**

Sociocultural theories of body image posit that negative body image arises from the internalisation of societal ideals that are communicated via sociocultural channels, particularly the tripartite influences of mass media, peers, and family (Keery et al., 2004). More specifically, the sociocultural perspective suggests that negative body image is a function of the extent to which individuals perceive themselves to be physically aligned with socially prescribed appearance ideals (Tiggemann, 2012). Sociocultural models emphasise the influences occurring within local sociocultural environments, such as localised social and cultural practices, standards, and beliefs.

Early research documented cultural differences in appearance ideals, with several non-Western contexts, such as populations in the South Pacific, preferring a heavier figure over the Western thin ideal (for an overview, see Swami, 2015). However, more contemporary evidence suggests that the female thin ideal (and associated body dissatisfaction) has become a transnational phenomenon (Swami et al., 2010). The changing nature of body size ideals in non-Western nations has been attributed to Westernisation (for example, the globalisation of Western media) and modernisation (i.e., increasing affluence), which, in turn, lead to local cultural changes that promote the thin ideal (Swami, 2015). Indeed, to date, research has indicated that there are significant differences in facets of negative and positive body image across national and cultural contexts, but effect sizes tend to be small or negligible (for reviews, see Swami, 2015, 2020). For example, Swami and colleagues (2010) investigated women's body image dissatisfaction across 26 countries from ten global regions. The results indicated that body image ideals varied significantly across global regions, but the effect sizes for these differences were small across high socioeconomic status (SES) sites. Conversely, there were larger differences across SES sites within nations, with women from lower SES sites tending to idealise a heavier body size and having lower body dissatisfaction than women from higher SES sites (Swami et al., 2010).

In comparison to facets of negative body image, relatively little research has examined the similarities and differences in facets of positive body image across national and cultural contexts. The limited extant investigations have indicated that there are significant cross-national differences in facets such as body appreciation and body pride, but, again, effect sizes were generally small (Góngora et al., 2020; Lemoine et al., 2018; Razmus et al., 2019; Todd & Swami, 2020; for a review, see Swami, 2018). However, Swami (2018) highlights an important caveat when interpreting the extant cross-cultural research on positive body image. Namely, reliance on translations of measurement tools that have been originally developed in the West may not adequately capture aspects of positive body image that are specific to other cultural contexts. Indeed, qualitative research with different cultural groups appears to indicate that, while some core components of positive body image are communal, there are elements of positive body image that may be unique to specific cultural groups (e.g., McHugh et al., 2014; for a review, see Swami, 2018). An additional limitation of the extant positive body image literature is the lack of invariance testing before conducting between-group tests (e.g., Swami, Mada et al., 2012; Taylor et al., 2013), which could produce artefactual results.

Overall, while body image ideals (and associated levels of negative and positive body image) are becoming more uniform across national and cultural contexts, awareness of local cultural factors remains crucial to understanding the developing nature of body image ideals (Swami, 2015, 2018). Accordingly, cultural context remains an important factor that should be considered when examining associations between body image and other constructs, particularly as research examining facets of positive body image in cross-cultural and cross-national contexts remains nascent at present (Swami, 2018).

### **1.2.3. The development and stability of body image across the lifespan**

Age and appearance are intrinsically linked: as we age, our physical appearance continually changes. Across the lifespan, people will have experiences that both facilitate positive body image – for example, discovering new social contexts, and experiencing agency and empowerment during late adolescence and early adulthood (Holmqvist Gattario & Frisé, 2019), or having a child (e.g., Bailey, 2001) – and promote negative body image (e.g., more frequent experiences of sexual objectification among women in adolescence and early adulthood). Accordingly, there are alternative theories regarding whether aging has a positive or negative impact upon body image. On the one hand, it has been argued that ageing promotes more positive body image, because older adults are less likely to be targeted and influenced by idealised media images, which tend to portray young women and men (Bessenoff & Del Priore, 2007; Jankowski et al., 2016; Tiggemann, 2015). This argument is particularly prominent among objectification theorists, who posit that young women and girls are at greater risk of being sexually objectified as a result of societal pressures (Frederickson & Roberts, 1997). Consequently, as women age, they may experience a reduction in the pressure to focus on their physical appearance. On the other hand, it has also been argued that Western ageist attitudes, in tandem with age-related changes in body shape, weight and skin (e.g., the development of wrinkles) might cause increases in negative body image over the course of adulthood (Becker et al., 2013; Ricciardelli et al., 2018; Tiggemann, 2015).

Regarding negative body image, longitudinal research suggests that there tends to be an increase in negative body image between the ages of 12 and 17 – for both girls and boys – (Bucchianeri et al., 2013; Eisenberg et al., 2006; Frisé et al., 2015; Paxton et al., 2006), which is maintained throughout adolescence into emerging adulthood (Bucchianeri et al., 2013; Frisé et al., 2015; Rogers et al., 2018). This change has been attributed to the range of pressures and developmental issues associated with adolescence (Ricciardelli & Yager, 2016), as well as physical changes during puberty, such as increases in BMI (Bucchianeri et

al., 2013; Paxton et al., 2006). The research concerning age and negative body image in adulthood is more equivocal, and findings may depend upon the measure of negative body image being used, and the demographic characteristics of the sample (e.g., age group, cultural group, gender). For example, some research indicates that negative body image lessens throughout adulthood, with adolescent girls tending to qualitatively report more negative body image experiences compared to young adult and older women (Piran, 2016). Similarly, in a sample of 322 women aged 20 to 84 years, Tiggemann and Lynch (2001) found that levels of self-objectification, habitual body monitoring, and appearance anxiety all significantly decreased linearly with age. Conversely, Tiggemann and Lynch (2001) found that levels of body dissatisfaction remain stable in women across adulthood. More recent research indicates that the association between age and negative body image is mediated by gender, with large-scale studies ( $N = 12,176$ ; 1338, aged 16 to 88 years) finding age-related increases in body dissatisfaction in women, but no association between age and body dissatisfaction in men (Frederick et al., 2016; Quittkat et al., 2019).

The literature concerning positive body image across the lifespan is also equivocal. Several cross-sectional studies have found age to be significantly and positively associated with body appreciation (e.g., Swami et al., 2015; Tiggemann & McCourt, 2013). Older adults ( $n = 353$ , age  $M = 74.2$ ) have also been found to report significantly higher body satisfaction than young adults ( $n = 459$ , age  $M = 20.4$ ) (Barnett et al., 2020). Conversely, Augustus-Horvath and Tylka (2011) found body appreciation decreased with age. Specifically, women in middle adulthood (aged 40-60 years,  $n = 245$ ) were significantly less appreciative of their bodies than women in emerging adulthood (aged 18-25 years,  $n = 318$ ), but women in early adulthood (26-39 years,  $n = 238$ ) did not significantly differ in body appreciation from either group. Moreover, in a sample of participants aged 18-75 years ( $N = 158$ ), Tiggeman and

McCourt (2013) also found that body areas satisfaction significantly decreased linearly with age.

In summary, the extant literature indicates that the associations between body image and age are complex, and largely reflect the conceptualisation of positive and negative body image as separate constructs. That is, the overall body of literature indicates that positive and negative body image are experienced simultaneously across the lifespan (e.g., Bailey et al., 2016), with ageing positively associated with a greater ability to appreciate the body for positive attributes other than physical appearance (e.g., body functionality; Jankowski et al., 2016), but simultaneously associated with experiences of dissatisfaction with aspects of the body and appearance (Jankowski et al., 2016; Tiggemann & Lynch, 2001; Tiggemann & McCourt, 2013). Consequently, age is an important factor that needs to be considered when investigating the associations between body image and other variables, because findings may be dependent upon the developmental window being investigated.

#### **1.2.4. Body image and gender**

“Gender, which includes culturally-constructed expectations for women and men, shapes women’s and men’s bodies and their psychological experience of them” (Tylka & Calogero, 2010, p. 601). The impact of gender, and gendered experiences of the body, on body image has been extensively studied (for overviews, see Calogero & Thompson, 2010; Ricciardelli et al., 2018; Tylka & Calogero, 2010) and the extant literature documents robust gendered differences across various components (i.e., perceptual, affective and cognitive) and dimensions (i.e., negative and positive) of body image. For example, a large body of literature documents that there are several differences in the ways that women and men perceive their bodies. First, men tend to perceive their bodies as holistic, global entities, whereas women tend to focus on discrete sections on the body (e.g., Halliwell & Dittmar, 2003). Second, a robust body of research indicates that women and girls are significantly

more likely to view themselves from an externalised (i.e., third-person) perspective, whereas men and boys are more likely to view themselves from a first-person perspective (Calogero, 2009; Calogero & Thompson, 2010; Grabe et al., 2007; Halliwell & Dittmar, 2003; McKinley & Hyde, 1996; Moradi & Huang, 2008). Finally, research also indicates gendered differences in perceptions of body size (McCreary, 2002). Specifically, women are likely to overestimate their body size and perceive themselves as overweight (Grover et al., 2003), whereas men tend to underestimate their body size, perceive themselves as underweight, and aspire to gain muscle mass (McCreary & Sasse, 2000). This perceptual difference is not specific to Western samples; for example, studies with Japanese samples have produced consistent findings (Kagawa et al., 2007).

Research has also documented gendered differences in the affective components of body image, across negative and positive dimensions. Regarding negative body image, girls and women have reported significantly higher levels of body dissatisfaction (Grogan, 2017; Holmqvist et al., 2007; Paxton et al., 1991; Thompson et al., 1991; Vincent & McCabe, 2000), body shame (Calogero et al., 2007; Groesz et al., 2002; Tiggemann & Kuring, 2004; Tiggemann & Slater, 2001; Tylka & Hill, 2004) and appearance anxiety (Dion et al., 1990; Tiggemann & Kuring, 2004) than men and boys (for a review, see Calogero & Thompson, 2010). Regarding positive body image, research has consistently documented that men report significantly higher levels of body appreciation than women in both Western and non-Western samples (for reviews, see Ricciardelli et al., 2018; Tiggemann, 2015), although a recent meta-analysis indicates that the effect size of this difference is small ( $d = 0.27$ ; He et al., 2020).

These differences have been accounted for by several key body image theories, such as objectification theory (Frederickson & Roberts, 1997) and body conceptualisation theory (Franzoi, 1995), which suggest that societal influences render women more likely to evaluate

their body based on its external appearance (i.e., “body-as-object”) and men more likely to evaluate their body based upon its functional capabilities (i.e., “body-as-process”; Franzoi, 1995). As outlined above, an extensive body of research indicates that body image is experienced differently by men and women, to the extent that it may be considered a gendered construct (Calogero & Tylka, 2010). Accordingly, it is crucial that gender is considered when examining the associations between body image and other variables, because it will likely account for a significant proportion of the variance in body image variables.

### **1.3. The relationships between interoception and body image**

#### **1.3.1. Theoretical underpinnings**

Scholars have hypothesised associations between interoception and body image, with most theoretical accounts focusing on the balance of attentional resources across interoceptive and exteroceptive stimuli (Badoud & Tsakiris, 2017; Stanghellini et al., 2015). The competition of cues hypothesis (Pennebaker, 1982; Pennebaker & Lightner 1980) postulates that attentional resources are finite and that attention directed towards interoceptive stimuli will reduce the resources available for exteroceptive stimuli, and *vice versa*. Some authors have extended this line of reasoning to suggest that the precision of a stimulus (that is, the reliability of the information that the stimulus conveys) will determine the direction of attention, with stimuli that are more precise (i.e., known to be more reliable) afforded more attention (Ainley et al., 2016). The competition between interoceptive and exteroceptive cues can be examined using manipulations of body ownership, such as the rubber hand illusion (Botvinick & Cohen, 1998). For example, a stronger experience of the rubber hand illusion has been associated with lower IAcc in the cardiac domain (Tsakiris et al., 2011). This finding suggests that, when interoceptive signals are less precise, the processing of exteroceptive stimuli are prioritised. Consistent with this theoretical rationale,

research has indicated that individuals with lower IAcc in the cardiac domain may be more reliant upon exteroceptive cues as a basis for bodily awareness (Tajadura-Jimenez & Tsakiris, 2014). In summary, for people with lower IAcc, the precision of interoceptive information may be deemed to be less reliable and, consequently, neural representations of the body may be more reliant on exteroceptive inputs (Ainley et al., 2016; Badoud & Tsakiris, 2017).

It is also possible that individuals with lower IAcc are more affected by exteroceptive inputs (e.g., visual stimuli) and broader influences (e.g., sociocultural appearance ideals) (Mussap & Salton, 2006), which could result in a greater focus on the extent to which appearance-related characteristics of the body meet sociocultural beauty standards, as well as detachment from the positive functions that the body is capable of performing. Indeed, participants with body image disturbances and disordered eating symptomology have been found to prioritise exteroceptive cues over interoceptive cues (Eshkevari et al., 2012, 2014), and feeling detached from/external to one's own body appears to be a key experience that distinguishes clinical participants from non-clinical participants (i.e., clinical participants report a significantly higher feeling of detachment from their own bodies; Stanghellini et al., 2012, 2015). Furthermore, susceptibility to the rubber hand illusion has been found to account for 10% of the variance in bulimic symptomatology in women and men and 22% of the variance in susceptibility to unhealthy body change strategies in men (Mussap & Salton, 2006). In both of the pathways identified by Mussap and Salton (2006), the degree of acceptance, and perceived importance, of cultural standards of beauty was a significant mediator.

### **1.3.2. Evidence from clinical studies**

To support the hypothesis that interoception and body image may be linked causally, Badoud and Tsakiris's (2017) review predominantly relied upon research utilising women from clinical populations. In particular, a relationship between interoception and body image

has been deduced from samples with a diagnosed eating disorder (ED), because interoceptive deficits (i.e., insensitivity to hunger signals) and distorted body image are both core psychopathological features of EDs (Davey, 2014; Khalsa et al., 2018). For example, early longitudinal studies on adolescents showed that impairments in IAW are associated with later vulnerability to the development of EDs (Killen et al., 1996; Leon et al., 1995; Lilenfeld et al., 2006). Furthermore, in a recent meta-analysis of 29 studies, Jenkinson and colleagues (2018) found a large effect size ( $d = 1.62$ ) for the differences in IAW between participants with diagnosed EDs ( $n = 4308$ ) and healthy control participants ( $n = 3459$ ). Significant correlations have also been identified between facets of IAW and ED symptomology, where lower IAW is associated with stronger ED symptomology (e.g., Bizeul et al., 2001; Brown et al., 2017; Cascino et al., 2019).

EDs have also been associated with lower cardiac IAcc. For example, cross-sectional studies have found that participants with anorexia nervosa ( $\eta^2 = .08$ -.16; Pollatos et al., 2008; Pollatos, Herbert, Berberich et al., 2016), and recovered bulimia nervosa ( $d = 1.16$ ; Klabunde et al., 2013) have significantly lower cardiac IAcc compared to healthy matched controls. Recent evidence also indicates a correlation between cardiac IAcc and the progression of treatment for anorexia nervosa ( $r = .32$ ,  $N = 44$ ; Richard et al., 2019), suggesting cardiac IAcc improves with recovery from anorexia nervosa. However, these findings have not been consistently replicated. For example, Eskevari and colleagues (2014) found no significant differences in cardiac IAcc between participants with EDs ( $n = 74$ ) and healthy control participants ( $n = 60$ ). Indeed, it is possible that the differences in cardiac IAcc might be situation-specific within ED samples. For example, Khalsa and colleagues (2015) found no significant differences in cardiac IAcc between participants with anorexia nervosa ( $n = 15$ ) and healthy matched controls ( $n = 15$ ), but found that meal consumption resulted in significantly decreased cardiac IAcc for the participants with anorexia nervosa. The ED

group also had significantly greater cardiorespiratory magnitude compared to the control group during meal anticipation.

Overall, a substantial body of literature indicates that EDs are associated with deficits in explicit components of interoception, specifically characterised by lower IAW and cardiac IAcc. One interpretation of these findings is that body image disturbances are associated with, or possibly even driven by, altered interoceptive processing (Badoud & Tsakiris, 2017; see also Barca & Pezzulo, 2020). This interpretation is supported by findings from neuroimaging studies, which have shown altered functioning of the insula in participants with EDs during a range of body image-related tasks (e.g., Friedrich et al., 2010; Mohr et al., 2010, 2011; Sachdev et al., 2008). Nevertheless, it is important to note that causal inferences remain speculative (Badoud & Tsakiris, 2017), given that the extant literature is largely cross-sectional.

### **1.3.3. Evidence from non-clinical studies**

To date, a limited number of studies have examined the direct associations between components of interoception and body image in non-clinical populations. Overall, this body of research largely supports the hypothesis that there are associations between interoception and body image. Specifically, regarding facets of negative body image, Emanuelsen and colleagues (2014) found that lower cardiac IAcc was associated with significantly higher body dissatisfaction ( $r = -.40, -.29$ ) in samples of healthy Norwegian high school students ( $N = 82$ ) and Hungarian university students ( $N = 70$ ), respectively. Similarly, Ainley and Tsakiris (2013) demonstrated that British female university students ( $N = 50$ ) with lower cardiac IAcc were more likely to adopt an outsider's perspective and evaluate their bodies based upon appearance, rather than functional, capabilities (i.e., they self-objectified). Self-objectification has also been associated with facets of IAW: Myers and Crowther (2008) found a significant correlation between self-objectification and self-reported perceptions of

hunger and satiety cues in a sample of college women ( $r = .21$ ,  $N = 195$ ). However, more recently, Drew and colleagues (2020) found no significant associations between cardiac IAcc and body image dissatisfaction at a baseline timepoint or eight-weeks later in a combined sample of Hungarian ( $n = 38$ ) and Norwegian ( $n = 59$ ) participants. Nevertheless, it is possible that these findings are artefactual: the authors used translated measures that had not been psychometrically assessed and scores for two different national and linguistic groups were combined and compared without prior assessment of the measures for invariance across the groups. Relatedly, Zamariola and colleagues (2017) found no statistically significant differences between groups of healthy, young women with either high ( $n = 26$ ) or low ( $n = 25$ ) cardiac IAcc on perceptual assessments of body size estimation accuracy. However, it is possible that these findings are also artefactual, because the measure utilised (the ‘Body Image Revealer’ task) had not been previously validated and no indices of validity or reliability were reported.

A smaller body of research also suggests that greater IAw and IAcc are associated with more positive body image, but this remains a nascent area of research. Duschek and colleagues (2015) asked healthy Austrian participants with accurate ( $n = 30$ ) and poor ( $n = 30$ ) cardiac perception to complete the Attractive/Self-Confidence subscale from the German Body Appraisal Inventory (Brahler et al., 2000), which includes items assessing body satisfaction (e.g., “I am proud of my body”). Overall, participants with high IAcc exhibited significantly higher bodily satisfaction in comparison to the low IAcc group. Meanwhile, Oswald and colleagues (2017) demonstrated that IAw partially mediated the relationship between body appreciation and intuitive eating in Australian female university students ( $N = 200$ ). Finally, across two samples ( $N = 139, 133$ ), Daubenmier (2005) found that body satisfaction was significantly correlated with the awareness of interoceptive signals ( $r = .21, .23$ ) and responsiveness to interoceptive signals ( $r = .52, .41$ ).

#### **1.4. Motivation for the thesis**

From the reviews presented in Sections 1.3.2 and 1.3.3, it can be concluded that the available literature largely supports the existence of relationships between interoception and body image in both clinical and community samples. Such findings could have important applications: a more comprehensive understanding of the relationship between the two constructs could lead to the development of novel interventions that reduce body disturbances and/or promote positive body image by improving bodily awareness. However, if such a research direction is to be pursued, a number of oversights within the extant literature need to be rectified. In particular, at the point of PhD commencement, there were three key areas that the available literature had not adequately addressed.

Firstly, the majority of research on the topic is focused on the relationship between interoception and facets of negative body image (in particular, a psychopathological focus on body image disturbances), neglecting facets of positive body image. This is problematic because, as Tylka (2018) indicated, attention toward alleviating symptoms of negative body image, without considering facets of positive body image, results in clinical practices that are inadequate for the promotion of health and well-being as they relate to embodiment. Indeed, the benefits of body image therapies aimed at reducing symptoms of negative body image, without attempting to enhance aspects of positive body image, may be limited (Guest et al., 2019; Tylka, 2018). Furthermore, in the few studies that have explored the relationship between interoception and positive body image (Daubenmier, 2005; Duschek et al., 2015; Oswald et al., 2017), only singular facets of positive body image were examined, despite evidence to suggest that positive body image consists of multiple dimensions with minimal conceptual overlap (see Section 1.2.1). Therefore, unique associations between components of interoception and facets of positive body image, which may represent novel intervention targets, have been overlooked.

Similarly, the available research exploring interoception and body image has predominantly examined singular facets of IAW and IAcc. In the case of IAW, research suggests that there are a number of dimensions in addition to the basic awareness of internal signals, including differing elements of regulation, appraisal, and adaptive and maladaptive modes of attention towards bodily signals (Mehling, 2016; Mehling et al., 2009, 2012; see Section 1.1.1). However, the majority of the body image research has focused exclusively upon the perceptual aspect, which neglects distinctions between, for example, an anxiety-driven attention style and a more mindful attention style towards interoceptive cues (Mehling, 2016). These differences can have important implications for outcome variables. For example, the valence of responses to cardiac signals (i.e., whether they were experienced as unpleasant or pleasant) has been shown to negatively predict facets of intuitive eating, independent of cardiac perception accuracy (Herbert et al., 2013). Moving on to consider IAcc, associations between body image and IAcc have only been explored within the cardiac domain (e.g., Duschek et al., 2015; Emanuelsen et al., 2015; Pollatos et al., 2008; Pollatos, Herbert, Berberich et al., 2016), which is problematic for the reasons delineated in Section 1.1.1. It is plausible that other bodily domains, such as the sensitivity to gastric interoceptive signals, might be more relevant to facets of body image, particularly given the documented associations with both disordered (Brown et al., 2017; Daubenmier, 2005; Myers & Crowther, 2008) and intuitive eating styles (Oswald et al., 2017).

A final issue is related to homogenous sampling across studies, which limits the extent to which findings could be applied to more demographically diverse populations. Of note, all of the available research examining the associations between interoception and body image has been conducted in North America and Western Europe, and most studies have relied on small samples of predominantly young female university students and young female clinical samples (Badoud & Tsakiris, 2017, see Sections 1.3.2 and 1.3.3). As such, it is not

clear whether the extant findings are applicable to more diverse samples, particularly given that culture, age, and gender have been shown to account for variance in both interoception and body image separately (see Sections 1.1.2 to 1.1.4).

#### **1.4.1. Research questions**

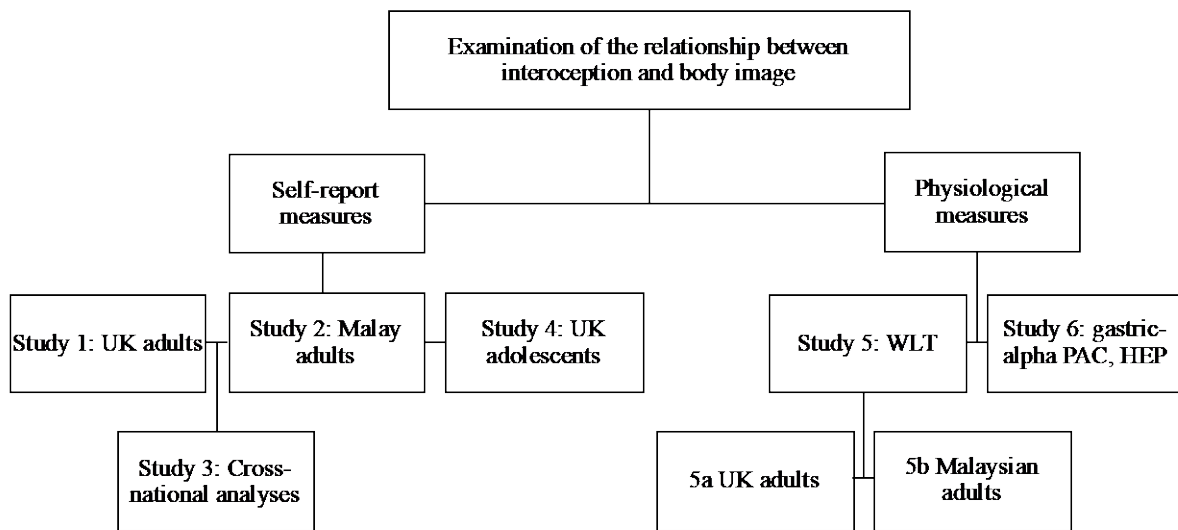
The aim of the present research was to add to extant knowledge by addressing the three aforementioned limitations of the available literature. To summarise, the primary research questions were:

What is the relationship between interoception and body image? Further:

- 1) Are the relationships robust across facets of positive and negative body image?
- 2) Are the relationships robust across components of interoception?
- 3) Are the relationships robust after accounting for the effects of culture, age, and gender?

#### **1.4.2. Research structure**

I addressed the research questions through a series of six studies, which fall into two conceptual groups (see Figure 1). The first four studies explored relationships between facets of body image and self-reported IAw in samples of adults and adolescents from the United Kingdom (UK), as well as Malaysian adults. These samples were selected to address the aforementioned limitation of sample homogeneity within the extant literature. Across all four studies, IAw was assessed using the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), which was selected because, at the point of commencing this research, it was the only available measure that could distinguish between perceptual, cognitive and affective components of IAw (Mehling, 2016; Mehling et al., 2012). Similarly, to reflect the multidimensional nature of body image, the studies included measures of positive and negative body image, which had been validated for use with the respective samples.



*Figure 1.* An overview of the 6 studies, organised by research methodology. WLT = Water Load Test, PAC = Phase-Amplitude Coupling, HEP = Heartbeat Evoked Potential.

The final two studies explored the relationships between facets of body image and explicit components of IAcc and IS, and implicit components of interoception across gastric and cardiac domains. Specifically, Study 5 examined relationships between measures of positive and negative body image and IS and IAcc in the gastric domain in samples of UK and Malaysian adults. Finally, Study 6 examined associations between an implicit component of gastric interoception and body image by assessing whether the degree of coupling between the activity in the stomach and brain (phase-amplitude coupling; PAC) is associated with measures of positive and negative body image in adults from the UK. In the same study, potential relationships between the magnitude of the brain’s response to heart activity (heartbeat evoked potential; HEP) and measures of positive and negative body image were also examined.

## **SECTION A. EXAMINING ASSOCIATIONS BETWEEN FACETS OF INTEROCEPTIVE AWARENESS AND BODY IMAGE**

### **2. Study 1: An examination of associations between facets of interoceptive awareness and body image in adults from the United Kingdom<sup>1</sup>**

#### **2.1. Introduction**

As I outlined in Section 1.4, an important limitation of the extant research and theorising concerning the associations between interoception and body image is that both constructs have generally been treated as unidimensional, which is a significant oversimplification given the body of evidence that both constructs are multidimensional (see Sections 1.1.1 and 1.2.1). More specifically, the majority of the extant literature has examined the perception of interoceptive cues in relation to body image (see Sections 1.3.2 and 1.3.3) without distinguishing between, for example, an anxiety-driven attention style and a more mindful attention style towards interoceptive cues (Mehling, 2016), which could uniquely contribute to the association between IAw and body image. Indeed, the way in which interoceptive signals are valued and responded to, but not necessarily the tendency to notice such stimuli, has been found to mediate the relationship between self-objectification and disordered eating attitudes in women (Daubenmier, 2005) and to partially mediate the relationship between body appreciation and intuitive eating in women (Oswald et al., 2017).

In a systematic review of the available self-report measures of IAw, Mehling and colleagues (2009) concluded that neither of the instruments that performed well psychometrically – the Body Awareness Questionnaire (Shields et al., 1989) and the Private Body Consciousness Subscale of the Body Consciousness Questionnaire (Miller et al., 1981)

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<sup>1</sup> This study was published as follows: Todd, J., Aspell, J. E., Barron, D., & Swami, V. (2019). Multiple dimensions of interoceptive awareness are associated with facets of body image in British adults. *Body Image*, 29, 6-16. <https://doi.org/10.1016/j.bodyim.2019.02.003>

– were able to distinguish between the beneficial (e.g., mindful) and maladaptive (e.g., anxiety driven) modes of attention towards internal bodily signals. It was also not possible to gain full coverage of the various dimensions of IAw that were reflected in the literature using any combination of the instruments under scrutiny. Therefore, Mehling and colleagues (2012) developed a new theoretical framework on IAw (the Multidimensional Assessment of Interoceptive Awareness; MAIA), which comprises eight dimensions: the ability to notice positive, negative and neutral bodily sensations (i.e., Noticing subscale); the ability to sustain attention towards such sensations (Attention Regulation subscale); the awareness of the relationship between emotional and bodily states (Emotional Awareness subscale); the use of attention to bodily sensations to regulate distress (Self-Regulation subscale); the inclination to attend to bodily sensations for insight (Body Listening subscale); the degree to which the body is experienced as a ‘safe’ and ‘trustworthy’ source of information (Trusting subscale); the tendency to attend to or ignore sensations of pain or discomfort (Not-Distracting subscale); and, finally, the extent to which a person worries about or catastrophises sensations of pain or discomfort (Not-Worrying subscale).

Outside of the present doctoral research, explorations of how the eight dimensions of IAw specified by Mehling and colleagues (2012) relate to facets of body image are limited to one clinical study. In a psychometric assessment of the MAIA using a sample of individuals with eating disorders, Brown and colleagues (2017) found that scores for the Not-Distracting and Trusting subscales were inversely associated with all subscales of the Eating Disorder Examination Questionnaire (Fairburn & Beglin, 1994), including the Shape Concern and Weight Concern subscales. Specifically, Brown and colleagues (2017) reported that individuals with the greatest shape and weight concerns, respectively, tended to distract themselves from uncomfortable body sensations, and evidenced lower levels of trust in their

internal bodily signals. Similarly, the ability to use attention towards bodily sensations to regulate distress also approached significance as a negative predictor of weight concern.

When considered altogether, the results from previous research (i.e., Brown et al., 2017; Daubenmier, 2005; Oswald et al., 2017) preliminarily suggest that appraisals of interoceptive cues are associated with body image, and may even be more closely aligned with facets of body image than the tendency to notice interoceptive stimuli. However, it was not clear whether these findings would generalise to samples that are nonclinical or more diverse in terms of age and gender.

I also highlighted in Section 1.4 that the extant research and theorising on associations between interoception and body image are insufficient with regard to the consideration of potential relationships between facets of interoception and positive body image, which could represent novel intervention targets (Tylka, 2018). Outside of the publications arising from the present doctoral thesis, associations between interoception and facets of positive body image have only been examined in three studies to date, one of which (Duschek et al., 2015) examined cardiac IAcc using a method that has been recently challenged (see Section 1.1.1). In the context of the limited available literature, it is plausible that positive relationships will exist between many facets of IAw and positive body image. For example, the tendency to notice and sustain attention towards interoceptive signals could reinforce the positive functions that the body performs and reduce susceptibility to self-objectification (Daubenmier, 2005; see also Ainley & Tsakiris, 2013). It could also be posited that the extent to which bodily signals are trusted will be positively associated with positive body image (Brown et al., 2017; Oswald et al., 2017).

### **2.1.1 Aims**

The primary aim of Study 1 was to expand the available literature considering relationships between body image and interoception (see Sections 1.3.2 and 1.3.3) by

exploring the explanatory power of multidimensional IAw. I was particularly keen to explore how the dimensions of IAw assessed by the MAIA might be related to facets of positive body image, given the paucity of research investigating relationships between interoception and positive body image more generally. To that end, I focused on a wider set of positive body image variables (i.e., body appreciation, body pride, and functionality appreciation) than has been explored previously (Daubenmier, 2005; Duschek et al., 2015; Oswald et al., 2017), using psychometrically-valid instruments designed specifically to measure these constructs. Although there are a range of indices of positive body image that could have been utilised (for a review, see Webb et al., 2015), I selected these facets of positive body image because research indicates that they are core facets of the positive body image construct, and that this combination of measures provides broad coverage of the construct (Swami, Furnham, et al., 2020).

I also elected to examine relationships between scores on the MAIA and two further negative body image variables, namely overweight preoccupation and appearance orientation. I sought to explore the relationship between overweight preoccupation and the MAIA because it has not yet been directly explored in nonclinical participants, though unique relationships between facets of the MAIA and weight concern have been identified in a clinical sample (Brown et al., 2017). Meanwhile, I sought to examine appearance orientation because findings related to IAcc and IAw in the extant literature have been mixed. Appearance orientation, which assesses the importance and investment an individual places on their appearance, can be considered an index of self-objectification (Davis et al., 2001; Moradi & Huang, 2008), and the extant theorising (outlined in Section 1.3.1) would suggest that focus upon exteroceptive appearance should be associated with reduced IAcc and IAw. However, appearance orientation has been associated with cardiac perception in both positive (Duschek et al., 2015) and negative directions (Ainley & Tsakiris, 2013). Therefore, I

included appearance orientation in the present work to explore whether multidimensional IAw would provide some clarity.

Furthermore, a number of further limitations affect the extant literature examining relationships between IAw and indices of body image, including a reliance on small samples of (predominantly female) university students and a paucity of research considering nonclinical populations (see Section 1.4). Thus, as a final aim, I sought to address these limitations in the present study by recruiting a large sample of women and men, with a wide age range that would be more representative of age variations in community samples. Due to the well-documented effects of gender, age, and BMI on indices of body image (see Sections 1.2.2 to 1.2.4), I sought to examine the extent to which dimensions of IAw would be significantly associated with outcome measures once gender, age, and BMI had been accounted for.

### **2.1.2. Hypotheses**

The MAIA Noticing subscale assesses the ability to notice interoceptive signals, rather than the valence or purpose of such attention, and can therefore be considered as the subscale most akin to measures of IAw that have been utilised in the extant literature (Mehling, 2016). Therefore, I first hypothesised that the Noticing subscale would be negatively associated with overweight preoccupation and positively associated with the positive body image indices. Given the contrasting evidence in the available literature, it was not clear whether scores on the Noticing subscale would be positively or negatively associated with appearance orientation. Secondly, I hypothesised that scores on the MAIA Trusting, Not-Worrying, and Not-Distracting subscales – which assess adaptive and maladaptive attention-styles toward internal bodily signals (Mehling, 2016) – might be more closely associated with overweight preoccupation and appearance orientation (in a negative direction) and the positive body image indices (in a positive direction) than the Noticing

subscale (Daubenmier, 2005; Oswald et al., 2017). Similarly, I expected that scores on the Attention Regulation, Self-Regulation, and Body Listening subscales – which have been collectively referred to as regulatory aspects of IAW (Mehling, 2016) – would be negatively associated with overweight preoccupation and appearance orientation, and positively associated with the positive body image indices. Finally, it was not clear whether significant relationships would emerge between the body image indices and the remaining MAIA dimension (Emotional Awareness – awareness of the connection between emotional and bodily states), but this was included in preliminary analyses for exploratory reasons, given the dearth of research in the area.

## **2.2. Method**

### **2.2.1. Participants**

The sample ( $N = 646$ ) consisted of 199 men and 446 women, and one person who described their gender as ‘other.’ All participants were citizens and residents of the UK. The participants were aged between 18 and 76 years ( $M = 38.92$ ,  $SD = 11.71$ ) and the majority of participants reported their ethnicity as White (92.4%; Asian or British Asian = 3.1%; Black or African Caribbean = 1.9%; other = 2.7%). Self-reported BMI values ranged from 15.22 to 49.57 ( $M = 27.25$ ,  $SD = 6.08$ ). For women, mean BMI was 26.10 and for men mean BMI was 27.72. Both values are comparable to the most recent UK averages for women and men ( $M = 27.2$  and  $27.4$ , respectively; National Health Service Digital, 2016). In terms of educational qualifications, 16.7% had completed minimum secondary schooling, 27.1% had completed A-Levels or further education equivalents, 36.7% had an undergraduate degree, 15.6% had a postgraduate degree, 1.4% were still in full-time education, and 2.5% had some other qualification. In terms of relationship status, 40.1% were married, 24.9% were partnered and cohabiting, 20.7% were single, 6.8% were partnered but not cohabiting, 6.3% considered

themselves as single but dating, and 1.2% reported some other status. The majority of the sample (92.4%) reported their sexual orientation as being heterosexual.

### 2.2.2 Measures

**Interoception.** IAw was assessed using the MAIA (Mehling et al., 2012), a 32-item self-report measure that comprises eight subscales. The MAIA provides a multidimensional profile of IAw, with each subscale assessing a different dimension of IAw. The Noticing subscale assesses the subjective awareness of body sensations (4 items). The Attention Regulation subscale assesses the ability to control and maintain attention towards bodily sensations (7 items). The Emotional Awareness subscale assesses the awareness of the relationship between emotional and bodily states (5 items). The Self-Regulation subscale assesses whether a person uses attention to bodily sensations to regulate distress (4 items). The Body Listening subscale assesses how often a person actively attends to their bodily sensations for insight (3 items). The Trusting subscale assesses the extent to which a person experiences their body as a ‘safe’ and ‘trustworthy’ source of information (3 items). The Not-Distracting subscale assesses how often a person tends to ignore sensations of pain or discomfort (3 items). Finally, the Not-Worrying subscale assesses the extent to which a person worries about or catastrophizes sensations of pain or discomfort (3 items).

Responses for all MAIA items were given on a 6-point scale, ranging from *never* (0) to *always* (5). Scores for each subscale were computed as the mean of all associated items, and higher scores reflect greater IAw. Scores on the MAIA have adequate levels of internal consistency and good convergent and discriminant validity (Brown et al., 2017; Mehling, 2016; Mehling et al., 2012). Throughout the present doctoral thesis, I have estimated internal consistency using McDonald’s  $\omega$  and its associated 95% CI, which performs more favourably than Cronbach’s alpha for the analysis of dichotomous or Likert-type data (e.g., Zumbo et al., 2007). Values greater than .70 reflect adequate internal reliability (Dunn et al., 2014). Values

for each MAIA subscale were as follows: Noticing = .69 (95% CI = .63, .72); Attention regulation = .86 (95% CI = .84, .88); Emotional Awareness = .80 (95% CI = .77, .83); Self-Regulation = .84 (95% CI = .82, .86); Body Listening = .74 (95% CI = .70, .77); Trusting = .79 (95% CI = .76, .82); Not-Distracting = .52 (95% CI = .43, .59); Not-Worrying = .61 (95% CI = .55, .67). Although the latter two values were consistent with previous research (Mehling, 2016; Mehling et al, 2018), they are indicative of poor internal consistency (Gaderman et al., 2012) and so the Not-Distracting and Not-Worrying subscales were excluded from further analyses<sup>2</sup>.

**Body appreciation.** Body appreciation was assessed using the Body Appreciation Scale-2 (BAS-2; Tylka & Wood-Barcalow, 2015b). The BAS-2 comprises 10 items that assess body-related positive opinions and acceptance (regardless of actual physical appearance), respect for the body by engaging in healthy behaviors, and protection of body image in relation to sociocultural appearance ideals. All items were rated on a 5-point scale, ranging from 1 (*never*) to 5 (*always*), and an overall score was computed as the mean of all items. Higher scores on this scale reflect greater body appreciation. Scores on the BAS-2 have a 1-dimensional structure, are invariant across gender, and have adequate internal consistency and test-retest reliability over a 3-week period, as well as good patterns of convergent, incremental, and discriminant validity (for reviews, see Swami, 2018; Tylka & Wood-Barcalow, 2015b). In the present study,  $\omega$  for BAS-2 scores was .95 (95% CI = .95, .96).

**Functionality appreciation.** To assess functionality appreciation, I asked participants to complete the Functionality Appreciation Scale (FAS; Alleva et al., 2017). The FAS is a 7-

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<sup>2</sup> For the interested reader, the correlations between the body image indices and the MAIA Not-Distracting subscale ranged from -.03 to -.08. Correlations between the MAIA Not-Worrying subscale and the body image indices ranged from .03 to -.22. Due to the low reliability of the scales, these results require validation in future work. However, in the present work, it is unlikely that either scale would have emerged as significant predictors in the hierarchical regressions, given the magnitude of the correlations between the remaining MAIA scales and the body image indices (see Tables 2-6).

item scale that assesses the extent to which an individual appreciates and respects the body for the functions it is capable of performing. Items were rated on a 5-point scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) and an overall score was computed as the mean of all items, with higher scores reflecting greater functionality appreciation. Scores on the FAS have a 1-dimensional structure, are invariant across gender, have adequate internal consistency and test-retest reliability over a 3-week period, and good convergent, discriminant, and incremental validity (Allewaert et al., 2017). In the present study,  $\omega$  for FAS scores was .90 (95% CI = .88, .91).

**Body pride.** To measure body pride, I used the Authentic Pride subscale of the Body and Appearance Self-Conscious Emotions Scale (BASES; Castonguay et al., 2014). This is a 6-item measure that characterises body pride as personal appearance-related achievements and behaviours. Items for this subscale were rated on a 5-point scale, ranging from 1 (*never*) to 5 (*always*). The scale is scored by calculating the mean of all 6 items and higher scores reflect greater body pride. Castonguay et al. (2014) reported that BASES scores had good factorial validity and that subscale scores had good test-retest reliability over a 2-week period, as well as good construct validity. In the present study,  $\omega$  for Authentic Pride subscale scores was .96 (95% CI = .95, .96).

**Additional body image measures.** Two subscales from the Multidimensional Body-Self Relations Questionnaire-Appearance Scales (MBSRQ-AS; Cash, 2000) were used to assess appearance orientation and overweight preoccupation, respectively. The Appearance Orientation subscale assesses the investment and importance individuals place on their appearance, with higher scores reflecting greater importance and extensive grooming behaviors and lower scores reflecting apathy towards personal appearance (12 items). The Overweight Preoccupation subscale assesses weight-related anxiety and vigilance, as well as eating restraint (4 items), with higher scores reflecting greater overweight preoccupation.

Cash (2000) reported that scores on the MBSRQ-AS have adequate internal consistency and 1-month test-retest reliability for both men and women. Here,  $\omega$  for Appearance Orientation and Overweight Preoccupation scores were .89 (95% CI = .87, .90) and .80 (95% CI = .77, .82), respectively.

**Demographics.** Participants were requested to provide demographic details, consisting of gender, age, ethnicity (based on categories in the UK census), educational attainment, relationship status, sexual orientation, height, and weight. I used the final two items to compute self-reported BMI as  $\text{kg/m}^2$ .

### 2.2.3. Procedure

The study was approved by the Anglia Ruskin University departmental ethics committee (approval number: EHPGR-10). Participants were recruited via the Prolific Academic website on May 18-19, 2018, and the survey was hosted on Qualtrics. Prolific Academic is a crowdsourcing Internet marketplace where individuals complete academic surveys in return for monetary compensation. Such websites have been shown to produce valid and reliable body image data (Gardner et al., 2012). Samples recruited from sites such as these are also more diverse in terms of age, ethnicity, and sexual orientation in comparison to college samples (Buhrmester et al., 2011). My intention was to recruit a homogeneous sample in terms of cultural and national identity, so eligibility was limited to UK citizens of adult age. In addition, participation was limited to those who had good approval ratings from previous studies (an Academic Prolific score of  $\geq 96$ ), and Academic Prolific ID codes, along with Internet Protocol (IP) addresses, were examined to ensure that no participant took the survey more than once. All participants received brief introductory information about the project and provided digital informed consent. Participants completed the measures described above in a counterbalanced order and anonymously. Within the survey, participants were prompted to answer omitted questions, but were still free to leave these blank if they chose to

do so. Participants completed the survey in 12 minutes on average and were paid £1.00 as remuneration. All participants received written debriefing information at the end of the survey, which included the study aims and hypotheses.

## **2.3. Results**

### **2.3.1. Data screening**

There were missing data only for participant height (0.5%), weight (8.2%), and age (8.0%). I also removed improbable BMI values ( $< 12$  or  $> 50$  kg/m<sup>2</sup>; 2% of the total data set) and treated these as missing data. Little's (1988) MCAR analysis revealed that these data were missing completely at random,  $\chi^2(20) = 43.422, p = .784$ . Therefore, I replaced missing values using the expectation-maximisation method. Further data screening did not reveal any unduly influential univariate or multivariate outliers.

### **2.3.2. Descriptive statistics**

Means and standard deviations for all variables are reported in Table 2. As can be seen, significant gender differences (after Bonferroni correction,  $p = .05/13 = .0038$ ) were identified for the MAIA Trusting subscale (men reported significantly greater experience of their bodies as safe and trustworthy in comparison to women), body appreciation (men had significantly greater body appreciation), body pride (men reported significantly greater body pride), appearance orientation (women reported significantly more investment in their appearance), overweight preoccupation (women reported significantly greater levels of overweight preoccupation), and BMI (with men having significantly higher BMIs than women).

Table 2

*Means, Standard Deviations, and Bivariate Correlations between the Different Measures for Women (Lower Diagonal) and Men (Upper Diagonal).*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) MAIA Noticing		.56**	.69**	.56**	.60**	.41**	.25**	.35**	.18**	.17*	.07	-.05	.05
(2) MAIA Attention Regulation	.63**		.44**	.72**	.61**	.59**	.47**	.42**	.42**	.23**	.02	.09	.02
(3) MAIA Emotional Awareness	.71**	.56**		.51**	.56**	.26**	.20**	.32**	.20**	.21**	.05	-.07	.07
(4) MAIA Self- Regulation	.50**	.72**	.53**		.55**	.57**	.43**	.33**	.39**	.20**	.02	.04	.03
(5) MAIA Body Listening	.66**	.69**	.65**	.60**		.36**	.28**	.28**	.26**	.19**	.17*	.04	.05
(6) MAIA Trusting	.46**	.62**	.48**	.61**	.51**		.69**	.59**	.46**	.08	-.21**	-.05	-.01
(7) Body appreciation	.35**	.53**	.38**	.57**	.41**	.70**		.67**	.64**	.10	-.32**	-.24**	-.09

(8) Functionality appreciation	.39**	.39**	.43**	.42**	.37**	.52**	.63**		.47**	.14	-.22**	-.18*	-.07
(9) Body pride	.31**	.41**	.34**	.42**	.34**	.49**	.68**	.45**		.46**	.03	-.08	-.16*
(10) Appearance orientation	.23**	.09	.23**	.07	.13**	.12*	.12*	.22**	.37**		.37**	<.01	-.22**
(11) Overweight preoccupation	.08	-.08	.10*	-.14**	-.02	-.20**	-.36**	-.17**	-.14**	.37**		.35**	-.01
(12) BMI	-.06	-.11*	-.03	-.12**	-.03	-.19**	-.32**	-.18**	-.27**	.03	.32**		.15*
(13) Age	.02	.03	-.04	.05	.04	-.01	.06	.03	-.10*	-.19**	-.17**	.05	
<i>M</i> (Men)	3.21	2.67	3.10	2.77	2.38	3.29	3.40	4.09	2.85	2.94	2.50	27.76	37.76
<i>SD</i> (Men)	0.09	0.09	1.00	1.02	1.10	0.99	0.06	0.06	0.89	0.71	0.97	6.46	11.97
<i>M</i> (Women)	3.22	2.50	3.23	2.57	2.44	2.88	3.06	3.96	2.60	3.31	3.16	26.10	39.46
<i>SD</i> (Women)	0.89	0.92	0.99	1.06	1.05	1.04	0.86	0.07	0.91	0.72	1.00	4.97	11.57
<i>t</i>	0.07	2.38	1.57	2.25	0.79	4.69	4.73	2.18	3.18	6.02	7.93	3.57	1.70
<i>p</i>	.943	.018	.118	.025	.432	†<.001	†<.001	.029	†.002	†<.001	†<.001	†<.001	.089
<i>d</i>	0.02	0.26	0.13	0.19	0.06	0.40	0.54	0.26	0.28	0.52	0.68	0.29	0.14

*Note.* Men  $n = 199$ , Women  $n = 446$ ; \* $p < .05$ . \*\* $p < .01$ . †Significant gender difference after Bonferroni correction ( $.05/13 = .0038$ ). MAIA = Multidimensional Assessment of Interoceptive Awareness, BMI = Body mass index.

### 2.3.3. Correlations

Bivariate correlations between all variables – conducted separately for women and men – are reported in Table 2. I controlled for false discovery rate (FDR) using the Benjamini and Hochberg (1995) procedure, which was computed using the *Stats* package in *R* (*R* Development Core Team, 2014). Adjusted thresholds for rejecting the null hypothesis were computed separately for women and men. For some variables, the pattern of correlations was the same for both genders: body appreciation, functionality appreciation, and body pride all had predominantly small ( $\geq .20$ ) to moderate ( $\geq .50$ ) (cf. Ferguson, 2009) positive correlations with each of the MAIA subscales. In contrast, for the MAIA Trusting subscale, correlations with body appreciation and functionality appreciation were moderate. Finally, overweight preoccupation only had a small negative correlation with the MAIA Trusting subscale.

I also observed some gender-specific effects. While appearance orientation had small positive correlations with the MAIA Emotional Awareness subscale for both genders, there was a small positive correlation with the MAIA Noticing subscale for women only, and small positive correlations with the Attention Regulation and Self-Regulation subscales for men only. Similarly, BMI had a small negative correlation with body appreciation, and small positive correlation with overweight preoccupation for both genders, but a small negative correlation with body pride was observed only for women. Finally, there was a small negative correlation between age and appearance orientation for men.

Fischer's *r*-to-*z* transformation was computed to examine whether there were statistically significant differences in the correlation coefficients across gender (see Table 3). Within the key relationships of interest (i.e., between the MAIA variables and the body image variables) there were no significant differences across gender after controlling for FDR.

Table 3

*Absolute Fischer's  $z_{observed}$  Values for Gender Group Comparison of the Correlation Coefficients.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) Noticing		1.27	0.46	0.97	1.16	0.72	1.28	0.54	1.62	0.73	0.12	0.12	0.35
(2) Attention Regulation			1.87	0.00	1.62	0.55	0.93	0.42	0.14	1.68	1.17	2.34*	0.12
(3) Emotional Awareness				0.32	1.66	2.99	2.30	1.49	1.76	0.25	0.59	0.47	1.28
(4) Self-Regulation					0.87	0.72	2.19	1.22	0.42	1.55	1.88	1.87	0.23
(5) Body Listening						2.17*	1.72	1.17	1.03	1.03	2.23	0.82	0.12
(6) Trusting							0.23	1.18	0.45	0.47	0.12	1.66	0.00
(7) Body appreciation								0.81	0.83	0.24	0.53	1.01	1.75
(8) Functionality appreciation									0.3	0.96	-0.61	0.00	1.17
(9) Body pride										1.27	1.99	2.29*	0.71
(10) Appearance orientation											0.00	0.29	0.37
(11) Overweight preoccupation												0.39	1.18
(12) BMI													1.18
(13) Age													

*Note.*  $N = 646$ . Men,  $n = 199$ . Women,  $n = 446$ . \* $p < .05$ . BMI = Body mass index.

#### **2.3.4. Hierarchical multiple regression analyses**

To assess which facets of IAW predicted body image, five separate multiple hierarchical regression analyses were conducted, with body appreciation, functionality appreciation, body-related pride, appearance orientation, and overweight preoccupation as the criterion variables. Because none of the correlation coefficients differed significantly across gender, I chose to conduct hierarchical multiple regression analyses utilising the data from both men and women (controlling for gender in the first step) rather than conducting regressions separately for each gender. BMI and age were also included in a first step, to examine which MAIA variables significantly predicted additional variance in body image once these demographic variables had been taken into consideration. MAIA subscale scores were then entered as predictor variables in a second step. Variance inflation factors (VIFs) below 10 indicate that multicollinearity is not a limiting issue (Hair et al., 1995). In the present study VIFs for all five regressions were  $\leq 2.92$ . Results for body appreciation and functionality appreciation are reported in Table 4, results for body-related pride are reported in Table 5, and results for appearance orientation and overweight preoccupation are reported in Table 6.

Table 4

*Multiple Hierarchical Regressions with Body Appreciation and Functionality Appreciation as Criterion Variables.*

Step	Variable	Body appreciation					Functionality appreciation				
		B	SE	$\beta$	<i>t</i>	<i>p</i>	B	SE	$\beta$	<i>t</i>	<i>p</i>
Step 1		$F(3, 642) = 29.16, p < .001, \text{Adj. } R^2 = .12$					$F(3, 642) = 9.27, p < .001, \text{Adj. } R^2 = .04$				
	BMI	-0.04	0.01	-.30	-7.93	< .001	-0.02	0.01	-.18	-4.71	< .001
	Gender	-0.28	0.07	-.15	-3.95	< .001	-0.10	0.06	-.07	-1.77	.077
	Age	0.01	0.01	.03	0.90	.371	0.01	0.01	.02	0.41	.680
Step 2		$F(9, 636) = 90.51, p < .001, \text{Adj. } R^2 = .56, \Delta \text{Adj. } R^2 = .44, \Delta F$					$F(9, 636) = 36.86, p < .001, \text{Adj. } R^2 = .33, \Delta \text{Adj. } R^2 = .30, \Delta F$				
		$p < .001$					$p < .001$				
	BMI	-0.03	0.01	-.20	-7.44	< .001	-0.01	0.01	-.11	-3.28	.001
	Gender	-0.07	0.05	-.04	-1.46	.145	-0.02	0.05	-.01	-0.31	.759
	Age	0.01	0.01	.02	0.91	.365	0.01	0.01	.01	0.41	.682
	Noticing	-0.10	0.04	-.01	-2.35	.019	0.05	0.04	.07	1.28	.202
	Attention	0.09	0.04	.10	2.20	.028	0.01	0.04	.01	0.19	.847
	Regulation										
	Emotional	0.02	0.04	.03	0.69	.494	0.12	0.03	.18	3.62	< .001
	Awareness										
	Self-Regulation	0.12	0.03	.14	3.50	.001	0.01	0.03	.01	0.27	.788
	Body Listening	0.01	0.03	.02	0.41	.704	-0.01	0.03	-.02	-0.36	.723
	Trusting	0.45	0.03	.54	15.12	< .001	0.27	0.03	.42	9.50	< .001

*Note.*  $N = 646$ . BMI = Body mass index.

Table 5

*Multiple Hierarchical Regression with Body Pride as the Criterion Variable.*

Step	Variable	Authentic pride					
		B	SE	$\beta$	<i>t</i>	<i>p</i>	Semi-partial correlation
Step 1		$F(3, 642) = 16.99, p < .001, \text{Adj. } R^2 = .07$					
	BMI	-0.03	0.01	-.22	-5.60	< .001	-.213
	Gender	-0.18	0.08	-.09	-2.32	.021	-.088
	Age	-0.01	0.01	-.10	-2.32	.010	-.099
Step 2		$F(9, 636) = 32.12, p < .001, \text{Adj. } R^2 = .30, \Delta\text{Adj. } R^2 = .23, \Delta F p < .001$					
	BMI	-0.02	0.01	-.15	-4.52	< .001	-.149
	Gender	-0.05	0.07	-.02	-0.68	.497	-.022
	Age	-0.01	0.01	-.11	-3.27	.001	-.107
	Noticing	-0.07	0.05	.07	-1.34	.180	-.044
	Attention	0.13	0.06	.13	2.27	.024	.075
	Regulation						
	Emotional	0.07	0.05	.07	1.44	.149	.047
	Awareness						
	Self-Regulation	0.11	0.04	.12	2.38	.017	.078
	Body Listening	0.02	0.04	.02	0.43	.664	.014
	Trusting	0.26	0.04	.30	6.70	< .001	.220

*Note.*  $N = 646$ . BMI = Body mass index.

Table 6

*Multiple Hierarchical Regressions with Appearance Orientation and Overweight Preoccupation as Criterion Variables.*

Step	Variable	Appearance orientation					Overweight preoccupation				
		B	SE	$\beta$	<i>t</i>	<i>p</i>	B	SE	$\beta$	<i>t</i>	<i>p</i>
Step 1		$F(3, 642) = 21.95, p < .001, \text{Adj. } R^2 = .09$					$F(3, 642) = 56.13, p < .001, \text{Adj. } R^2 = .20$				
	BMI	-0.01	0.01	-.01	-0.24	.810	0.06	0.01	.32	9.13	< .001
	Gender	0.39	0.06	.25	6.53	< .001	0.60	0.08	.27	7.62	< .001
	Age	-0.01	0.01	-.20	-5.20	< .001	-0.01	0.01	-.14	-3.97	< .001
Step 2		$F(9, 636) = 12.22, p < .001, \text{Adj. } R^2 = .14, \Delta\text{Adj. } R^2 = .05, \Delta F p < .001$					$F(9, 636) = 26.11, p < .001, \text{Adj. } R^2 = .26, \Delta\text{Adj. } R^2 = .06, \Delta F p < .001$				
	BMI	< 0.01	0.01	.01	0.05	.960	0.05	0.01	.30	8.50	< .001
	Gender	0.37	0.06	.24	6.22	< .001	0.05	0.08	.22	6.21	< .001
	Age	-0.01	0.01	-.20	-5.33	< .001	-0.01	0.01	-.14	-4.13	< .001
	Noticing	0.10	0.05	.12	2.05	.041	0.16	0.06	.14	2.61	.009
	Attention	0.01	0.05	.01	0.13	.894	0.01	0.07	.01	0.095	.925
	Regulation										
	Emotional	0.11	0.04	.15	2.62	.009	0.10	0.05	.10	1.94	.053
	Awareness										
	Self-	-0.02	0.04	-.03	-0.46	.643	-0.08	0.05	-.08	-1.45	.147
	Regulation										
	Body	0.01	0.04	.01	-0.03	.976	0.04	0.05	.04	0.78	.436
	Listening										
	Trusting	0.01	0.04	.01	0.05	.964	-0.23	0.05	-.23	-4.92	< .001

*Note.*  $N = 646$ . MAIA = Multidimensional Assessment of Interoceptive Awareness, BMI = Body mass index.

## 2.4. Discussion

In this study, I sought to examine relationships between multiple dimensions of IAW and a number of facets of body image. Overall, I identified significant predictive relationships between the dimensions of IAW and all five facets of body image. After taking into consideration the variance accounted for by gender, BMI, and age, the MAIA variables accounted for 44.0% of the variance in body appreciation, 29.6% in functionality appreciation, 23.0% in body pride, 6.0% in overweight preoccupation, and 5.0% in appearance orientation. In the final models, five MAIA subscales emerged as significant predictors for at least one facet of body image. However, the final MAIA subscale – Body Listening – did not significantly predict any of the body image indices.

I first hypothesised that the Noticing subscale would be positively associated with the three positive body image variables. Correlational analyses supported this hypothesis, but in the regression models Noticing emerged as a significant predictor only for body appreciation. Contrary to expectation and previous literature (Badoud & Tsakiris, 2017), the association between Noticing and body appreciation was negative. Similarly, while I predicted that the Noticing subscale would be negatively associated with Overweight Preoccupation, in the regression model Noticing emerged as a significant positive predictor, despite the lack of a statistically meaningful correlation (Ferguson, 2009) with the Noticing subscale for women or men. The regression models show the relative contribution of Noticing to the prediction of the body image variables alongside all of the other IAW and demographic variables under scrutiny, so it is possible that once all of the other variables have been accounted for, the direction of the relationships between Noticing and Body Appreciation, and Noticing and Overweight Preoccupation, are an accurate depiction of the relationships between the variables. Nevertheless, given the positive relationship identified between Noticing and body appreciation within the correlations, it is also possible that one of the other variables may be

biasing the regression slope towards a negative effect (see Fuller, 1987). Indeed, though VIFs were all within acceptable limits, the correlations between the MAIA Noticing and the Attention Regulation and Emotional Awareness subscales were relatively high for both men and women (see Table 2).

In addition, I found that Noticing was positively correlated with appearance orientation for women and men, and this relationship was consistent within the regression model, supporting the findings of Duschek and colleagues (2015). Overall, the ability to notice interoceptive signals – when considered as an isolated variable – could be considered adaptive, in that it is positively associated with facets of positive body image, but not associated with overweight preoccupation. However, once other facets of IAw and demographic variables have been accounted for, the tendency to notice internal bodily signals appears to be more maladaptive. Indeed, the pattern of the relationships between Noticing and the body image variables within the regression models – particularly the positive relationship with appearance orientation – suggests that this variable is perhaps more reflective of a tendency towards self-surveillance.

My second hypothesis was that the MAIA Trusting, Not-Worrying, and Not-Distracting subscales would be more closely associated with facets of body image than the Noticing subscale, and that the direction of these relationships would be inverse for Overweight Preoccupation and Appearance Orientation, and direct for the positive body image indices (i.e., higher IAw scores are associated with greater positive body image). Whilst the Not-Worrying and Not-Distracting subscales could not be included in the main analyses due to poor internal consistency (addressed more fully below), the hypotheses regarding the Trusting subscale were supported for every body image facet under scrutiny except appearance orientation. Indeed, of all of the MAIA subscales, the Trusting subscale demonstrated the strongest, most consistent relationship with the body image variables,

suggesting that the extent to which interoceptive signals are trusted, and the body is deemed as a ‘safe’ place, is perhaps the most relevant facet of IAW for our understanding of positive body image. This supports previous research, which has indicated that the way in which interoceptive signals are valued and responded to might be more closely associated with facets of body image than the extent to which interoceptive cues are perceived (Brown et al., 2017; Daubenmier, 2005; Oswald et al., 2017).

My third hypothesis was that the Attention Regulation, Self-Regulation, and Body Listening subscales (the ‘regulatory’ subscales; Mehling, 2016) would be positively associated with the three positive body image variables, and negatively associated with overweight preoccupation and appearance orientation. These hypotheses were partially supported: in the regression models, the Attention Regulation and Self-Regulation subscales emerged as significant (positive) predictors for both body appreciation and body pride, but not for functionality appreciation, overweight preoccupation, or appearance orientation. Body Listening, however, did not explain a statistically significant proportion of the variance for any of the body image variables included here. Nevertheless, the ability to sustain and regulate attention towards interoceptive signals appears to be an adaptive skill: such attention towards the body may make it more likely for individuals to be able to appreciate their bodies and feel proud of their bodies. Previous research has demonstrated that attention regulation and self-regulation are modifiable skills (Bornemann et al., 2015); therefore, it is possible that these variables could represent viable therapeutic targets for promoting positive body image.

Finally, I included the MAIA Emotional Awareness subscale in the study on an exploratory basis because, in the available literature, no studies have yet explored how the dimension might be related to facets of body image in a non-clinical sample. The correlational results from the present study indicate that awareness of the association between

emotional and bodily states tended to be weakly, but positively, associated with all of the body image facets under scrutiny for men and women. For both genders, the strongest association was with functionality appreciation. Meanwhile, within the regression models, emotional awareness remained a statistically significant (positive) predictor for functionality appreciation and also emerged as a positive predictor of appearance orientation. Given the novelty of the research, it is not clear at present why emotional awareness emerged as a significant predictor for two body image indices but not the remainder; perhaps this suggests a greater underlying emotional component for functionality appreciation and appearance orientation that could be explored in future research.

Overall, previous research has demonstrated broad associations between the awareness and perceptual acuity of interoceptive signals and body image, where reduced IAw and IAcc have tended to be associated with more negative body image (Badoud & Tsakiris, 2017; see Section 1.3 for an overview). In the present work, I have demonstrated that distinct dimensions of IAw, such as the way in which interoceptive signals are appraised and regulated, have unique relationships with facets of body image. In particular, the extent to which interoceptive signals are noticed (the dimension of IAw within the present study that most closely aligns with measures used in previous body image literature; Mehling, 2016) emerged as a *negative* predictor of body appreciation, and a *positive* predictor of overweight preoccupation and appearance orientation. Meanwhile, the extent to which interoceptive signals are regarded as ‘safe’ and ‘trustworthy’ emerged as the strongest, most consistent predictor for all of the positive body image indices and overweight preoccupation. This is an important extension of previous work because the extant literature would predict that broadly increasing IAw would be clinically beneficial for groups that are known to have both low interoception and body image disturbances, such as patients with eating disorders (Pollatos et al., 2008). However, the results from the present study demonstrate that clinical protocols

would need to be more targeted, as only certain facets of IAw are positively associated with positive body image.

As a second novel contribution to the literature, I believe the present work to be the first evidence of relationships between facets of interoception and two positive body image variables: functionality appreciation and body pride. The present findings also extend the work of Oswald and colleagues (2017) – who demonstrated an association between IAw and body appreciation in female university students – by showing that this relationship is also stable in men and a more demographically-diverse sample of adults. Indeed, where previous research on the subject has tended to focus on young women (see Badoud & Tsakiris, 2017), the present study benefitted from the inclusion of both men and women of a wider age range. However, despite the broad age range, there was only weak correlation between age and appearance orientation for men, with the remainder of the effect sizes for age below the recommended minimum for a practically significant effect (Ferguson, 2009).

Nevertheless, several significant differences were observed for gender (see Table 2), predominantly for the body image variables. Of note, the effect size for overweight preoccupation ( $d = 0.68$ ) was the largest across all of the variables under scrutiny, with women tending to report greater overweight preoccupation than men. There was also a moderate effect size for appearance orientation, with women tending to report greater investment in their appearance ( $d = 0.52$ ). These observations have important ramifications within the regression models: for overweight preoccupation, MAIA variables accounted for 6% of the variance, whilst demographic factors accounted for 20% of the variance – the greatest proportion across all of the regression models – with BMI and gender making the greatest contribution (see Table 6). Similarly, I observed that a greater proportion of the variance for appearance orientation was accounted for by demographic factors (9.0%) than by all of the MAIA variables combined (5.0%), with the majority of the variance within the

demographic factors being accounted for by gender. Objectification theory (Fredrickson & Roberts, 1997) posits that Western society encourages women, more so than men, to view themselves from an outsiders' (i.e., exteroceptive) perspective, which could account for the significant effect of gender, and the lesser contribution of IAw, to the prediction of appearance orientation and overweight preoccupation. Future work could perhaps address this possibility by exploring possible mediating effects of internalisation of sociocultural appearance ideals.

#### **2.4.1. Limitations**

An important limitation of this study is the reliance upon self-report measures, some of which had poor internal consistency. While I had intended to investigate all of the eight dimensions of IAw included in the MAIA, the Not-Worrying and Not-Distracting subscales were excluded due to low internal consistency reliability. These subscales have also demonstrated suboptimal internal consistency in previous studies (for reviews, see Mehling, 2016; Mehling et al., 2018; Todd, Barron et al., 2020). This is possibly because each scale only contains three items each and five of these are the only negatively worded items within the full questionnaire. In response to this, Mehling and colleagues (2018) have recently developed the MAIA-2, which has improved psychometric properties and could be used in future research.

Relatedly, an additional limitation may be the degree to which body trust is truly distinct from facets of positive body image, particularly body appreciation. Construct overlap can be demonstrated through strong direct correlations (i.e.,  $r > .70$ ; Newman et al., 2010). In the present study, significant and strong correlations were observed between body trust and body appreciation for both women and men, respectively ( $r = .70, .69$ ), which suggests that body trust may be conceptually intertwined with body appreciation in the present sample of UK adults. While the two concepts are theoretically distinct (i.e., the MAIA Trusting

subscale measures the extent to which bodily stimuli are considered reliable and trustworthy sources of information whereas the BAS-2 assesses the degree of active appreciation and respect for one's body) there is, nevertheless, one overlap in the items of the two scales (i.e., Trusting Item #1 "I am at home in my body", and BAS-2 Item #9 "I am comfortable in my body"). Conversely, there were moderate correlations ( $r \leq .59$ ) between body trust and the remaining positive body image variables (functionality appreciation and body pride) for women and men, suggesting a small degree of overlap, but that body trust is distinct from these facets of positive body image in UK adults. Given the novelty of the current study, these findings require further scrutiny and replication. In particular, techniques such as Item Pool Visualisation might be useful for examining item commonality (e.g., Trusting Item #1 and BAS-2 Item #9) and scale commonality between the MAIA Trusting subscale and the BAS-2.

Further limitations of the present work relate to the sampling strategy. First, although Prolific Academic respondents are demographically diverse (Palan & Schitter, 2018; Peer et al., 2017), the sample should not be considered representative of the UK population. In particular, the sample was fairly homogenous in terms of ethnicity (92.4% White). A second limitation relates to the screening process for eating disorder symptomology. My intention was to assess the relationship between facets of IAW and body image in a nonclinical population, and I therefore included having a present or previous diagnosis of an eating disorder within the exclusion criteria. However, due to practical constraints, I did not include a screening questionnaire (such as the Eating Disorder Inventory-3; Garner, 2004), which could have been used to indicate data for exclusion. Therefore, it is possible that the sample includes participants who might be unaware that they meet the requirements for a clinical diagnosis, or who have not yet been formally diagnosed, and future research should seek to address this issue.

### **2.4.2. Conclusion**

In summary, the present work identified unique associations between several dimensions of IAw and five facets of body image in a population of community adult women and men. The results from the present study build on previous research, which suggests that the way in which interoceptive cues are appraised may be more closely associated with body image than the accuracy of interoceptive processing (Brown et al., 2017; Daubenmier, 2005; Oswald et al., 2017). Further work is necessary to confirm whether a causal relationship exists between IAw and body image; that is, due to the cross-sectional design utilised in the current study, this can only be inferred hypothetically at present. Indeed, whilst longitudinal research supports the assertion that early impairments in IAw are associated with later vulnerability to the development of eating disorders (Killen et al., 1996; Leon et al., 1995; Lilenfeld et al., 2006), it is also possible that relationships between the variables are bidirectional (Cook-Cottone, 2018). Nevertheless, the results from the present study could have important clinical applications. For example, groups that are known to have both low IAw and body image disturbances, such as patients with eating disorders (e.g., Eshkevari et al., 2014; Pollatos et al., 2008) could potentially benefit from nuanced interventions that increase trust in interoceptive signals, and the ability to sustain attention toward interoceptive signals as a method of regulating psychological distress. Indeed, research indicates that all three of these facets of IAw are modifiable through mindfulness-based practices (Bornemann et al., 2015).

### **3. Study 2: Examining associations between facets of interoceptive awareness and body image in Malaysian adults<sup>3</sup>**

#### **3.1. Introduction and aims**

As described in Chapter 1, interoception and body image have been explored separately (albeit, to a limited extent) in non-Western contexts. However, to date, the relationships between the two constructs have not been explored outside of Northern America and Western Europe (see Section 1.4). Given that research on interoception and body image as separate constructs has indicated regional variance (see Sections 1.1.2 and 1.2.2), it is plausible that the relationships between IAw and body image may not generalise from Western to non-Western contexts. The current research sought to explore this possibility by examining relationships between multiple facets of IAw and body image in Malaysian adults.

##### **3.1.1. The Malaysian context**

Malaysia is an interesting cultural context to examine the association between IAw and body image for several reasons. First, the conceptualisation of multidimensional IAw in Malaysia appears to be unique (i.e., MAIA scores reduce to only three dimensions in Malaysian adults, compared to eight subscales in samples from the United States and Western Europe; for an overview see Section 1.1.2, see also Todd, Barron et al., 2020). This finding suggests that IAw may depend upon local contextual factors in Malaysia. For example, there are cultural values specific to Malaysian Malays, such as *maruah* – which refers to a sense of dignity or pride regarding both self-perceptions and what others think about the individual (Goddard, 1997) – and *senang hati*, which refers to an untroubled, relaxed state of mind (Goddard, 1997). In particular, it is possible that the concept of *senang hati* has a localised impact on the extent to which Malaysians pay attention to sensations of physical discomfort. Indeed, the tendency to distract attention from sensations of discomfort appears to be

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<sup>3</sup> This study is currently under peer-review.

regarded as a positive attribute in Malaysian adults (Todd, Barron et al., 2020), which contrasts with the negative loading observed in Western samples (for a review, see Todd, Barron et al., 2020).

Malaysia is also a rapidly developing nation, with major socioeconomic development, industrialisation, and urbanisation occurring over the last few decades. These developments have had several important social implications that are relevant to body image and bodily perceptions (for overviews, see Swami, 2006; Swami et al., 2013). In particular, Swami (2006) has discussed how rapid economic advances led to the deregulation of mass media, which, in turn, triggered an increase in the prevalence of Westernised body ideals, and greater assimilation of Western cultural values. Alongside these developments, there have been changes to gendered relations, with women experiencing greater employment opportunities, health control, and legal rights. Altogether, these societal changes have resulted in the adoption of the Western thin ideal, which has been conflated with femininity, success and happiness in urban Malaysian contexts (Swami, 2006, 2015). Similarly, male muscularity is idealised to a similar extent in urban Malaysia as it is in the UK (Swami & Tovée, 2005).

Finally, Malaysia is undergoing a national nutritional and lifestyle transition (e.g., Fournier et al., 2015; Shamsul, 2012), with increasing prevalence of overweight and obesity alongside micronutrient deficiencies (Institute of Public Health, 2015; World Health Organisation, 2018). Swami (2006) has suggested that the increasing rates of overweight and obesity may have further justified the fear of overweight and the glorification of the thin ideal, which, in turn, promotes greater body dissatisfaction. Indeed, several studies have reported that large proportions of the Malaysian population experience body dissatisfaction across childhood, adolescence, and adulthood (for an overview, see Swami et al., 2013).

### **3.1.2. Hypotheses**

Altogether, the results from Study 1 and previous research findings from North American and Western European samples have indicated four trends: (1) there tend to be positive associations between facets of IAw and positive body image; (2) there tend to be negative but weak associations between facets of IAw and negative body image; (3) correlations between IAw and positive body image tend to be greater in magnitude than correlations between facets of IAw and negative body image; and, (4) the magnitude of the correlations between IAw and body image vary across facets of IAw, with the IAw facet of body trust tending to be more closely associated with body image than the extent to which interoceptive stimuli are noticed. To test these hypotheses, the present study examined associations between multidimensional IAw and indices of positive body image (i.e., body appreciation and functionality appreciation) and negative body image (i.e., weight discrepancy in women and drive for muscularity in men), in Malaysian Malay adults. These constructs were selected on the basis of significant associations in Study 1, as well as the availability of validated measures for use with Malay-speaking populations.

### **3.2. Method**

#### **3.2.1. Participants**

A total of 815 adults (403 women, and 412 men) who self-reported as being of Malay ancestry participated in the study. Malays represent the majority ethnic group in Malaysia (Department of Statistics Malaysia, 2017) and must be Muslim, as defined by Article 160 of the Constitution of Malaysia. The participants were aged between 18 and 69 years ( $M = 33.89$ ,  $SD = 8.80$ ), and ranged in self-reported body mass index (BMI) from 13.26 to 49.86  $\text{kg/m}^2$  ( $M = 24.82$ ,  $SD = 5.48$ ). In terms of educational qualifications, 32.1% had completed secondary schooling, 39.4% had an undergraduate degree, 18.7% had a postgraduate degree, and the remainder had some other qualification. Of the total sample, 34.6% were single, 62.7% were married, 2.3% were divorced, and 0.4% had some other marital status.

### 3.2.2. Measures

**Interoception.** The MAIA (Mehling et al., 2012; Malay translation: Todd, Barron et al., 2020) was used to assess facets of IAw. Although scores on the English version of the scale reduce to eight factors (Mehling et al., 2012), in previous psychometric work I found that scores on the Malay version reduced to three dimensions (Todd, Barron et al., 2020), tapping: the ability to sustain and control attention to bodily sensations (Attention Regulation; 9 items), the tendency to notice bodily sensations and how they connect to emotional states (Bodily and Emotional Awareness; 8 items), and the extent to which bodily sensations are regarded as ‘safe’ and trustworthy (Trusting; 3 items). All items were scored on a 6-point scale, ranging from *never* (0) to *always* (5). Scores for each subscale were computed as the mean of all associated items, and higher scores reflect greater IAw. Scores on the Malay version of the MAIA have been shown to have adequate internal consistency (Todd, Barron et al., 2020). In the present study, internal consistency coefficients – estimated using McDonald’s  $\omega$  – for scores on each subscale were as follows: Attention Regulation = .89 (95% CI = .86, .91), Bodily and Emotional Awareness = .88 (95% CI = .85, .91), Trusting = .89 (95% CI = .83, .91).

**Functionality appreciation.** Functionality appreciation was assessed using the FAS (Alleva et al., 2017; Malay translation: Swami, Todd et al., 2019), as described previously. Scores on the Malay version of the FAS have been shown to have a unidimensional factor structure and adequate construct and incremental validity (Swami, Todd et al., 2019). In the present study,  $\omega$  for FAS scores was .91 (95% CI = .89, .93).

**Body appreciation.** Body appreciation was assessed using the BAS-2 (Tylka & Wood-Barcalow, 2015b; Malay translation: Swami, Mohd. Khatib et al., 2019), as described previously. In previous research, the Malay BAS-2 was found to have a unidimensional factor structure, and BAS-2 scores evidenced adequate internal consistency, and good

construct and incremental validity (Swami, Mohd. Khatib et al., 2019). In the present study,  $\omega$  for BAS-2 scores was .92 (95% CI = .91, .93).

**Weight discrepancy.** To measure a facet of negative body image, women were asked to complete the Photographic Figure Rating Scale (PFRS; Malay translation: Swami et al., 2013). The PFRS is comprised of 10 greyscale photographic images of women with their faces obscured. The images are standardised so that they represent established BMI categories, ranging from emaciated ( $< 15.0 \text{ kg/m}^2$ ) to obese ( $> 30.0 \text{ kg/m}^2$ ). The figures are positioned on a 10-point scale, with 1 representing the image with the lowest BMI, and 10 representing the figure with the highest BMI. Participants are asked to indicate the numbers that represent the figure that they believe is most closely matched to their own body, and the figure that they would most like to possess. Scores for actual-ideal weight discrepancy were calculated as the absolute difference between the ratings for current and ideal figures, with higher scores reflecting greater weight discrepancy. In previous research, the PFRS has demonstrated adequate construct validity and test-retest reliability (Swami et al., 2008; Swami, Steiger et al., 2012). Men did not complete the PFRS because no male version of the PFRS is available.

**Drive for muscularity.** To measure a facet of negative body image, men were asked to complete the Drive for Muscularity Scale (DMS; Malay translation: Swami et al., 2016). The DMS assesses muscularity-orientated attitudes and behaviours, including the desire to have a more muscular body. The DMS is comprised of 15 items, which are rated on a Likert-scale ranging from 1 (*always*) to 6 (*never*). Overall scores were computed as the mean of all items, and items were reverse-scored so that higher overall scores indicate greater drive for muscularity. In Malaysian men, DMS scores were found to have adequate internal consistency, and good convergent validity (Swami et al., 2016). In the present study,  $\omega$  for

the overall DMS scores in men was .94 (95% CI = .93, .95). Women did not complete the DMS because its psychometric properties have not yet been examined in Malaysian women.

**Demographics.** Participants were also asked to report their gender identity, age, height, and weight. These demographic details were used for descriptive purposes only. I computed self-reported BMI ( $\text{kg/m}^2$ ) using the height and weight data.

### **3.2.3. Procedure**

Ethics approval for the study was obtained from the Anglia Ruskin University departmental research ethics committee prior to data collection (approval code: EHPGR-13). The data were collected between March and April (2019) using a Qualtrics research panel. The research survey was advertised as a study on “attitudes toward the body”, and the advertisement included a brief summary of the subject theme, an estimated duration (15 minutes), and details of remuneration (participants were offered Qualtrics points, which can be exchanged for cash, gift cards, or donations to charity). My intention was to recruit a homogeneous sample in terms of cultural and national identity, so eligibility was limited to adults ( $\geq 18$  years) with Malaysian citizenship, who were of Malay ancestry and fluent in Malay. In addition, participation was limited to those who had good approval ratings from previous studies. IP addresses were examined to ensure that participants did not complete the survey more than once. All participants were required to provide digital informed consent. Following this, participants were asked to complete the measures described above, presented in a counterbalanced order. Written debriefing information was presented at the end of the survey.

## **3.3. Results**

### **3.3.1. Preliminary analyses**

I removed improbable BMI values ( $< 12$  or  $> 50 \text{ kg/m}^2$ ) and treated these as missing data. Altogether, missing data accounted for 0.29% of the main data set but were not missing

completely at random (MCAR), as determined by Little's MCAR analyses,  $\chi^2(5159) = 7888.36, p < .001$ . Therefore, missing values were imputed using the multiple imputation technique. Further data screening did not reveal any unduly influential outliers. Means and standard deviations for all variables are reported in Table 7. I observed gender differences for bodily and emotional awareness with women reporting higher scores. However, these differences were not statistically significant after a Bonferroni correction was applied ( $p = .05/8 = .0063$ )

### **3.3.2. Bivariate correlations**

Bivariate correlations between all variables were conducted separately for women and men. FDR corrections (again, computed using the Benjamini and Hochberg, 1995, procedure) were also computed separately. As can be seen in Table 7, all of the MAIA variables were significantly and positively correlated with the positive body image variables (i.e., body appreciation and functionality appreciation), for both women and men. Correlations between the MAIA variables and the negative body image variables (i.e., weight discrepancy and drive for muscularity) tended to be weaker and generally below the threshold for statistical significance. Fischer's  $r$ -to- $z$  transformation was computed to examine differences in the pattern of the correlation coefficients across gender (see Table 8). Of note, there was a statistically significant difference in the association between attention regulation and body appreciation, with the correlation being of greater magnitude for men.

Table 7

*Means, Standard Deviations, and Bivariate Correlations between all Measures for Women (Upper Diagonal) and Men (Lower Diagonal).*

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Attention regulation			.58**	.50**	.26**	.21**	-.08		.10	.14**
(2) Bodily and emotional awareness		.72**		.56**	.31**	.42**	-.08		.10*	-.04
(3) Trusting		.60**	.53**		.56**	.48**	-.28**		-.08	-.06
(4) Body appreciation		.36**	.35**	.60**		.53**	-.42**		-.17**	.08
(5) Functionality appreciation		.30**	.40**	.51**	.52**		-.23**		-.07	-.05
(6) Actual-ideal weight discrepancy									.55**	.05
(7) Drive for muscularity		-.08	-.02	-.12*	-.02	.03				
(8) Body mass index		.05	.04	-.02	-.01	.05		-.04		.11*
(9) Age		.05	.08	.09	.06	.14**		-.22**	.32**	
Women	<i>M</i>	3.25	3.80	3.85	4.17	4.43	2.20		24.49	33.55
	<i>SD</i>	1.03	0.83	1.10	0.67	0.61	1.56		5.39	8.88
Men	<i>M</i>	3.24	3.63	3.73	4.08	4.38		4.01	25.13	34.24
	<i>SD</i>	0.84	1.04	1.00	0.76	0.71		1.14	5.56	8.72
	<i>t</i>	-0.10	-2.45	-1.72	-1.67	-1.19			1.68	1.12
	<i>p</i>	.922	.015	.085	.094	.232			.092	.263
	<i>d</i>	0.01	0.18	0.11	0.13	0.08			0.12	0.08

*Notes.* \* $p$ -FDR < .05, \*\*  $p$ -FDR < .01, women  $n = 403$ , men  $n = 412$ .

Table 8

*Absolute Fischer's  $z_{\text{observed}}$  for Gender Group Comparison of the Correlation Coefficients.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Attention regulation		3.49**	2.05*	1.58*	1.37	0.72	1.29
(2) Bodily and emotional awareness			0.61	0.64	0.34	0.86	-1.71
(3) Trusting				-0.86	-0.57	-0.86	-2.14*
(4) Body appreciation					0.20	-2.40*	0.29
(5) Functionality appreciation						-1.71	-2.72*
(6) Body mass index							-3.15*
(7) Age							

*Note.* \* $p\text{-FDR} < .05$ , \*\* $p\text{-FDR} < .001$ . Women  $n = 403$ , men  $n = 412$ .

### **3.3.3. Hierarchical multiple regression analyses**

A series of four multiple regression analyses were conducted with the MAIA variables entered simultaneously as the predictor variables and the body image variables entered as the criterion variables. The effects of gender identity, BMI, and age were controlled for in the first step. For the two gender-specific body image variables (weight discrepancy and drive for muscularity), only BMI and age were included in the first step. VIFs were  $\leq 1.98$ , indicating that multicollinearity was not a limiting issue (Hair et al., 1995). Results for body appreciation, functionality appreciation are reported in Table 9, and results for weight discrepancy and drive for muscularity are reported in Table 10.

Table 9

*Multiple Hierarchical Regressions with Body Appreciation, Functionality Appreciation as Criterion Variables.*

Step	Variable	Body appreciation					Functionality appreciation				
		B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
Step 1		$F(3, 811) = 6.71, p < .001, \text{Adj. } R^2 = .02$					$F(3, 811) = 1.18, p = .316, \text{Adj. } R^2 < .01$				
	BMI	-.02	.01	-.13	-3.59	< .001	.01	.01	.01	0.21	.831
	Gender	.08	.05	.06	1.57	.116	.06	.05	.04	1.26	.208
	Age	.01	.01	.09	2.60	.009	.01	.01	.05	1.39	.164
Step 2		$F(6, 808) = 55.41, p < .001, \text{Adj. } R^2 = .29, \Delta \text{Adj. } R^2 = .27, \Delta F p < .001$					$F(6, 808) = 55.76, p < .001, \text{Adj. } R^2 = .29, \Delta \text{Adj. } R^2 = .29, \Delta F p < .001$				
	BMI	-.01	.01	-.09	-3.07	.002	.01	.01	.02	0.79	.429
	Gender	.04	.04	.03	0.82	.411	-.01	.04	-.01	-0.12	.905
	Age	.01	.01	.07	2.23	.026	.01	.01	.03	1.04	.298
	Attention Regulation	-.01	.03	-.02	-0.40	.692	-.09	.03	-.12	-2.70	.007
	Bodily and Emotional Awareness	-.01	.03	-.02	-0.34	.731	.18	.03	.26	5.85	< .001
	Trusting	.37	.03	.54	14.24	< .001	.28	.02	.44	11.67	< .001

Table 10

*Multiple Hierarchical Regressions with Actual-Ideal Weight Discrepancy and Drive for Muscularity as Criterion Variables.*

Step	Variable	Actual-ideal weight discrepancy					Drive for muscularity				
		B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
Step 1		$F(2, 400) = 91.40, p < .001, \text{Adj. } R^2 = .31$					$F(2, 409) = 10.67, p < .001, \text{Adj. } R^2 = .05$				
	BMI	.16	.01	.56	13.43	< .001	.01	.10	.02	0.42	.675
	Age	.01	.01	.02	0.43	.668	-.03	0.01	-.23	-4.58	<.001
Step 2		$F(5, 397) = 44.58, p < .001, \text{Adj. } R^2 = .35, \Delta\text{Adj. } R^2 = .04, \Delta F p < .001$					$F(5, 406) = 6.35, p < .001, \text{Adj. } R^2 = .06, \Delta\text{Adj. } R^2 = .01, \Delta F p = .019$				
	BMI	.16	.01	.54	13.00	< .001	.01	.01	.01	0.26	.794
	Age	.01	.01	.02	0.41	.683	-.03	.01	-.22	-4.49	< .001
	Attention Regulation	.01	.11	.01	0.03	.974	-.11	.09	-.10	-1.29	.198
	Bodily and Emotional Awareness	-.02	.10	-.01	-0.22	.827	.19	.08	.17	2.26	.025
	Trusting	-.33	.01	-.21	-4.18	< .001	-.14	.07	-.14	-2.17	.030

*Note.* Actual-ideal weight discrepancy was completed by women only ( $n = 403$ ), drive for muscularity was completed by men only ( $n = 412$ ).

BMI = body mass index.

### 3.4. Discussion

In Study 2, I examined associations between facets of IAw and body image in a sample of Malaysian Malay adults. Overall, I identified significant relationships between IAw and facets of positive body image (body appreciation, and functionality appreciation) for both women and men. I also identified significant associations between IAw and facets of negative body image (actual-ideal weight discrepancy for women, and drive for muscularity for men). In the final models, all three of the MAIA subscales emerged as significant predictors for at least one of the body image facets. These findings represent the first evidence of associations between facets of IAw and body image in a non-Western cultural context.

Consistent with my first hypothesis, I observed positive associations between facets of IAw and both body appreciation and functionality appreciation, respectively, for both women and men. These findings replicate previous findings from a sample of UK adults in Study 1, and with other previous research using Western samples (Daubenmier, 2005; Oswald et al., 2017). Thus, one preliminary conclusion that might be drawn from the present study is that the association between IAw and positive body image is transnational, however this assertion requires further scrutiny in future research for several reasons that I elaborate upon below (see Sections 3.4.1 and 3.4.2). In terms of theoretical mechanisms, it is possible that people who are more able to regulate attention toward their internal bodily signals are better able to appreciate the positive functions that their bodies perform, which, in turn, might promote a more generalised appreciation of the body (e.g., Alleva et al., 2015; Alleva et al., 2018a, 2018b). In addition, it is also plausible that people who are more able to regulate attention toward interoceptive signals might be more able to attend to the body's needs, which could also promote positive body image (Andrew et al., 2016; Cook-Cottone, 2018; Wood-Barcalow et al., 2010). However, it is important to note that due to the design of the

present research, a causal relationship between IAW and positive body image can only be inferred hypothetically at present (see Section 3.4.1).

I also identified weak, largely negative associations between the MAIA variables and both of the negative body image variables, and these associations were consistent after controlling for the effects of BMI and age in the regression analyses. These findings align with my second hypothesis and extend previous research, which has identified inverse associations between IAW and overweight preoccupation (e.g., Study 1; Brown et al., 2017) and muscle dysmorphia (e.g., Babusa & Túry, 2012), respectively, in samples of Western adults. As I outlined in Section 1.3.1, scholars have previously suggested that a reduced sensitivity to interoceptive stimuli could constitute a risk factor for the development of more negative body image, due to an over-reliance upon exteroceptive stimuli such as visual appearance-related characteristics (Badoud & Tsakiris, 2017). For example, individuals with a lower sensitivity to interoceptive stimuli might prioritise visual perceptions of the body (e.g., bodily shape or size) over sensations from internal stimuli. This reliance upon external cues could promote a state of disconnect from the body – where it is viewed from an external, appearance-based perspective – which can foster negative body image (Frederickson & Roberts, 1997).

Consistent with the findings from Study 1 and my third hypothesis, I observed a divergence in the findings across the positive and negative body image variables, with the associations between IAW and positive body image being generally of greater magnitude than the associations between facets of IAW and negative body image. Specifically, after taking into consideration the variance accounted for by gender, BMI, and age, the MAIA variables accounted for 27% of the variance in body appreciation, and 29% in functionality appreciation. However, after taking into consideration the variance accounted for by BMI and age, the MAIA variables accounted for only 4% of the variance in actual-ideal weight

discrepancy in women, and just 1% of the variance in drive for muscularity in men. These findings support the conceptual distinction between positive body image and negative body image (see Tylka, 2018; see also Section 1.2.1). That is, while the inverse correlations between facets of positive and negative body image observed in the present study ( $r = -.02$  to  $-.42$ ) are typical of the extant literature (Tylka, 2018), the two constructs are also known to interact with outcome variables in unique ways (e.g., Davis et al., 2019; Gillen, 2015; Thomas & Warren-Findlow, 2019). As was the case in Study 1, demographic variables explained a greater proportion of the variance in scores for the negative body image variables than the MAIA variables. In particular, BMI explained the largest proportion of the variance in actual-ideal weight discrepancy scores (whereby a higher BMI predicts greater actual-ideal weight discrepancy) and age for drive for muscularity (whereby as men age, they become less preoccupied with muscularity).

My final hypothesis was that the magnitude of the correlations between IAW and body image would vary across facets of IAW, with the IAW facet of body trust tending to be more closely associated with body image than the extent to which interoceptive stimuli are noticed (after the findings from Study 1; see also Brown et al., 2017; Daubenmier, 2005; Oswald et al., 2017). Consistent with expectations, body trust was a significant positive univariate predictor of body appreciation and functionality appreciation, and a significant negative univariate predictor of actual-ideal weight discrepancy (women) and drive for muscularity (men). Indeed, of the three MAIA subscales, body trust made the largest contribution to variance in scores for the body image variables. Conversely, while the IAW facet of bodily and emotional awareness (which includes the Noticing subscale from the English version of the MAIA) emerged as a significant positive univariate predictor of functionality appreciation, it was also a positive univariate predictor of drive for muscularity, despite the lack of a statistically meaningful correlation (Ferguson, 2009).

This is a puzzling finding, but nevertheless appears consistent with the findings for the MAIA Noticing subscale from Study 1. The regression models illustrate the relative contribution of bodily and emotional awareness to the prediction of the body image variables alongside all of the other IAW and demographic variables. As such, it is possible that once all of the other variables have been accounted for, the direction of the beta coefficients for the associations between bodily and emotional awareness and functionality appreciation, and between bodily and emotional awareness and drive for muscularity, respectively, are an accurate depiction of the relationships between these variables. For example, Malaysian Malay men might be less attuned to care for and respect their bodies, because masculinity norms focus men's attention elsewhere (e.g., the attainment of psychological well-being through non-corporeal means, such as occupational success). Indeed, given the consistent findings from Study 1, it is possible that the tendency to notice interoceptive stimuli may be reflecting a tendency towards self-surveillance when considered in relation to facets of negative body image. Nevertheless, (while VIFs were all within acceptable limits), it is also possible that one of the other variables could have biased the regression slope for drive for muscularity (i.e., regression dilution; Fuller, 1987).

Similarly, the IAW facet of attention regulation emerged as a significant negative predictor of functionality appreciation within the regression analyses (despite a positive direct correlation) and was not a significant predictor for any of the other body image facets. Thus, a possible interpretation of these findings is that the IAW facet of Attention Regulation might be maladaptive in Malaysian adults, when considered in relation to body image. This is somewhat surprising because the findings from Study 1 indicated that the ability to sustain attention toward interoceptive stimuli tends to be associated with a more positive body image. One possible source of variation relates to differences in the factor structure of the MAIA across English- and Malay-speaking samples. Specifically, an item that is reverse

scored in the English MAIA (“I distract myself from sensations of discomfort”), loads positively onto the Attention Regulation subscale of the Malaysian MAIA (Todd, Barron et al., 2020). However, again, it is also possible that the finding is a reflection of regression dilution (Fuller, 1987), particularly given that the direct correlation between attention regulation and functionality appreciation was positive for men and women.

### **3.4.1. Limitations**

It is important to note that all of the measures used within the present work were developed with Western samples. These measures have all been translated and validated for use with Malaysian-speaking samples previously, and, while some measures (e.g., the BAS-2 and the FAS) have been found to be equivalent across Malay- and English-speaking samples (Todd & Swami, 2020), in many cases the measurement tools differ in dimensionality (e.g., the majority of the MAIA subscales). This is problematic because measurement tools that have been originally developed in the West may not adequately capture aspects of IAW and body image that are specific to other cultural contexts such as Malaysia. Indeed, research on interoception and positive body image with different cultural groups appears to indicate that, while some core components of the constructs are communal, there are aspects that may be unique to specific cultural groups (Freedman et al., 2020; Swami, 2018). As such, it is possible that the present research may not fully capture the associations between IAW and body image in Malaysian adults.

The present findings should also be considered in the context of other limitations. First, I relied on an online sample of Malaysian citizens, which may limit generalisability, especially as an estimated quarter of Malaysians are not yet online (Malaysian Communications & Multimedia Commission, 2017). Relatedly, inclusion criteria for the present study was limited to Malaysians of Malay ancestry. While Malays are the majority ethnic group in Malaysia (Department of Statistics Malaysia, 2017), it is important to note

that Malaysia is ethnically heterogeneous, and future work should seek to examine whether the present findings are robust across other ethnic segments.

Second, given the cross-sectional nature of the present work it is unclear whether the relationships identified in the present work are stable longitudinally, or indeed, whether a causal relationship between IAW and body image exists in Malaysian adults. Longitudinal research with samples from the United States and Western Europe supports the assertion that early impairments in IAW are associated with later vulnerability to the development of eating disorders (for a review, see Lilenfeld et al., 2006), but other cultural groups have yet to be considered. Similarly, longitudinal explorations of the associations between IAW and positive body image are also warranted, particularly as the associations appear to be greater in magnitude than the associations between IAW and negative body image across diverse samples (i.e., Malaysia and the UK).

### **3.4.2. Conclusion**

The present work provides initial evidence that there are significant associations between facets of IAW and body image in a non-Western cultural context. While the conceptualisation of multidimensional IAW appears to be unique in Malaysian-speaking samples (Todd, Barron, et al., 2020), the findings from the present study indicate that IAW is nonetheless an important source of variance for facets of positive body image in Malaysian adults. Given that several of the key trends in the data appear consistent across the present study and Study 1, it might also be hypothesised that some relationships between IAW and body image are robust across diverse cultural contexts. In particular, across both UK and Malaysian samples, associations between facets of IAW and positive body image have tended to be greater in magnitude than the associations between facets of IAW and negative body image. In addition, across both samples, the IAW facet of body trust emerged as a consistent univariate predictor for facets of positive and negative body image. This is a particularly

noteworthy finding, because the subscale is equivalent across Malay- and English-speaking samples (that is, the MAIA Trusting subscale contains the same items across both the English and Malaysian versions of the MAIA, and evidences partial measurement invariance across English- and Malay-speaking samples; see Appendix I). Accordingly, it is possible to statistically examine whether the correlations between the IAw facet of body trust and the positive body image facets of body appreciation and functionality appreciation (which can also be examined across English- and Malay-speaking samples; Todd & Swami, 2020) differ significantly in terms of magnitude across the UK and Malaysian samples, and I sought to examine this possibility in Study 3.

#### **4. Study 3: Examining whether the associations between IAw and positive body image are robust across samples from Malaysia and the United Kingdom.<sup>4</sup>**

##### **4.1. Aims and hypotheses**

The aim of Study 3 was to further examine whether the associations between IAw and facets of positive body image are consistent across the UK and Malaysian samples, using measures that have evidenced measurement equivalence across the two national groups. These sites were chosen primarily because comparable data is available for analyses (i.e., the samples from Study 1 and Study 2), but also because they represent distinct national and cultural groups. On the one hand, Malaysia is Eastern, has a newly industrialised market economy, and is undergoing a nutrition transition (for an overview, see Section 3.1.1). On the other hand, the UK is Western, has a high-income economy, and a Westernised pattern of diets. Accordingly, the two countries are characterised by distinct human development indicators, such as life expectancy at birth (Malaysia: 76.0 years, UK: 81.2 years), expected years of schooling (Malaysia: 13.5 years, UK: 17.4 years), and gross national income per capita (Malaysia: \$27227, UK: \$39507) (Conceição, 2019). The two countries are also distinct in terms of key health indicators, with an estimated 30% of adults in the UK classified as obese, compared to 15% in Malaysia (World Health Organization, 2018).

As an initial aim, I sought to explore whether there were significant group differences in body appreciation, functionality appreciation, and body trust across nationality and gender, and whether there are any interactions between nationality and gender. To date, very few studies have examined facets of positive body image and IAw, respectively, cross-nationally, and none have specifically compared samples from the UK and Malaysia (for overviews, see Sections 1.1.2 and 1.2.2). On the basis of the limited available literature (Góngora et al.,

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<sup>4</sup> Sections of this study have been published, as follows: Todd, J., & Swami, V. (2020). Assessing the measurement invariance of two positive body image instruments in adults from Malaysia and the United Kingdom. *Body Image*, 34, 112-116. <https://doi.org/10.1016/j.bodyim.2020.05.009>

2020; Lemoine et al., 2018; Ma-Kellams, 2014; Razmus et al., 2019; Swami, 2018), I expected small cross-national differences, with the Malaysian participants evidencing higher positive body image, but lower body trust ( $H_1$ ). However, it was unclear whether there would be an interaction with gender.

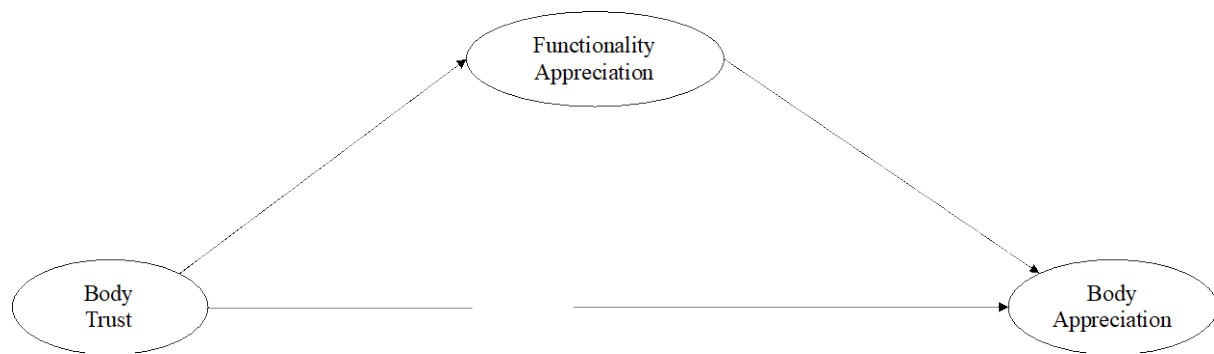
Next, I sought to examine whether the correlations between the IAw facet of body trust and the positive body image facets of body appreciation and functionality appreciation differed significantly in terms of magnitude across the UK and Malaysian samples. Previous research and theorising suggest that non-Western samples (in particular, Asian samples) may devote greater attentional resources to exteroceptive stimuli, whereas Western samples may devote comparatively greater attention to interoceptive sources of information (for an overview, see Section 1.1.2). Accordingly, I hypothesised that the magnitude of the correlations between body trust and the positive body image variables would be significantly higher for the UK group ( $H_2$ ), which could, in turn, indicate that IAw may be more relevant to body image in Western samples compared to non-Western samples.

As a third aim, I planned to examine the proportion of variance that body trust accounted for in body appreciation and functionality appreciation scores, respectively, after accounting for national group, gender, age, and BMI. Given that body trust significantly predicted body appreciation and functionality appreciation scores in each national group separately (see Study 1 and Study 2), I expected that body trust would uniquely account for a significant proportion of the variance in positive body image scores, over-and-above the variance associated with national group, BMI, gender, and age ( $H_3$ ).

Finally, in Studies 1 and 2, I suggested that the association between IAw and positive body image might be mediated by functionality appreciation. That is, a possible underlying mechanism which could explain the associations between IAw and positive body image is the ability to notice and sustain attention towards interoceptive stimuli directly increasing

awareness of the positive functions that the body performs, which, in turn, could promote a more generalised appreciation of the body. This hypothesis is grounded in previous research, which has demonstrated that focusing on body functionality is related to greater body appreciation (Avalos & Tylka, 2006; Wood-Barcalow et al., 2010). Furthermore, interventions aimed at increasing awareness of body functionality have been found to promote facets of positive body image, including body appreciation. For example, randomised controlled trials in clinical and community samples have indicated that focusing on body functionality during a writing-based intervention significantly increases body appreciation (Alleva et al., 2015; Alleva et al., 2018a, 2018b). My proposed mechanism is also aligned with the embodiment model (Menzel & Levine, 2011), which suggests that participating in embodying activities (i.e., activities that encourage awareness of and attentiveness to the body) promotes integration between the body and the mind, which directly fosters a more positive body image. For example, taking part in physical activities that emphasise body functionality has been associated with greater body appreciation (Langdon & Petracca, 2010; Swami & Tovée, 2009).

Thus, as a final aim, I sought to conduct a preliminary investigation of this hypothesis by examining whether the pathway between MAIA Trusting subscale scores and BAS-2 scores is partially mediated by FAS scores (see Figure 2), with the expectation that functionality appreciation would significantly mediate the association between body trust and body appreciation for the reasons discussed above (H<sub>4</sub>). As an additional exploratory analysis, I intended to explore whether the mediational model is invariant across UK and Malaysian adults, and across women and men. That is, I intended to examine whether the pattern of loadings for the model pathways was consistent across the different groups. On the basis of the findings from Study 1 and Study 2, I preliminarily expected that the model fit would be invariant across UK and Malaysian adults, and across women and men (H<sub>5</sub>).



*Figure 2.* Hypothesised associations between body trust, functionality appreciation and body appreciation.

## 4.2. Method

### 4.2.1. Participants

Data (i.e., BAS-2, FAS and MAIA Trusting scores, as well as demographic data consisting of gender, age, ethnicity, and BMI) for the present study were obtained by combining the samples from Study 1 and Study 2 ( $N = 1,411$ ). Specifically, I included participants who self-identified as being of British White ancestry from Study 1 ( $N = 596$ , women  $n = 416$  or 69.7%) and all participants who self-identified as being of Malaysian Malay ancestry from Study 2 ( $N = 815$ , women,  $n = 403$  or 49.4%). These criteria were included to ensure that both samples were ethnically homogenous, and representative of the majority ethnic group in each national context.

### 4.2.2. Measures

**Body appreciation.** Participants completed the BAS-2 (as described in Sections 2.2.2. and 3.2.2.) in English or Malay. In a previous study, I found that BAS-2 scores evidence partial scalar invariance across the UK and Malaysian samples (Todd & Swami, 2020), indicating that latent BAS-2 scores can be compared across these national groups (Davidov et al., 2012). In the total sample,  $\omega$  for BAS-2 scores was .96 (95% CI = .92, .97).

**Functionality appreciation.** Participants completed the FAS (described in Sections 2.2.2. and 3.2.2.) in English or Malay. In a previous study I found that FAS scores are also partially invariant across UK and Malaysian samples (Todd & Swami, 2020), allowing for

comparisons of latent FAS scores across these national groups (Davidov et al., 2012). In the total sample,  $\omega$  for FAS scores was .93 (95% CI = .90, .95).

**Interoception.** Participants completed the Trusting subscale of the MAIA (described in Sections 2.2.2. and 3.2.2.) in English or Malay. Preliminary analyses (see Appendix I) indicated that Trusting scores are partially invariant across the two national groups, allowing for comparisons of latent Trusting scores across the two groups (Davidov et al., 2012). In the total sample,  $\omega$  for Trusting scores was .85 (95% CI = .81, .89).

#### **4.2.3. Analytic strategy**

First, I sought to determine whether there were significant group differences in body appreciation, functionality appreciation, and body trust across nationality and gender ( $H_1$ ). To do so, I computed a series of ANCOVAs (Section 4.3.1). Next, I sought to examine whether the magnitude of the associations between body trust and the positive body image variables significantly differed across national groups ( $H_2$ ) using Fisher's *r*-to-*z* transformation (Section 4.3.2). Following this, I examined whether body trust accounts for a significant proportion of the variance in the positive body image scores, over-and-above the variance associated with national group, BMI, gender, and age ( $H_3$ ). I determined this by computing two hierarchical regressions, with BMI, gender, and age included in the first step, national group included in the second step (to determine the amount of variance uniquely accounted for by national group), and body trust included in the third step (Section 4.3.3). Finally, I used structural equation modelling to examine whether the pathway between body trust and body appreciation is mediated by functionality appreciation ( $H_4$ ), and multigroup CFA to determine whether the mediational model is invariant across national group and gender ( $H_5$ ).

### **4.3. Results**

#### **4.3.1. Between-group comparisons**

There were significant differences across national groups in age,  $t(1409) = 9.90, p < .001, g = 0.53$ , and BMI,  $t(1409) = 8.03, p < .001, g = 0.43$ , with the UK sample being both significantly older ( $M = 39.32, SD = 11.77$ , versus  $M = 33.89, SD = 8.80$ ) and higher in BMI ( $M = 27.29, SD = 6.04$ , versus  $M = 24.81, SD = 5.48$ ) than the Malaysian sample. Therefore, I included age and BMI as covariates in later analyses.

Because full or partial measurement invariance across gender has previously been established (Alleva et al., 2017; Swami, Mohd. Khatib et al., 2019; Swami, Todd et al., 2019; Todd, Barron et al., 2020; Tylka & Wood-Barcalow, 2015), I proceeded to examine latent mean scores using 2 x 2 analyses of covariance (ANCOVAs). BAS-2, FAS, and Trusting scores, respectively, were entered as dependent variables, national group (UK versus Malaysian) and gender (women versus men) were entered as between-subjects variables, and BMI and age were entered as covariates. As a measure of effect size, I used Cohen's (1988) benchmarks, where  $\eta_p^2$  of .01 is small, .06 is medium, and .14 is large.

In terms of the BAS-2, results indicated that BMI,  $F(1, 1405) = 65.94, p < .001, \eta_p^2 = .05$ , and age,  $F(1, 1405) = 6.32, p = .012, \eta_p^2 < .01$ , were significant covariates. The interaction between national group and gender was significant,  $F(1, 1405) = 17.53, p < .001, \eta_p^2 = .01$ , with Malaysian women reporting greater body appreciation than Malaysian men, but UK men reporting greater body appreciation than UK women. In addition, there were significant main effects of national group,  $F(1, 1405) = 395.48, p < .001, \eta_p^2 = .22$ , and gender,  $F(1, 1405) = 6.79, p = .009, \eta_p^2 = .01$ , with Malaysian participants reporting greater body appreciation than UK participants, and men's mean body appreciation greater than women's mean body appreciation (see Table 11).

For functionality appreciation, the results indicated that BMI was a significant covariate,  $F(1, 1405) = 7.27, p = .007, \eta_p^2 = .01$ , whereas age was not,  $F(1, 1405) = 2.63, p = .105, \eta_p^2 < .01$ . The interaction between national group and gender was significant,  $F(1,$

1405) = 4.84,  $p = .028$ ,  $\eta_p^2 < .01$ , with Malaysian women reporting greater functionality appreciation than Malaysian men, but UK men reporting greater functionality appreciation than UK women. The main effect of national group was significant,  $F(1, 1405) = 102.18$ ,  $p < .001$ ,  $\eta_p^2 = .07$  (Malaysian participants had higher functionality appreciation than UK participants), but the main effect of gender was not,  $F(1, 1405) = 0.70$ ,  $p = .402$ ,  $\eta_p^2 < .01$  (see Table 11).

For body trust, the results indicated that BMI was a significant covariate,  $F(1, 1405) = 14.72$ ,  $p < .001$ ,  $\eta_p^2 = .01$ , whereas age was not,  $F(1, 1405) = 1.01$ ,  $p = .316$ ,  $\eta_p^2 < .01$ . The interaction between national group and gender was significant,  $F(1, 1405) = 18.94$ ,  $p < .001$ ,  $\eta_p^2 < .01$ , with Malaysian women reporting greater body trust than Malaysian men, but UK men reporting greater body trust than UK women. The main effect of national group was significant,  $F(1, 1405) = 130.97$ ,  $p < .001$ ,  $\eta_p^2 = .08$  (Malaysian participants had greater body trust than UK participants), as was the main effect of gender,  $F(1, 1405) = 5.39$ ,  $p = .020$ ,  $\eta_p^2 < .01$  (overall men had greater body trust than women; for full descriptive statistics see Table 11).

Table 11

*Descriptive Statistics for the Analyses of Variance.*

Variable	National group	Gender	<i>N</i>	<i>M</i>	<i>SD</i>
Body appreciation	UK	Women	416	3.03	0.84
		Men	180	3.37	0.85
		Total	596	3.14	0.86
	Malaysian	Women	403	4.17	0.67
		Men	412	4.08	0.76
		Total	815	4.12	0.72
	Total	Women	819	3.59	0.95
		Men	592	3.87	0.85
		Grand average	1411	3.71	0.92
Functionality appreciation	UK	Women	416	3.94	0.69
		Men	180	4.07	0.62
		Total	596	3.98	0.67
	Malaysian	Women	403	4.43	0.61
		Men	412	4.38	0.71
		Total	815	4.40	0.66
	Total	Women	819	4.18	0.70
		Men	592	4.28	0.70
		Grand average	1411	4.23	0.70
Body trust	UK	Women	416	2.88	1.03
		Men	180	3.29	0.99
		Total	596	3.01	1.04
	Malaysian	Women	403	3.85	1.00
		Men	412	3.73	1.10
		Total	815	3.79	1.05
	Total	Women	819	3.34	1.13
		Men	592	3.58	1.08
		Grand average	1411	3.44	1.12

Table 12

*Absolute Fischer's  $z_{observed}$  for National Group Comparison of the Correlation Coefficients between the Different Measures for Women (lower diagonal), and Men (Upper Diagonal).*

	(1)	(2)	(3)	(4)	(5)
(1) Body trust		1.72	1.28	-0.33	-1.11
(2) Body appreciation	3.34**		2.61*	2.61*	-1.67
(3) Functionality appreciation	0.76	2.16*		-2.58*	-2.35
(4) BMI	-1.60	-2.28*	-1.59		-2.01
(5) Age	0.71	-.29	1.14	-.86	

*Note.* UK women  $n = 416$ , UK men  $n = 180$ , Malaysian women  $n = 403$ , Malaysian men  $n = 412$ . \* $p > .05$ , \*\* $p > .001$ , positive values indicate that a greater coefficient for the UK sample and negative values indicate a greater coefficient for the Malaysian sample. BMI = Body mass index.

#### 4.3.2. Comparison of correlation coefficients

Fisher's  $r$ -to- $z$  transformation was computed to examine whether there were statistically significant differences in the patterns of correlation coefficients across the national groups. Adjusted thresholds for rejecting the null hypothesis were again computed using the Benjamini and Hochberg (1995) FDR procedure. The full results are reported in Table 12. As can be seen, the magnitude of the correlation between body trust and body appreciation significantly differed across women from the UK and Malaysia, with the correlation stronger in magnitude for UK women ( $r = .70$  vs  $r = .56$ ,  $p < .001$ ). Conversely, the magnitude of the correlation between body trust and functionality appreciation did not significantly differ across national groups for women, and there were no significant

differences in the correlations between body trust and the positive body image variables across national groups for men.

#### **4.3.3. Hierarchical regressions**

Next, two hierarchical regressions were computed, with body appreciation and functionality appreciation included as criterion variables, respectively. For both analyses, the effects of BMI, gender identity, and age were controlled for in the first step, then national group was entered in the second step, and finally body trust was entered in the third step. Across both regressions, VIFs were  $\leq 1.15$ , indicating that multicollinearity was not a limiting issue (Hair et al., 1995). The full results are reported in Table 13. For body appreciation, national group accounted for a statistically significant 20% of the variance, after controlling for BMI, gender identity and age. After accounting for variance associated with all four variables (i.e., BMI, gender, age, and national group), body trust emerged as a statistically significant predictor, accounting for an additional 25% of the variance in body appreciation, with the direction of the association indicating that participants who reported greater body trust tended to report higher levels of body appreciation.

For functionality appreciation, national group accounted for a statistically significant 7% of the variance, after controlling for BMI, gender identity and age. After accounting for variance associated with all four variables (i.e., BMI, gender, age, and national group), body trust emerged as a statistically significant predictor, accounting for an additional 24% of the variance in functionality appreciation, with the direction of the association indicating that participants who reported greater body trust tended to report higher levels of functionality appreciation.

**Table 13**

*Multiple hierarchical regressions with body appreciation and functionality appreciation as criterion variables.*

Step	Variable	Body appreciation					Functionality appreciation				
		B	SE	$\beta$	<i>t</i>	<i>p</i>	B	SE	$\beta$	<i>t</i>	<i>p</i>
Step 1		$F(3, 1407) = 55.55, p < .001, \text{Adj. } R^2 = .10$					$F(3, 1407) = 11.87, p < .001, \text{Adj. } R^2 = .02$				
	BMI	-.04	< .01	-.27	-10.84	<.001	-.02	< .01	-.13	-4.98	< .001
	Gender	.24	.05	.13	5.18	<.001	.09	.04	.06	2.41	.016
	Age	< .01	< .01	-.05	-1.90	.058	< .01	< .01	-.03	-0.95	.341
Step 2		$F(4, 1406) = 161.11, p < .001, \text{Adj. } R^2 = .31, \Delta\text{Adj. } R^2 = .20, \Delta F p < .001$					$F(4, 1406) = 36.75, p < .001, \text{Adj. } R^2 = .09, \Delta\text{Adj. } R^2 = .07, \Delta F p < .001$				
	BMI	-.03	< .01	-.19	-8.66	< .001	-.01	< .01	-.09	-3.32	.001
	Gender	.08	.04	.04	-1.96	.050	.02	.04	.01	0.53	.599
	Age	< .01	< .01	.05	2.19	.028	<.01	< .01	.03	1.20	.230
	National group	.89	.04	.48	20.71	< .001	.39	.04	.28	10.43	< .001
Step 3		$F(5, 1405) = 369.54, p < .001, \text{Adj. } R^2 = .56, \Delta\text{Adj. } R^2 = .25, \Delta F p < .001$					$F(5, 1405) = 147.17, p < .001, \text{Adj. } R^2 = .33, \Delta\text{Adj. } R^2 = .24, \Delta F p < .001$				
	BMI	-.02	< .01	-.14	-7.61	<.001	< .01	< .01	-.03	-1.32	.188
	Gender	.04	.03	.02	-1.31	.191	.01	.03	.01	0.31	.758
	Age	< .01	< .01	.04	2.13	.033	< .01	< .01	.02	0.91	.362
	National group	.57	.04	.31	15.74	< .001	.15	.03	.11	4.42	< .001
	Body trust	.45	.02	.54	28.89	< .001	.33	.01	.53	23.13	< .001

*Note.* *N* = 1411, BMI = Body mass index.

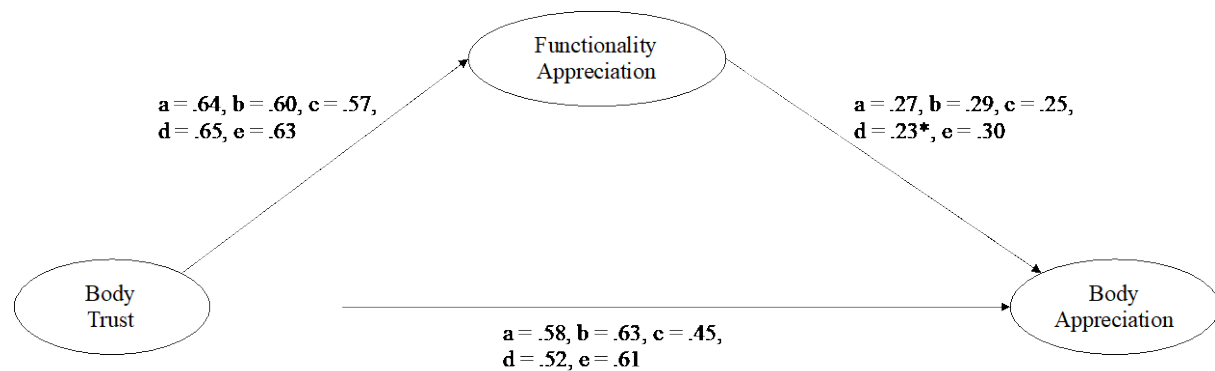
#### 4.3.4. Structural equation modelling

Finally, I used structural equation modelling techniques (path analysis and multi-group CFA) to examine the fit of the hypothesised mediation model in the full sample. Analyses were computed using the *Lavaan* package (Rosseel, 2012) in *R* (*R* Development Core Team, 2018). Assessment of the data for normality indicated that they were neither univariate (all  $p < .001$ ), nor multivariate normal (Mardia's skewness = 480.08,  $p < .001$ ; Mardia's kurtosis = 30.55,  $p < .001$ ), so parameter estimates were obtained using the robust maximum likelihood method with the Satorra-Bentler correction (Satorra & Bentler, 2001).

All pathways within the model were significant (see Figure 3) and fit indices suggest that the model adequately fitted the data:  $SB\chi^2(167) = 598.05$ ,  $SB\chi^2_{\text{normed}} = 3.58$ , robust RMSEA = .051 (90% CI = .046-.055), SRMR = .029, robust CFI = .971, robust TLI = .967, BL89 = .971. Bootstrapping procedures were used to calculate direct, indirect, and total effects for all effects through all significant paths in the fitted model, drawing on 5,000 bootstrap samples from the dataset. The results indicated that the relationship between body trust and body appreciation is partially mediated by functionality appreciation. The standardised indirect effect was 0.640 (SE = .024, 95% CI = .348 - .441) x 0.271 (SE = .049, 95% CI = .215-.408) = 0.174 (SE = .018, 95% CI = .087-.158). The standardised direct effect was 0.579 (SE = .029, 95% CI = .360-.472) after controlling for mediation. The standardised total effect was 0.753 (SE = .024, 95% CI = .491-.584).

Next, I assessed configural invariance (i.e., the pattern of loadings of the pathways on indicators) of the final model across national group and gender. Results showed that the model fitted the data across both UK and Malaysian adults,  $SB\chi^2(334) = 847.82$ ,  $SB\chi^2_{\text{normed}} = 2.54$ , robust RMSEA = .055 (90% CI = .051-.060), SRMR = .041, robust CFI = .956, robust TLI = .955, BL89 = .957, and across both women and men,  $SB\chi^2(334) = 814.26$ ,  $SB\chi^2_{\text{normed}}$

= 2.44, robust RMSEA = .054 (90% CI = .049-.058), SRMR = .033, robust CFI = .968, robust TLI = .963, BL89 = .967.



*Figure 3.* Path diagram with standardised loading estimates for the partial mediation between body trust and body appreciation by functionality appreciation. a = total sample; b = UK adults; c = Malaysian adults; d = total men; e = total women. All standardised loadings were significant at  $p > .001$  except \*, which was  $p = .003^5$ .

#### 4.4. Discussion

In Study 3, I sought to further examine whether the associations between facets of IAw and positive body image are robust across Western and non-Western samples. The findings from the present study indicate that associations between IAw and positive body image are largely consistent across samples from the UK and Malaysia, and that the IAw facet of body trust explains a significant proportion of the variance in body appreciation and functionality appreciation scores – over-and-above the variance accounted for by national group. In addition, the findings from the present study indicate that the association between body trust and body appreciation is partially mediated by functionality appreciation, and that this model is invariant across adults from the UK and Malaysia, and across women and men.

One of my primary hypotheses was that the magnitude of the correlations between body trust and the positive body image variables would significantly differ across the national samples, with the magnitude of the correlations being greater for the UK participants.

<sup>5</sup> For simplicity, the model presented in Figure 3 includes only the three latent constructs. However, the tested model also incorporated the MAIA Trusting, BAS-2, and FAS items as observed variables.

Consistent with this expectation, the magnitude of all correlations was greater for UK adults compared to Malaysian adults, although only the correlation between body trust and body appreciation in women differed significantly across the national groups. This finding could indicate that interoceptive stimuli are of lesser relevance to positive body image (in particular, body appreciation) for non-Western samples in comparison to Western samples. Indeed, previous research (albeit limited) has indicated that there are cross-cultural differences in components of interoception, with the findings broadly indicating that non-Western participants evidence lower perceptual acuity, and greater difficulties in distinguishing between facets of IAW (for an overview, see Section 1.1.2). Findings such as these have been interpreted in relation to differences in attention styles across individualist and collectivist cultures, with cultural tendencies to prioritise attention toward either the self or the social context (Ma-Kellams, 2014; Freedman et al., 2020). Accordingly, it is possible that interoceptive stimuli may be particularly important in Western cultural contexts, but in non-Western cultural contexts one's body image may be more dependent upon more externalised factors, such as perceived acceptance by others. Future research could perhaps examine this possibility using qualitative techniques, or measures such as the Body Acceptance by Others Scale-2 (Swami, Todd et al., 2020).

In the ANCOVAs, there were medium-to-large (Cohen, 1988) main effects of national group, with Malaysian participants having higher BAS-2 and FAS scores than UK participants. These differences were larger than the negligible-to-small effect sizes reported in previous cross-national comparisons (e.g., Góngora et al., 2020; Lemoine et al., 2018). One reason for the larger cross-national differences reported in the present study may be that previous studies utilised culturally- or geographically similar populations, whereas in the present study I utilised two national groups that were substantively different both in terms of geographic location and socio-economic development (see Section 4.1). It is possible that the

Western notion that changes to one's physical appearance are both healthy and required (Becker, 2004) may be relatively less emphasised in the developing context of Malaysia (Swami, 2015), which could facilitate positive body image. However, further work is required to better understand this difference. Importantly, in the regression analyses, I also found that body trust uniquely accounted for 25% of the variance in body appreciation scores, and 24% of the variance in functionality appreciation scores, over-and-above the variance accounted for by national group, BMI, gender, and age. These findings are consistent with my third hypothesis, and suggest that – while the magnitude of the correlations between body trust and positive body image may differ across the UK and Malaysian samples – the association between body trust and positive body image is a transnational phenomenon.

As an additional contribution to knowledge, I also examined whether the association between body trust and body appreciation is mediated by functionality appreciation, and whether this mediational model is invariant across national groups and gender. The results were consistent with my hypotheses: the association between body trust and body appreciation was partially mediated by functionality appreciation, and the final model was found to be invariant across both UK and Malaysian adults, and across men and women. These findings provide preliminary support for the previously described theoretical mechanism (Section 4.1), whereby attention towards interoceptive stimuli may promote a global body appreciation via increased awareness of the positive functions that the body performs. The present findings also build upon existing research, which has indicated that participation in embodied activities that emphasise body functionality promotes body appreciation (e.g., Alleva et al., 2015; Alleva et al., 2018a, 2018b; Langdon & Petracca, 2010; Swami & Tovée, 2009).

#### **4.4.1. Limitations**

While a strength of the present study was the cross-national comparison of two geographically distinct populations, it is not clear whether the findings are generalisable to ethnic minority groups in Malaysia and the UK, given that both samples were ethnically homogenous. The present study was also limited by the reliance on measures that evidence measurement equivalence across English- and Malay-speaking samples; future research should seek to examine more complex models that include a wider range of variables (when appropriate measures become available). Relatedly, it is possible that cross-sample differences in un-measured constructs (e.g., degree of acculturation, socioeconomic status) affected the present results. Finally, given the cross-sectional nature of the present work, causal inferences regarding associations between interoception and positive body image remain conjecture at present. This is particularly important when interpreting the findings of the mediation model: as Bollen and Pearl (2013, p. 309) caution, “fitting the data does not prove the causal assumptions, but it makes them tentatively more plausible”. As such, the findings from the present work require replication, and, ideally, further examination using experimental or longitudinal methodology.

#### **4.4.2. Conclusion**

Overall, the present findings indicate that while nationality accounts for a significant proportion of the variance in facets of IAw and positive body image – and the associations between these constructs – body trust also uniquely accounts for a significant proportion of the variance in body appreciation and functionality appreciation scores. The present study also provides preliminary evidence of a pathway between IAw and body appreciation that is partially mediated by functionality appreciation, and indicates that this pathway is consistent across both men and women, and samples from diverse national contexts.

## **5. Study 4: Examining associations between facets of interoceptive awareness and body image in adolescents from the United Kingdom<sup>6</sup>**

### **5.1. Aims**

To date, understanding of the associations between interoception and body image during adolescence remains severely limited. This is important because evidence suggests that adolescence is a significant period for the development of both interoceptive processing and body image (for overviews, see Sections 1.1.3 and 1.2.3). For example, regarding interoception, findings from neuroimaging studies suggest that between 13 and 17 years of age, adolescents experience increased activity in regions associated with interoceptive processing, in comparison to pre-adolescents, young adults, and mature adults (Li et al., 2017; May et al., 2014). Similarly, regarding body image, research suggests that there tend to be increases in negative body image between the ages of 12 and 17 – for both girls and boys – with the sharpest increases occurring between the ages of 13 and 15 (Bucchianeri et al., 2013; Eisenberg et al., 2006; Frisén et al., 2015). In the context of these findings, it is therefore necessary to explore associations between interoception and body image during adolescence, because results with adult populations may not generalise to younger age groups.

In particular, there are three areas that the available adolescent literature does not adequately address. First, research has exclusively focused upon associations between facets of interoception and negative body image (Emanuelson et al., 2014) and associations with psychopathology (e.g., Dakanalis et al., 2014; Killen et al., 1996; Leon et al., 1995), while associations with facets of positive body image remain unexplored. In adult samples, research indicates that the associations between IAW and positive body image tend to be of greater

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<sup>6</sup> This study has been published, as follows: Todd, J., Aspell, J. E., Barron, D., & Swami, V. (2019). An exploration of the associations between facets of interoceptive awareness and body image in adolescents. *Body image*, 31, 171-180. <https://doi.org/10.1016/j.bodyim.2019.10.004>

magnitude than associations between IAw and negative body image (e.g., Studies 1 and 2). This could be due to the relatively greater focus on exteroceptive appearance within the construct of negative body image, in contrast to the preferential focus upon physiological factors, such as body functionality, strengths, and health within the construct of positive body image (Avalos et al., 2005; Tiggemann & McCourt, 2013; Tylka & Wood-Barcalow, 2015; Wood-Barcalow et al., 2010).

Second, though evidence supports IAw as a multifaceted construct (see Section 1.1.1), the majority of the adolescent literature has only considered the perceptual aspects of interoception (e.g., Emanuelsen et al., 2014), which do not distinguish between adaptive and maladaptive modes of attention towards interoceptive signals (Mehling et al., 2009; 2012). In adult samples, research has indicated that appraisals of interoceptive stimuli are more closely associated with facets of body image than the tendency to notice such cues (i.e., Studies 1 and 2; see also Brown et al., 2017; Oswald et al., 2017). However, it is not yet clear whether these findings will generalise to non-clinical adolescent boys and girls.

Finally, it has not been ascertained whether relationships between interoception and body image are consistent across gender during adolescence. The identification of gender differences in the associations between IAw and body image could have important implications for the targeting of interventions. To date, the available literature is equivocal: the inverse association between interoception and negative body image has been found to be of greater magnitude for adolescent girls than boys in a Hungarian subsample, but there were no statistically significant gender differences in a Norwegian subsample (Emanuelsen et al., 2014). Furthermore, due to the dearth of research exploring interoception and positive body image during adolescence, it is not known whether gender is an important factor for the relationship between facets of IAw and positive body image. Previous qualitative research has indicated that the positive comments that adolescent girls receive typically relate to

appearance, while the comments that adolescent boys receive typically relate to body functionality (McCabe et al., 2006; see also Holmqvist Gattaro & Frisen, 2019). It is possible that this difference in exteroceptive inputs could promote differences in the extent to which interoceptive stimuli are relied upon for facets of positive body image, particularly the appreciation of body functionality.

In the present study, I sought to address the three aforementioned limitations of the available adolescent literature. To summarise, the primary aims were to: (1) explore associations between IAw and positive body image; (2) expand the current body of literature – which suggests associations between perceptual facets of interoception and negative body image during adolescence – by considering further facets of IAw, such as the appraisal and regulation of interoceptive stimuli, and; (3) explore whether the associations between facets of IAw and body image are consistent across gender. To facilitate aim (1), I selected three variables to provide broad coverage of the positive body image construct: body appreciation, appreciation of body functionality, and body pride. To facilitate aim (2), I included measures of body shame and body surveillance (that is, the extent to which individuals monitor their appearance from an externalised perspective; McKinley & Hyde, 1996). Finally, to facilitate aim (3), I planned to conduct analyses separately for girls and boys and compare the magnitude of associations across gender.

### **5.1.1. Hypotheses**

In terms of hypotheses, at the broadest level I expected to identify positive associations between IAw and positive body image, and negative associations between IAw and body shame and body surveillance. As previously discussed, it is possible that the magnitude of the associations between IAw and negative body image variables would be greater for girls (Emanuelson et al., 2014). It was unclear whether there would be an effect of gender upon the associations between IAw and positive body image. More specific hypotheses related to the

univariate facets of IAw. In line with previous research (Brown et al., 2017) and the findings from Studies 1 and 2, I expected to identify differences in the magnitude of the relationships between the perceptual, cognitive, and behavioural elements of IAw and the facets of body image under investigation. I hypothesised that the associations between body trust and the body image indices would be positive and strongest in magnitude. I also expected to identify positive associations between the Regulatory aspects of IAw (i.e., the MAIA Attention Regulation and Self-Regulation subscales) and the positive body image variables. Finally, I expected to find that the tendency to notice interoceptive stimuli (as evidenced by scores on the MAIA Noticing subscale) would have the weakest associations with the body image variables and that the associations would possibly be of an inverse orientation (consistent with Study 1).

## **5.2. Method**

### **5.2.1. Participants**

Participants were all students in year groups 9-11 at a secondary school in Cambridgeshire, in the UK. The sample ( $N = 277$ ) consisted of 140 girls and 125 boys, and 12 people who described their gender as 'other'. Due to the gender-specific nature of all further analyses, I only included participants who described themselves as 'male' or 'female.' The remaining ( $n = 265$ ) participants were aged between 13 and 16 ( $M = 14.11$ ,  $SD = 1.01$ ), and the majority of participants self-reported their ethnicity as White (69.8%; Asian or British Asian = 13.7 %; Black, British Black, or African Caribbean = 6.1%; mixed or multiple ethnic groups = 5.0%; other = 5.4%).

### **5.2.2. Measures**

**Interoception.** I assessed IAw using the MAIA questionnaire (Mehling et al., 2012), as previously described. Because the MAIA has not been validated for use with adolescent samples, I conducted a pilot study (see Appendix II) which confirmed the understanding and

appropriateness of the items in an adolescent sample. I did not include the Not Distracting and Not Worrying subscales because scores on these subscales consistently perform poorly in terms of internal consistency coefficients (Mehling, 2016; see also Study 1). Confirmatory factor analysis (CFA) indicated that the 6-factor structure had adequate fit in the present study following modifications (see Appendix II). Omega for scores on each MAIA subscale were as follows: Noticing = .79 (95% CI = .74, .83); Attention regulation = .91 (95% CI = .87, .92); Emotional Awareness = .82 (95% CI = .76, .85); Self-Regulation = .89 (95% CI = .86, .92); Body Listening = .84 (95% CI = .79, .88); Trusting = .91 (95% CI = .88, .93).

**Body appreciation.** Body appreciation was assessed using the Body Appreciation Scale-2 for children (BAS-2C; Halliwell et al., 2017). The BAS-2C comprises 10 items that assess body-related positive opinions and acceptance (regardless of actual physical appearance), respect for the body by engaging in healthy behaviours, and protection of body image when exposed to appearance-based media. All items were rated on a 5-point scale, ranging from 1 (*never*) to 5 (*always*) and an overall score was computed as the mean of all items. Higher scores on this scale reflect greater body appreciation. Scores on the BAS-2C have a 1-dimensional structure in children and adolescents, are invariant across gender, and have adequate internal consistency and test-retest reliability over a 6-week period, and good patterns of construct, criterion-related, and incremental validity (Halliwell et al., 2017). In the present work,  $\omega$  for scores on this scale was .94 (95% CI = .93, .95).

**Functionality appreciation.** Functionality appreciation was assessed using the Functionality Appreciation Scale (FAS; Alleva et al., 2017), as described previously. In a pilot study (see Appendix II), the understanding and appropriateness of the items was confirmed with an adolescent sample. CFA indicated that the 1-dimensional factor structure had adequate fit in the present data following modifications (see Appendix II). In the present study,  $\omega$  for scores on this scale was .89 (95% CI = .86, .91).

**Body pride.** Body pride was assessed using the Authentic Pride subscale of the BASES (Castonguay et al., 2014), as described previously. A pilot study (see Appendix II), confirmed the understanding and appropriateness of the items with an adolescent sample, and CFA indicated that the one-dimensional factor structure had an adequate fit in the present work following modifications. In the present work,  $\omega$  for scores on this subscale was .94 (95% CI = .92, .95).

**Additional body image measures.** Two subscales from the Objectified Body Consciousness-Youth Scale (OBC-Youth; Lindberg et al., 2006) were used to assess body shame and body surveillance, respectively. The Body Shame subscale (5 items) assesses the degree to which individuals feel shame when their body does not conform to cultural ideals. The Body Surveillance subscale (4 items) assesses the degree to which individuals adopt an externalised (outsider's) perspective to monitor their appearance. Participants rated their agreement with each item on a 7-point scale, ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) or indicated that the item did not apply to them. Higher scores indicate greater body shame or body surveillance. Scores on these subscales have demonstrated adequate internal consistency, test-retest reliability over a 2-week period, and construct validity in groups of adolescent girls and boys (Lindberg et al., 2006; Slater & Tiggemann, 2011). In the present work,  $\omega$  for scores on the body shame and body surveillance subscales were .91 (95% CI = .88, .93) and .91 (95% CI = .88, .93), respectively.

**Demographics.** Participants were asked to provide demographic details consisting of gender, age, ethnicity (based on ethnicity categories in the UK census), height, and weight. I used the final two items to compute self-reported body mass index (BMI) as  $\text{kg/m}^2$ .

### 5.2.3. Procedure

Permission was sought from the head teacher of a secondary school in Cambridgeshire and the study was approved by the Anglia Ruskin University Faculty

research ethics committee (approval number: FST/FREP/17/742). Both parents and students received a study information sheet and a consent form to read and to sign. The study took place under controlled conditions during lessons within the school day. Students completed the questionnaire using computers. All participants volunteered their time and were not offered remuneration. Teachers provided an appropriate alternative activity for pupils who had not consented. At the start of the survey, all participants were presented with a written summary of the information sheet and were asked to provide additional digital informed consent before completing the survey. Participants completed the measures described above in an anonymous form, which was presented in randomised order. The questionnaire was completed in 14 minutes on average. All participants received written debriefing information at the end of the survey and this information was also sent home to parents following the study.

### **5.3. Results**

#### **5.3.1. Data screening**

A substantial proportion of the data for self-reported BMI was missing (43.5%; 45.7% for girls and 38.4% for boys). I therefore elected to exclude this variable from analyses. For the remaining variables, missing data ( $< 3.0\%$  of the total dataset) were missing completely at random, as determined by Little's (1988) Missing Completely at Random test,  $\chi^2(3579) = 3557.43, p = .598$ . Therefore, I replaced missing values using the multiple imputation technique, using the *MICE* package (van Buuren, 2018) in *R* (*R* development Core Team, 2014). Further data screening did not reveal any unduly influential univariate or multivariate outliers.

#### **5.3.2. Descriptive statistics**

Means and standard deviations for all variables are reported in Table 14. I controlled for false discovery rate (FDR) through use of the Benjamini-Hochberg (1995) procedure,

which was computed using the *Stats* package in *R*. As can be seen in Table 14, statistically significant gender differences after FDR correction were identified for body appreciation (boys reported significantly greater body appreciation), body surveillance (girls reported a significantly greater tendency to monitor their appearance), and body shame (girls reported significantly greater levels of body shame).

Table 14

*Means, Standard Deviations, and Bivariate Correlations between All Variables for Girls (Upper Diagonal) and Boys (Lower Diagonal).*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Noticing		.58**	.45**	.46**	.42**	.26*	.16	.18*	.19*	.02	.04	.08
(2) Attention Regulation	.66**		.54**	.68**	.64**	.41**	.26*	.34**	.32**	-.04	-.02	-.08
(3) Emotional Awareness	.66**	.67**		.58**	.50**	.32**	.24*	.33**	.24*	.09	.03	.08
(4) Self-Regulation	.48**	.57**	.64**		.72**	.51**	.34**	.41**	.35**	-.04	-.10	-.03
(5) Body Listening	.40**	.60**	.54**	.64**		.46**	.23*	.20*	.29**	-.07	.03	.04
(6) Trusting	.30*	.55**	.37**	.39**	.50**		.53**	.51**	.37**	-.16	-.42**	.11
(7) Body appreciation	.33**	.44**	.35**	.49**	.41**	.44**		.68**	.71**	-.38**	-.47**	-.01
(8) Functionality appreciation	.26*	.45**	.29*	.36**	.36**	.39**	.52**		.59**	-.15	-.34**	.03
(9) Body pride	.44**	.52**	.44*	.59**	.50**	.38**	.62**	.50**		-.21*	-.33**	.03
(10) Body surveillance	.29*	.30*	.27*	.25*	.20*	.17	.04	.17	.34**		.53**	.10
(11) Body shame	.17	.13	.15	.23*	.28*	<.01	-.08	-.03	.14	.45**		-.19*

(12) Age	-.04	-.10	-.05	-.02	-.07	-.05	-.02	-.05	.09	.20*	.13	
<i>M</i> (Boys)	3.16	3.16	3.31	2.97	2.69	3.41	3.87	4.12	3.50	4.10	3.10	13.80
<i>SD</i> (Boys)	1.09	1.02	1.04	1.09	1.06	1.19	0.75	0.63	0.99	1.48	1.36	0.86
<i>M</i> (Girls)	3.20	2.98	3.26	2.84	2.43	3.06	3.40	3.92	3.22	5.45	4.06	14.16
<i>SD</i> (Girls)	0.77	.81	0.83	1.00	1.00	1.08	0.89	.70	0.97	1.21	1.48	1.07
<i>t</i>	†0.37	†1.55	†0.45	1.03	2.07	2.54	†4.64	2.46	2.35	8.38	5.51	†3.07
<i>p-FDR</i>	.713	.163	.712	.367	.060	.028	<.001	.028	.034	<.001	<.001	.006
<i>d</i>	0.04	0.20	0.05	0.12	0.25	0.31	0.57	0.30	0.29	1.00	0.68	0.37

*Notes.* Boys  $n = 125$ , Girls  $n = 140$ . \* $p$ -FDR <.05, \*\*  $p$ -FDR <.001, where FDR = False Discovery Rate. †Denotes that Levene's test was significant and, therefore, Welch's  $t$  value was utilised.

### 5.3.3. Bivariate correlations

Bivariate correlations between all variables were computed separately for boys and girls. Adjusted thresholds for rejecting the null hypothesis were also computed separately. The full results are reported in Table 14.

**5.3.3.1. Boys.** Each of the MAIA subscales tended to have small ( $\geq .20$ ), positive associations with the body image variables. A notable exception to this was body pride, which was moderately ( $\geq .50$ ) associated with the MAIA Attention Regulation, Self-regulation, and Body Listening subscales. Regarding age, there was a small, positive association with body surveillance; associations with all other variables were  $< .20$ .

**5.3.3.2. Girls.** There tended to be small, positive associations between the MAIA subscales and the positive body image variables, and negative associations with the negative body image variables. The MAIA Trusting subscale exceeded this, with moderate associations with body appreciation and functionality appreciation. All of the associations between the MAIA subscales and the negative body image variables were  $> .20$ , except the association between body shame and the MAIA Trusting subscale, which approached a moderate effect size. Regarding age, associations with all variables were  $< .20$  and the association with body shame ( $r = -.19$ ) was the only incidence of statistical significance.

**5.3.3.3. Gender differences.** Fisher's  $r$ -to- $z$  transformation was computed to examine differences in the pattern of the correlation coefficients across gender. The full results are reported in Table 15. Of note, the associations between the MAIA subscales and body pride, body surveillance, and body shame were significantly different, with the correlations generally tending to be of greater magnitude for boys.

Table 15

*Fischer's  $z_{\text{observed}}$  Values for Gender Comparisons of the Correlation Coefficients.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) MAIA Noticing		1.06	2.71*	0.3	-0.16	0.33	1.42	0.64	2.17*	2.28*	1.03
(2) MAIA Attention Regulation			1.69	-1.36	-0.56	1.76	1.62	1.03	1.91	2.77*	1.21
(3) MAIA Emotional Awareness				0.83	0.47	0.48	0.92	-0.33	1.81	1.50	0.97
(4) MAIA Self-Regulation					-1.14	-1.22	1.52	-0.41	2.53*	2.41*	2.64*
(5) MAIA Body Listening						0.49	1.62	1.38	2.01*	2.25*	2.02*
(6) MAIA Trusting							-0.92	-1.2	0.04	2.63*	3.62**
(7) Body appreciation								-1.95	-1.34	3.48**	3.4**
(8) Functionality appreciation									-1.05	2.59*	2.65*
(9) Body pride										4.47**	3.89**
(10) Body surveillance											-0.82
(11) Body shame											

*Notes.* Boys  $n = 125$ , Girls  $n = 140$ . \*  $p > .05$ , \*\* $p > .001$ ; MAIA = Multidimensional Assessment of Interoceptive Awareness. A positive value indicates that the magnitude of the correlation was greater for boys, and a negative value indicates that the magnitude was greater for girls.

### 5.3.4. Multiple regression analyses

Multiple regression analyses were conducted separately for boys and girls. Five pairs of regressions were conducted: the body image variables were entered as criterion variables, and the MAIA variables were entered simultaneously as predictor variables. Correlational analyses (see Table 14) indicated that it was not necessary to control for age. VIFs were  $\leq 2.84$  for all regressions, indicating that multicollinearity was not a limiting issue (Hair et al., 1995).

**5.3.4.1. Boys.** The results for body appreciation, functionality appreciation, and body pride are reported in Table 16. As can be seen, the MAIA variables accounted for 29.3% of the variance for body appreciation, 21.4% of the variance for functionality appreciation, and 38.9% of the variance for body pride. The results for body surveillance and body shame are reported in Table 17. The MAIA variables accounted for 6.5% of the variance for body surveillance, and 7.2% of the variance for body shame. At the univariate level, the MAIA Self-Regulation, Attention Regulation, Body Listening, and Trusting subscales all emerged as a significant predictor for at least one of the body image variables, while the Noticing and Emotional Awareness scales did not. In the case of body surveillance, none of the MAIA subscales were significant univariate predictors.

Table 16

*Multiple Regressions for Boys, with Body Appreciation, Functionality Appreciation, and Body Pride as Criterion Variables.*

MAIA Variable	Body appreciation					Functionality appreciation					Body pride				
	B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
Noticing	.044	.077	.064	0.57	.569	-.025	.065	-.046	-0.39	.697	.132	.094	.145	1.40	.165
Attention	.089	.092	.123	0.97	.333	.195	.078	.331	2.49	.014	.152	.113	.157	1.34	.183
Regulation															
Emotional	-.080	.088	-.111	-0.91	.367	-.050	.075	-.086	-0.67	.505	-.111	.108	-.116	-1.02	.308
Awareness															
Self-	.241	.077	.351	3.15	.002	.090	.065	.163	1.39	.168	.369	.094	.406	3.91	<.001
Regulation															
Body	.021	.077	.029	0.27	.791	.017	.066	.029	0.26	.799	.105	.095	.113	1.11	.271
Listening															
Trusting	.151	.059	.240	2.55	.012	.090	.050	.178	1.79	.076	.062	.073	.074	0.85	.397
Adj. $R^2$	.293				< .001	.214				< .001	.389				< .001
$F(df)$	9.55 (6)					6.63 (6)					14.14 (6)				

*Notes.*  $n = 125$ . MAIA = Multidimensional Assessment of Interoceptive Awareness.

Table 17

*Multiple Regressions for Boys, with Body Shame and Body Surveillance as Criterion Variables.*

MAIA Variable	Body surveillance					Body shame				
	B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
Noticing	.190	.169	.144	1.12	.265	.170	.160	.136	1.06	.291
Attention	.195	.204	.139	0.96	.341	-.098	.193	-.074	-0.51	.611
Regulation										
Emotional	.025	.195	.018	0.13	.899	-.094	.184	-.072	-0.51	.609
Awareness										
Self-Regulation	.120	.170	.091	0.71	.482	.143	.160	.114	0.89	.375
Body Listening	-.017	.171	-.012	-0.10	.922	.413	.162	.321	2.56	.012
Trusting	.017	.131	.014	0.13	.895	-.203	.124	-.176	-1.64	.104
Adj. $R^2$	.065				.029	.072				.021
$F(df)$	2.45 (6)					2.61 (6)				

*Notes.*  $n = 125$ . MAIA = Multidimensional Assessment of Interoceptive Awareness.

**5.3.4.2. Girls.** The results for body appreciation, functionality appreciation, and body pride are reported in Table 18. The MAIA variables accounted for 25.9% of the variance for body appreciation, 32.5% of the variance for functionality appreciation, and 14.5% of the variance for body pride. The results for body surveillance and body shame are reported in Table 19. The MAIA variables accounted for 22.0% of the variance for body shame. For body surveillance, the MAIA variables accounted for 0.7% of the variance and the regression was not significant ( $p = .324$ ). At the univariate level, the MAIA Trusting and Self-Regulation subscales emerged as significant positive predictors for facets of positive body image and there was also a significant inverse association between the Trusting subscale and body shame. Conversely, the MAIA Body Listening subscale emerged as a significant negative predictor for functionality appreciation, and a significant positive predictor for body shame.

Table 18

*Multiple Regressions for Girls, with Body Appreciation, Functionality Appreciation, and Body Pride as Criterion Variables.*

MAIA Variable	Body appreciation					Functionality appreciation					Body pride				
	B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
Noticing	-.030	.105	-.026	-0.29	.773	-.067	.079	-.074	-0.85	.397	-.016	.124	-.013	-0.13	.896
Attention	.038	.125	.034	.30	.765	.145	.095	.166	1.53	.129	.149	.148	.123	1.01	.316
Regulation															
Emotional	.071	.100	.066	0.71	.481	.125	.076	.148	1.65	.101	.022	.118	.019	0.19	.851
Awareness															
Self-	.115	.109	.129	1.05	.297	.185	.083	.262	2.23	.027	.138	.129	.141	1.07	.288
Regulation															
Body	-.110	.098	-.124	-1.12	.265	-.236	.074	-.337	-3.17	.002	-.007	.116	-.007	-0.06	.953
Listening															
Trusting	.401	.071	.487	5.66	< .001	.283	.054	.434	5.28	< .001	.225	.083	.250	2.70	.008
Adj. $R^2$	.259				< .001	.325				< .001	.145				< .001
$F(df)$	9.11 (6)					12.13 (6)					4.92 (6)				

Notes.  $n = 140$ . MAIA = Multidimensional Assessment of Interoceptive Awareness.

Table 19

*Multiple Regressions for Girls, with Body Shame and Body Surveillance as Criterion Variables.*

MAIA	Surveillance					Body shame				
Variable	B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
Noticing	.053	.163	.035	0.33	.744	.144	.179	.076	0.81	.421
Attention	-.071	.195	-.048	-0.37	.715	.006	.214	.003	0.03	.979
Regulation										
Emotional	.262	.156	.183	1.68	.095	.169	.171	.095	0.99	.324
Awareness										
Self-Regulation	.012	.170	.010	0.07	.946	-.163	.187	-.110	-0.87	.385
Body Listening	-.090	.153	-.075	-0.59	.559	.410	.168	.279	2.44	.016
Trusting	.192	.110	-.174	1.75	.083	-.741	.121	-.542	-6.14	< .001
Adj. $R^2$	.007				.324	.220				< .001
$F(df)$	1.17 (6)					7.52 (6)				

*Notes.*  $n = 140$ . MAIA = Multidimensional Assessment of Interoceptive Awareness.

## 5.4. Discussion

In the present study, I assessed relationships between multiple facets of IAw and body image in a sample of UK adolescent girls and boys. Overall, I identified significant relationships between facets of IAw and body appreciation, functionality appreciation, body pride, and body shame, for both girls and boys. However, regression analyses indicated that the MAIA variables were not significantly associated with body surveillance for girls and, while a statistically significant regression was observed for boys, none of the MAIA subscales emerged as significant univariate predictors.

Regarding the positive body image variables, my results complement and extend previous findings of associations between IAw and positive body image in adults (i.e., Studies 1-3; see also Daubenmier, 2005; Oswald et al., 2017) by demonstrating that these relationships are also present during adolescence. As an additional extension of the available literature, I observed notable gender differences in the patterns of association. Specifically, for body pride, the MAIA variables accounted for 38.9% of the variance in boys, but a more modest 14.5% for girls. Conversely, for functionality appreciation, the MAIA variables accounted for 32.5% of the variance for girls, but only 21.4% for boys. These findings suggest that IAw might be more relevant to the development of body pride for adolescent boys and more relevant to the development of functionality appreciation for adolescent girls. One possible explanation for these findings relates to the aforementioned antagonism in the processing of interoceptive and exteroceptive cues (attention toward one may reduce the resources available for the other, with attention directed according to the precision of the stimuli; Ainley et al., 2016; Badoud & Tsakiris, 2017; see Section 1.3.1. for an overview). In terms of exteroceptive inputs, there appears to be a gender-specific focus upon appearance versus body functionality in the sociocultural messages that adolescent girls and boys receive: the positive comments that adolescent girls receive typically relate to appearance,

while the comments that adolescent boys receive typically relate to body functionality (Holmqvist Gattario & Frisén, 2019; McCabe et al., 2006). Therefore, it is possible that the relatively greater contribution of exteroceptive stimuli regarding appearance renders interoceptive stimuli less salient or reliable for the development of body pride in adolescent girls. Similarly, for boys, it could be that the relatively greater contribution of exteroceptive stimuli regarding body functionality renders interoceptive stimuli less salient or reliable for the development of functionality appreciation.

While the above findings indicate nuanced patterns of results, it is also important to note that the inter-correlations between the positive body image variables were high, particularly for girls. Specifically, the direct correlations between body appreciation and functionality appreciation ( $r = .68$ ), and body appreciation and body pride ( $r = .70$ ), indicate that these facets of positive body image may not be distinct for adolescent girls (Newman et al., 2010). For boys, however, the inter-correlations between the positive body image variables were all lower in magnitude ( $< .62$ ), indicating a greater degree of distinction. Future work could examine the degree of commonality and distinguishability of these facets of positive body image in adolescent samples using techniques such as Item Pool Visualisation (as in, Swami, Furnham et al., 2020).

Turning next to consider the negative body image variables, I identified significant associations between body shame with the MAIA variables for both girls and boys. This is consistent with the finding of an association between interoception and body dissatisfaction in a previous adolescent study (Emanuelson et al., 2014). In the same study, Emanuelson and colleagues (2014) also presented conflicting evidence for gender differences in the magnitude of the association between interoception and body dissatisfaction: the association was found to be of greater magnitude for adolescent girls than boys in a Hungarian subsample, but there were no statistically significant gender differences for a Norwegian subsample. The results

from the present study support the hypothesis that facets of interoception explain a greater proportion of the variance for negative body image in girls. Specifically, the MAIA variables accounted for 22% of the variance for girls, but only 7.2 % of the variance for boys.

Together, these findings indicate that bodily awareness-based interventions to reduce facets of negative body image, such as body shame, might be more relevant for adolescent girls than adolescent boys. Indeed, consistent with previous research (Knauss et al., 2008), I found that levels of body shame were significantly higher for adolescent girls in comparison to adolescent boys.

Regarding body surveillance, I found that the MAIA variables were not associated in any statistically meaningful way for girls (Ferguson, 2009) and were only weakly associated for boys. As previously discussed, current theorising posits that, in the absence of accurate interoceptive percept, bodily awareness may be predominantly based upon exteroceptive cues (Tajadura-Jimenez & Tsakiris, 2014; Tsakiris et al., 2011), which may encourage a greater focus upon the visual aspects of the body (Badoud & Tsakiris, 2017). Against this context, it is surprising that body surveillance – the extent to which individuals monitor their appearance from an externalised (i.e., third person) perspective – was not found to be significantly associated with IAw in the present sample. One possible explanation for this finding is that the component of interoception under investigation (IAw) does not reflect the *precision* of interoceptive signalling (Murphy et al., 2020). Indeed, in adult samples, an inverse association between interoception and the tendency to adopt an externalised perspective has been evidenced when IAcc is assessed (Ainley & Tsakiris, 2013), but not when IAw is assessed (Tiggemann & Kuring, 2004; Tiggemann & Slater, 2001). I therefore recommend that future adolescent research should examine the association between body surveillance and IAcc.

Further gender differences were observed in the univariate relationships between the MAIA subscales and the body image variables. For adolescent girls, the MAIA Trusting subscale emerged as the strongest, and most consistent predictor variable, which is consistent with findings from UK and Malaysian adults (Studies 1-3). However, for adolescent boys, it appears that the ‘regulatory’ aspects of IAW (i.e., the Self-Regulation, Attention Regulation, and Body Listening subscales) are the most relevant to body image. Nevertheless, the overall shape of the results complements findings from adult research, which have indicated that the appraisal and regulation of interoceptive signals tend to be more closely associated with facets of body image than the tendency to notice interoceptive stimuli (Studies 1-3; see also Brown et al., 2017; Daubenmier, 2005; Oswald et al., 2017). Indeed, in the present study, the Noticing subscale did not emerge as a statistically significant univariate predictor within any of the regression analyses.

Given the consistent associations between body trust and facets of body image for both adolescent girls and samples of UK and Malaysian adults (Studies 1-3), further examination of these results is warranted. In particular, an important limitation may be the degree to which body trust is truly distinct from facets of positive body image, such as body appreciation. Construct overlap can be demonstrated through strong direct correlations (i.e.,  $r > .70$ ; Newman et al., 2010). In the present study, the MAIA Trusting subscale was only moderately correlated with BAS and FAS scores for girls ( $r = .53$  and  $.51$ , respectively). For boys the correlations were smaller ( $r = .44$  and  $.39$ , respectively). Therefore, my analysis suggests that there is a small degree of overlap, but that body trust and positive body image are distinct constructs, particularly for adolescent boys. However, in adult samples, the direct correlations between body trust and body appreciation have been found to be greater in magnitude ( $r = .70$  for women, and  $.69$  for men; see Study 1). Given the cross-sectional nature of both studies, it is not possible at present to ascertain why body trust appears to

become less distinct from body appreciation over time. In the absence of further data, it could be concluded that the MAIA Trusting subscale is related, but nonetheless distinct from positive body image in adolescents, but that it is conceptually intertwined with body appreciation in adults. Future research should seek to fully explore the extent to which body trust is distinct from positive body image – particularly for adults – through methods such as item pool visualisation, cluster analysis, or latent semantic analysis.

Additional univariate relationships that warrant further consideration relate to the MAIA Body Listening subscale, which emerged as a significant positive predictor of body shame for both genders, and a significant negative predictor of functionality appreciation for girls within the regression models. These results would appear to suggest that the tendency to ‘listen to’ interoceptive signals for insight is maladaptive during adolescence, when considered in relation to body image. An alternative possibility is that one of the other variables may have biased the regression slopes (see Fuller, 1987). While the direct correlations between body shame and body listening were positive, they were also below the recommended thresholds for statistically meaningful correlation in social sciences (Ferguson, 2009). Furthermore, with regards to the functionality appreciation result, the correlation between body listening and functionality appreciation was also weak, and, in contrast to the regression result, the correlation was *positive*. Therefore, a possible interpretation is that the univariate results for the Body Listening subscale have been affected by regression dilution (Fuller, 1987). Indeed, although VIFs were all within acceptable limits, the correlation between the MAIA Body Listening and the Self-Regulation subscales was high for girls, indicating conceptual overlap in this subsample (Newman et al., 2010).

#### **5.4.1. Limitations**

The large proportion of missing data for self-reported BMI is an important limitation of the present work. This appears to be a common issue with adolescent samples (for a

review, see Sherry et al., 2007). Given that BMI has been consistently associated with facets of interoception (e.g., Herbert et al., 2013; Herbert & Pollatos, 2014) and body image (e.g., Paxton et al., 2006; Tylka & Wood-Barcalow, 2015), it is plausible that BMI accounts for some of the variance that has been attributed to the MAIA variables within the present study, and future work should seek to address this issue. Future work should also seek to explore whether the relationships identified in the present work are robust across other facets of interoception during adolescence (Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2020), and whether they are stable longitudinally. Indeed, as previously discussed, due to the cross-sectional nature of the present work, it is not possible at present to ascertain when or why relationships between some facets of IAW and body image may change between adolescence and adulthood. In a similar vein, the data in the present study were gathered from adolescents at a single school in the UK and, as such, it will be important to determine to what extent the present findings are stable both nationally and in other social identity and cultural groups.

#### **5.4.2. Conclusion**

In summary, the present work identified associations between IAW and four facets of body image in an adolescent sample. Consistent with previous research (Studies 1 and 2; see also Daubenmier, 2005; Oswald et al., 2017), I observed that appraisals of interoceptive stimuli, and the regulation of attention toward interoceptive stimuli, appear to be more closely associated with body image than the tendency to notice interoceptive stimuli in a previously unexplored developmental period. As a further extension of previous literature, I also identified complex associations between facets of IAW and body image that appear to be gender-specific. Considered altogether, there is a growing body of evidence to suggest that mindful attention toward interoceptive signals could promote positive body image. The present work also indicates that potential interventions may need to be targeted according to

developmental stage (adolescence or adulthood) and gender. However, it is also important to note that, due to the cross-sectional design of the present (and previous) work, a causal relationship between IAw and body image can only be inferred hypothetically at present. In particular, whilst longitudinal research supports the assertion that early impairments in IAw are associated with later vulnerability to the development of eating disorders (Killen et al., 1996; Leon et al., 1995; Lilenfeld et al., 2006), no such studies have explored positive body image.

## **6. General discussion of Studies 1-4**

In this series of studies, I examined relationships between facets of IAw and body image. The overarching aims of this series of studies were to expand the available literature concerning relationships between IAw and body image (see Sections 1.3.2 and 1.3.3) by: (1) exploring the associations between the constructs in samples that are more diverse in terms of gender, age, and cultural and national identity; (2) exploring associations across facets of positive and negative body image, and; (3) exploring the explanatory power of multidimensional IAw. To that end, Study 1 examined the associations in a sample of adults from the UK; Study 2 examined the associations in a sample of Malaysian adults; Study 3 examined the extent to which the associations are robust across the two national samples, and; Study 4 examined the association in a sample of adolescents from the UK, with particular attention towards gender.

Despite necessitated differences in methodology across the four studies (in particular, the selection of measures that were psychometrically-valid for use with each of the target populations), there were several discernible trends across the four studies. First, at the broadest level of abstraction, statistically significant associations between IAw and body image were observed across all three samples. Second, facets of IAw were more closely associated with facets of positive body image in comparison to facets of negative body image. Finally, the magnitude of the associations between IAw and body image vary across facets of IAw, with appraisals of interoceptive stimuli (in particular, the IAw facet of body trust) tending to be more closely associated with body image than the extent to which interoceptive stimuli are noticed. In this section, I will discuss each of these findings in turn, before turning to discuss the overarching limitations of Studies 1 to 4.

## **6.1. Statistically significant associations between IAw and body image were observed across all three samples**

Across Studies 1 to 4, IAw uniquely accounted for significant proportions of the variance for all of the body image facets under examination. (The only exception to this was the negative body image facet of body surveillance, which was not significantly associated with IAw for UK adolescent girls.) As I previously outlined in Section 1.4, prior to the present series of studies, associations between interoception and body image had been examined exclusively in North America and Western Europe, and most studies relied on small samples of predominantly young female university students and young female clinical samples. The findings from Studies 1 to 4 extend the available literature by indicating that the relationship between body image and IAw is significant in wider populations than had been previously considered (i.e., samples of women and men from diverse national contexts, and at different developmental stages).

I also identified nuanced univariate patterns of findings that were specific to each of the respective samples, which is consistent with previous research indicating that interoception and body image vary as independent constructs across gender, lifespan development, and cultural groups (see Sections 1.1.2 to 1.1.4 and 1.2.2 to 1.2.4). For example, for adolescent girls, the MAIA Trusting subscale emerged as the strongest, and most consistent predictor variable, which is consistent with findings from UK and Malaysian adults (Studies 1-3). However, for adolescent boys, it appears that the ‘regulatory’ aspects of IAw (i.e., the Self-Regulation, Attention Regulation, and Body Listening subscales) are the most relevant to body image. Moreover, for UK adults, the MAIA Attention Regulation subscale emerged as a significant (positive) predictor for both body appreciation and body pride, but for Malaysian adults, Attention Regulation emerged as a significant negative predictor of functionality appreciation within the regression analyses. In future research,

qualitative methods could be used to further our understanding of multidimensional IAw in different demographic samples (as in, Freedman et al., 2020). Based upon the present findings (and previous research e.g., Freedman et al., 2020; Todd, Barron et al., 2020), it is plausible that the self-perceived ability to regulate attention towards interoceptive stimuli may be conceptualised in unique ways across different national contexts and across different developmental periods.

Considered altogether, there is a growing body of evidence to suggest that mindful attention toward interoceptive signals (e.g., through mindfulness-based practices; Bornemann et al., 2015) could promote positive body image. However, while there is an overall association between IAw and body image that generalises across diverse demographic groups, the findings from Studies 1 to 4 also indicate that potential interventions may need to be targeted to specific demographic groups. For example, body scan meditations (which have been previously been evidenced to improve components of interoception; Fischer et al., 2017; Kok & Singer, 2017; for a review see Gibson, 2019) could be adapted to focus on the most relevant facets of IAw for each demographic group (e.g., a specific focus on body trust, or attention regulation) for maximum efficacy.

## **6.2. Facets of IAw are more closely associated with facets of positive body image in comparison to facets of negative body image**

A second consistent finding across all three groups was that the MAIA variables explained a relatively greater proportion of the variance for the positive body image variables in comparison to the negative body image variables. This supports the previous findings of a conceptual distinction between positive body image and negative body image (for an overview, see Section 1.2.1). In particular, the distinction in the present findings could be due to the relatively greater focus on exteroceptive appearance within the construct of negative body image, in contrast to the preferential focus upon physiological factors, such as body

functionality, strengths, and health within the construct of positive body image (Avalos et al., 2005; Tiggemann & McCourt, 2013; Tylka & Wood-Barcalow, 2015; Wood-Barcalow et al., 2010). Regarding the positive body image findings, one possible mechanism that could explain the association between interoception and positive body image could be that people who are more able to regulate attention toward their internal bodily signals are better able to appreciate the positive functions that the body performs, which, in turn, promotes a more generalised body appreciation (see Study 3).

Meanwhile, for the negative body image variables, demographic factors – in particular, gender, and BMI – appeared to explain a greater proportion of the variance. For example, in UK adults (Study 1) the MAIA variables accounted for 6% of the variance in overweight preoccupation, while demographic factors accounted for 20% of the variance. Meanwhile for UK adolescents, most of the associations between facets of IAW and body image varied significantly across gender (Study 4). Age, on the other hand, did not appear to be overly relevant to the relationships. Indeed, despite the wide age range covered across the three studies, age was only weakly correlated with appearance orientation for UK men, and with drive for muscularity for Malaysian men, with the remainder of the effect sizes for age below the recommended minimum for a practically significant effect (Ferguson, 2009).

### **6.3. There are nuanced associations between facets of IAW and body image**

A final consistent finding across all three groups was that the magnitude of the associations between IAW and body image varied across facets of IAW, with appraisals of interoceptive stimuli tending to be more closely associated with body image than the extent to which interoceptive stimuli are noticed. In particular, there was a consistently strong association between body trust and the body image variables for all three samples: individuals who judged interoceptive signals to be safe and reliable sources of information tended to evidence greater positive body image and less negative body image. These findings

extend earlier research, which has indicated that the way interoceptive signals are valued and responded to might be more closely associated with facets of body image than the self-perceived tendency to notice interoceptive cues (Brown et al., 2017; Daubenmier, 2005; Oswald et al., 2017). It is possible that interoceptive affects and beliefs could have a top-down influence on the salience of interoceptive cues, whereby individuals who trust bodily stimuli are more likely to attend to bodily information and respond to bodily cues, both of which might promote a more positive body image.

Nevertheless, an important caveat to these findings, is that the degree of conceptual overlap between positive body image (in particular, body appreciation) and body trust remains unclear. It is possible, for example, that both constructs could fit within a higher-order dimension of ‘positive body affect’, which would refer to a generalised positivity toward the body. In particular, the correlations in the UK sample indicated that body trust and body appreciation might be conceptually intertwined. However, the results from the correlations in the UK adolescent sample and the Malaysian adult sample both suggest that the two constructs are related but distinct. Given the novelty of the present work, further replication and scrutiny of these associations are required to determine the degree of commonality between the two constructs, and whether the commonality varies by national group and developmental stage.

#### **6.4. General limitations of Studies 1-4**

All four studies were limited by the relatively poor psychometric properties of the MAIA (for a full review of the psychometric properties of the MAIA, see Todd, Barron et al., 2020). For example, in the Malaysian sample, the parent factor structure of the MAIA was not supported, which could indicate that the meaning and experience of IAW varies across culture (Todd, Barron et al., 2020). Furthermore, across all four studies, the MAIA Not-Distracting and Not-Worrying subscales were eliminated for reasons of poor internal

consistency (Study 1 and Study 4), or inconsistent factor loadings (Study 2; see Todd, Barron et al., 2020). In addition, some of the MAIA subscales were highly correlated, which complicated the interpretation of the regression analyses in Study 1 and Study 4. In future work, use of the MAIA-2 (Mehling et al., 2018) – which has slightly improved psychometric properties – might address some of these issues.

The studies are also limited by the use of a cross-sectional design, which precludes causal assertions. As previously indicated, this issue could be addressed in future work through the use of longitudinal research designs. Previous longitudinal work has indicated that early IAw impairments are associated with later development of negative body image (e.g., Killen et al., 1996; Leon et al., 1995; Lilenfeld et al., 2006). However, no research (to date) has examined whether IAw might be predictive of positive body image longitudinally. Given the strong associations between facets of IAw and positive body image that were identified in the present series of studies, future research focusing specifically on positive body image is warranted.

Finally, the present series of studies were all reliant upon self-report measures. While this approach enabled me to examine associations between previously neglected components of interoception (i.e., regulation, appraisals) and body image (i.e., positive body image), it is important that the relationships between IAw and facets of body image that have been identified in Studies 1 to 4 are examined across other components of interoception. In particular, a large body of research supports a divergence between self-reported IAw and the behavioural measures of IAcc and IS (for an overview, see Section 1.1.1). That is, self-assessments of IAw do not necessarily reflect the extent to which an individual can objectively detect interoceptive stimuli. Thus, in Section B (Studies 5 and 6), I explored the relationships between facets of body image and explicit components of IAcc and IS, and implicit components of interoception across gastric and cardiac domains.

## **SECTION B. EXAMINING ASSOCIATIONS BETWEEN BODY IMAGE AND BEHAVIOURAL AND IMPLICIT COMPONENTS OF INTEROCEPTION**

### **7. Study 5: An examination of associations between gastric interoception and body image in adults from the United Kingdom and Malaysia<sup>7</sup>**

#### **7.1. Introduction**

To date, examinations of the relationships between IAcc and body image have almost exclusively focused upon IAcc in the cardiac domain (e.g., Ainley & Tsakiris, 2013; Duschek et al., 2015; Drew et al., 2020; Emanuelsen et al., 2014; Eshkevari et al., 2014; Khalsa et al., 2015; Pollatos et al., 2008; Zamariola et al., 2017; for overviews and discussion, see Sections 1.3.2. to 1.4). This is problematic for two key reasons. First, research regarding the interrelation of IAcc indices across different bodily systems is equivocal, with domain-specific, functionally coupled, and unitary accounts all plausible (see Section 1.1.1). Second, a recent body of evidence has highlighted a large number of confounding variables associated with the measurement of IAcc in the cardiac domain (see Section 1.1.1).

Further research examining associations between body image and IAcc in other bodily domains is, therefore, warranted. In particular, the gastric domain might be especially relevant to body image, given that eating behaviours and appearance are inherently connected (i.e., the amount and types of food consumed over the long term have an influence on one's appearance; e.g., August-Horvath & Tylka, 2011; Daubenmier, 2005; Myers & Crowther, 2008; Oswald et al., 2017). Gastric interoception can be assessed unobtrusively using water load tests (WLTs; Andresen, 2009). When food or drink reach the stomach, gastric distension

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<sup>7</sup> This study was published as follows: Todd, J., Aspell, J. E., Barron, D., Toh, E. K. L., Zahari, H. S., Khatib, N. A. M., Laughton, R., & Swami, V. (2020). Greater gastric interoception is associated with more positive body image: Evidence from adults in Malaysia and the United Kingdom. *Body Image*, 34, 101-111. <https://doi.org/10.1016/j.bodyim.2020.05.011>

is induced. This distension activates vagal afferents, which communicate an increase in gastric volume to the brain (Hellström et al., 2004; Ritter, 2004). Gastric distension can induce satiation alone, independent of the nutritional value of the stomach contents (Phillips & Powley, 2000). During WLTs, gastric distension is induced using water. In the standardised 2-stage WLT protocol (WLT-II; van Dyck et al., 2016), participants drink first until satiation and then until maximum stomach fullness is perceived. Two key indices can be calculated from the WLT-II: the volume of water required to induce satiation (referred to here as *gastric interoceptive sensitivity*), and the percentage of satiation relative to maximum stomach capacity (referred to here as *gastric interoceptive accuracy*).

Investigations specifically reporting on associations between gastric interoception and body image are limited to one study: in developing the WLT-II, van Dyck and colleagues (2016) found gastric IS to be significantly and negatively correlated with drive for thinness and other facets of disordered eating symptomology in a sample of healthy Luxembourgian women ( $N = 99$ , age  $M = 22.86$ ). That is, greater drive for thinness was significantly associated with lower sensitivity to gastric distension, but no significant associations were found for gastric IAcc. Given the dearth of literature on the subject, it is important to further examine the relationships between gastric interoception and body image. In particular, fuller coverage of the body image construct (e.g., facets of positive body image) and the utilisation of samples that are more culturally diverse are key areas that require attention.

On the issue of cultural diversity, as noted in Section 1.4., there is a paucity of research examining relationships between interoception and body image outside of North American and Western European populations. Indeed, at present, no previous studies have considered associations between interoception and body image in a non-Western context outside of Study 2. This is an important limitation of the available literature because the value of existing models for populations beyond Western nations is unclear. In particular,

while the direction and strength of the relationships between self-reported facets of IAw and body image appear to be largely consistent across Western (UK) and non-Western (Malaysian) samples (see Study 3), further research is required to examine the role of culture upon the relationships between body image and other components of interoception – such as IAcc – because of the aforementioned distinction between components of interoception such as IAw and IAcc (see Section 1.1.1). That is, self-assessments of IAw do not necessarily correlate with the extent to which an individual can objectively detect interoceptive stimuli. Indeed, the distinction between IAw and IAcc has been particularly evident in previous cross-cultural studies of interoception (for a review, see Ma-Kellams, 2014; see also Section 1.1.2). In light of these findings, it is necessary to examine associations between body image and IAcc in non-Western samples, as the findings from the only available study concerning body image and IAw (Study 2) may not be robust across other components of interoception.

#### **7.1.1. Aims and hypotheses**

To summarise, understanding of the relationships between gastric interoception and body image is limited at present. I sought to rectify this issue, with particular attention paid towards coverage of positive body image and the possible impact of local cultural contexts – neither of which have been previously examined in relation to gastric interoception. Specifically, in the present study, I examined associations between gastric interoception and facets of positive body image across adults from the UK (a Western cultural context) and Malaysia (a non-western cultural context). The UK and Malaysia were selected specifically to build upon the limited extant research examining IAw and body image in Western (UK) and Non-Western (Malaysian) adults (i.e., Studies 1 to 3). Although there are a range of indices of positive body image that could have been utilised, I selected the only two measures of positive body image that measure core and central facets of the construct (Swami et al., 2020) and that have been shown to be invariant across English- and Malay-speaking samples

(Todd & Swami, 2020), namely the BAS-2 (Tylka & Wood-Barcalow, 2015) and the FAS (Allewaert et al., 2017).

As a final aim, I also sought to replicate and extend the only available study concerning associations between gastric interoception and negative body image (van Dyck et al., 2016), by examining a wider set of negative body image variables in a more diverse sample. To facilitate this, I examined associations between gastric interoception and facets of negative body image (i.e., overweight preoccupation and body shame) in a UK sample of adult women and men.

In terms of hypotheses, it was initially unclear whether gastric interoceptive IS and IAcc would be associated with positive body image due to a paucity of research on positive body image and behavioural components of interoception. Nevertheless, extrapolating from the IAW literature (Daubenmier, 2005; Oswald et al., 2017), and the findings from Section A, I expected that higher gastric IS and IAcc would be significantly associated with more positive body image. In terms of the negative body image indices, based upon van Dyck and colleagues' (2016) findings, I expected to find that lower gastric IS and IAcc would be significantly associated with more negative body image. I also expected that gender identity and BMI would account for some of the variance in the relationships between facets of body image and gastric IS and IAcc, respectively, and planned to control for these variables using hierarchical regressions.

Given the exploratory nature of the present work, I also assessed associations between the self-reported intensity of gastric sensations during the WLT-II (i.e., *gastric magnitude*, see Section 2.2.4) and facets of positive body image. As this was a novel line of research, it was unclear whether significant associations would emerge; nevertheless, I hypothesised that higher self-reported gastric magnitude would be significantly associated with more positive body image, for both the UK and Malaysian samples. Relatedly, I hypothesised that lower

self-reported gastric magnitude would be associated with more negative body image. Finally, I intended to examine whether associations between gastric interoception and body image are robust across samples from the UK and Malaysia. After Ma-Kellams (2014), I expected that the Malaysian sample would evidence significantly lower gastric interoceptive IS and IAcc than the UK sample, which could, in turn, indicate that components of IAcc may be less relevant to body image in non-Western samples. Therefore, I expected that the associations between the gastric interoception variables and the positive body image variables would be significantly weaker for the Malaysian group.

## **7.2. Method**

### **7.2.1. Participants**

In the UK, 93 British citizens enrolled at Anglia Ruskin University (women  $n = 54$ , men  $n = 39$ ) were recruited to take part in the study. Two male participants were excluded from the analyses because they did not adhere to the full protocol, leaving a final sample of 91 participants. These participants ranged in age from 18 to 56 years ( $M = 25.47$ ,  $SD = 8.40$ ) and in BMI from 16.60 to 55.05 kg/m<sup>2</sup> ( $M = 25.64$ ,  $SD = 5.74$ ). The majority of participants self-reported their ethnicity as British White (67.7%; British Asian = 14.0%; mixed = 8.6%; Black or African Caribbean = 5.4%; other = 4.3%). In Malaysia, 105 adults enrolled at a university in the state of Selangor were recruited to take part in the study. Five participants did not adhere to the full protocol and were therefore excluded, leaving a final sample of 100 participants (women  $n = 50$ , men  $n = 50$ ). These participants ranged in age from 18 to 36 years ( $M = 22.63$ ,  $SD = 3.25$ ) and in BMI from 15.57 to 40.35 kg/m<sup>2</sup> ( $M = 23.56$ ,  $SD = 5.18$ ).

### **7.2.2. Measures**

**Body appreciation.** Participants were asked to complete Body Appreciation Scale-2 (BAS-2; Tylka & Wood-Barcalow, 2015; Malay translation: Swami, Mohd. Khatib et al., 2019), as described previously, in English or Bahasa Malaysia (Malay). In the present study,

$\omega$  for body appreciation scores in the total sample was .90 (95% CI = .80, .94; UK sample: .89, 95% CI = .84, .92; Malaysian sample: .90, 95% CI = .87, .92).

**Functionality appreciation.** Participants were asked to complete the Functionality Appreciation scale (FAS; Alleva et al., 2017; Malay translation: Swami, Todd et al., 2019), as described previously, in English or Malay. In the present study,  $\omega$  for functionality appreciation scores in the total sample was .84 (95% CI = .77, .92; UK sample: .84, 95% CI = .78, .88; Malaysian sample: .85, 95% CI = .79, .89).

**Body shame.** To measure a facet of negative body image, UK participants were asked to complete the 8-item Body Shame subscale from the Objectified Body Consciousness Scale (McKinley & Hyde, 1996), as described previously. In the UK sample,  $\omega$  for body shame scores was .70 (95% CI = .64, .71). Malaysian participants were not asked to complete the Body Shame subscale because its psychometric properties have not yet been examined in a Malaysian sample.

**Overweight preoccupation.** To measure a second facet of negative body image, UK participants were asked to complete the Overweight Preoccupation subscale from the Multidimensional Body-Self Relations Questionnaire Appearance Scales (MBSRQ-AS; Cash, 2000), as described previously. In the UK sample,  $\omega$  for overweight preoccupation scores was .71 (95% CI = .59, .79). Malaysian participants were not asked to complete the Overweight Preoccupation subscale because its psychometric properties have not yet been examined in a Malaysian sample.

**Gastric interoception.** The 2-step Water Load Test (WLT-II) was performed using a standardised procedure that has been demonstrated to be both valid and reliable (van Dyck et al., 2016). Participants were asked to drink room temperature, non-carbonated water over two successive 5-minute intervals. At the first drinking stage, participants received the following written instruction: “During the following five minutes, we ask you to drink water until

perceiving a sign of satiation. By satiation we mean the comfortable sensation you perceive when you have eaten a meal and you have eaten enough, but not too much.” Consistent with van Dyck and colleagues (2016), participants were not told that there would be a second drinking stage until they had completed the first stage to ensure that consumption at the first stage was accurate. Between the first and second stages, participants received written debriefing information, which revealed that they would be asked to drink for a second time and included a reminder of their right to withdraw. All participants elected to proceed to the next stage of the experiment. At the second drinking stage, participants were presented with the following written instruction: “We now ask you to drink again. During the following five minutes please continue drinking until your stomach is completely full. That is, entirely filled with water.” For the Malaysian participants, the WLT-II instructions were first translated into Bahasa Malaysia (Malay) and then back-translated into English by two English-Malay bilinguals. The translation was then reviewed for discrepancies by a panel of four bilinguals with knowledge of the topic, and minor issues were settled using a consensual approach.

Across both drinking stages, water was self-administered in opaque 1.8-litre flasks, which participants drank from using long straws. Participants were not informed that the flasks had been filled with 1.5 litres of water. The flasks had a mirror-reflective interior to reduce visual cues regarding the volume of the contents and participants were told not to move the flask in any way. The volume of water consumed was recorded to the nearest 1 ml after the experimental session using digital weighing scales. No feedback was given at any point during the task. All instructions and questionnaires were delivered and completed using online survey software (Qualtrics™). Research assistants intervened only to deliver the flasks for the drinking stages and to answer any questions from participants following the study information and debriefing sessions. For the remainder of the study protocol, research assistants were located in an adjacent room (see Procedure section below).

Two key indices were calculated using the WLT-II data: the volume of water (ml) required to induce satiation (i.e., stage one consumption; gastric IS), and the percentage of satiation to total water volume (gastric IAcc), which was calculated as

follows:  $\frac{\text{Stage One Consumption}}{\text{Stage One Consumption} + \text{Stage Two Consumption}} \times 100$  (van Dyck et al., 2016). I interpreted

gastric IS values inversely, whereby a higher value indicates that satiation is perceived relatively later (i.e., a delayed response to gastric distension) and a lower gastric IS value indicates that satiation is perceived relatively sooner. I also interpreted gastric IAcc values inversely, whereby a lower value indicates greater accuracy because the participant is considered to have perceived satiation at a lower percentage of their total stomach capacity.

**Gastric magnitude.** Participants were asked to complete an 8-item questionnaire to assess subjective sensations related to the WLT-II, which was based upon the items reported by van Dyck and colleagues (2016). Specifically, participants indicated momentary sensations of stomach fullness, stomach tension, thirst, guilt, nausea, sluggishness, discomfort, and satiation. Items were answered on a 7-point scale (1 = *no sensation/not at all*, 7 = *extremely*). For the Malaysian participants, the items, instructions, and response scale were back-translated into Bahasa Malaysia using the same steps described above.

Participants were asked to answer the WLT-II questionnaire before the first water intake ( $t_0$ , baseline) and again after the first ( $t_1$ ) and second ( $t_2$ ) drinking stages. Separate principal-axis exploratory factor analyses (EFA) with data from the UK and Malaysian samples indicated that the following four items could be combined into one factor for both samples: guilt, nausea, sluggishness, and discomfort (for full EFA results, see Appendix III). I termed this factor negative gastric affect and  $\omega$  for these scores in the total sample was .82 (95% CI = .71, .83; UK sample:  $\omega$  = .78, 95% CI = .70, .84; Malaysian sample:  $\omega$  = .83 (95% CI = .75, .87)). The EFA analyses also allowed for the retention of a second factor comprising ratings of stomach fullness, thirst (reverse scored), and satiation. As these items

refer to the intensity of the sensations elicited by the WLT-II, I termed this factor gastric magnitude (Khalsa et al., 2018). Omega for gastric magnitude scores in the total sample was .73 (95% CI = .68, .78; UK sample: .72, 95% CI = .66, .79; Malaysian sample: .75, 95% CI = .62, .80). In accordance with the approach of Ferentzi, Bogdány and colleagues (2018), I computed difference scores ( $t_2$  ratings –  $t_0$  ratings) for negative gastric affect and gastric magnitude, where higher scores indicate greater negative gastric affect and gastric magnitude.

**Demographics.** Participants were asked to complete a demographic questionnaire, which included items related to age, ethnicity, and gender identity (participants were asked to choose one of the following options: male, female, other gender identity, prefer not to say). These were used for descriptive purposes.

**Body mass index.** Height and weight measurements were also collected as part of the study and these data were used to compute BMI as kg/m<sup>2</sup>. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Seca, USA). Weight was measured using a floor scale (Marsden M-430, Marsden, UK) to the nearest 0.1 kg, with participants wearing light clothing.

### 7.2.3. Procedure

Prior to data collection, ethics approval was obtained from the relevant ethics committees at Anglia Ruskin University and Perdana University (approval codes: FST/FREP/17/75; PU IRBHR0232). Exclusion criteria for the study included diagnosis of a physical condition that affects diet or weight (e.g., diabetes or Crohn's Disease) or present use of medications that affect diet or weight, diagnosis of a neurological or psychiatric condition, and pregnancy. Because the aim was to recruit two samples that were homogeneous in terms of cultural and national identity, eligibility in the UK was limited to UK citizens, and eligibility in Malaysia was limited to Malaysian citizens who are of

Malay ancestry (i.e., the majority ethnic group in Malaysia). To minimise possible experimenter effects, the procedure was conducted with minimal input from research assistants and a strict research protocol was adhered to. All participants were required to fast for a minimum of 3 hours before the study and to refrain from drinking for 2 hours before the study (consistent with van Dyck et al., 2016). All study materials were presented and completed using a computer terminal. First, participants were presented with an information sheet and provided written informed consent. Following this, participants completed a written screening questionnaire (to ascertain compliance with the fasting requirements and the inclusion/exclusion criteria). Data from individuals who did not meet the inclusion criteria ( $n = 6$ ) were excluded from the study. Participants then completed the body image measures (presented in a randomised order across participants), followed by the WLT-II. All of these steps were completed in an isolated room in a quiet laboratory, with the research assistant located in an adjacent room. Next, the research assistant recorded height and weight measurements. Finally, all participants received written debriefing information and had the opportunity to ask any questions. Participants were offered £7/RM40 as remuneration for their time or course credit. Testing was completed in an average of 40 minutes.

### **7.3. Results**

#### **7.3.1. Preliminary analyses**

Missing data accounted for 0.2% of the UK dataset and were missing completely at random, as determined by Little's (1988) MCAR test,  $\chi^2(1144) = 736.00, p = .999$ . Missing data were replaced using the multiple imputation technique with the *MICE* package (van Buuren, 2018) in *R* (*R* development Core Team, 2014). There were no missing data in the Malaysian data set. Further data screening did not reveal any unduly influential outliers.

There were no significant differences in the distribution of gender identities across the two national samples,  $\chi^2(1) = 1.68, p = .195$ , but there were significant group differences in

mean age,  $t(189) = 3.10, p = .002, d = 0.46$ , and mean BMI,  $t(189) = 2.63, p = .009, d = 0.38$ , with the UK sample being both significantly older ( $M = 25.56, SD = 8.47$ , versus  $M = 22.63, SD = 3.25$ ) and higher in BMI ( $M = 25.65, SD = 5.78$ , versus  $M = 23.56, SD = 5.18$ ) than the Malaysian sample.

Based on my previous work indicating that BAS-2 and FAS scores are partially invariant across UK and Malaysian samples (Todd & Swami, 2020), I computed a series of  $2 \times 2$  analyses of covariance (ANCOVAs), with the positive body image variables and the WLT-II indices included as dependent variables, and national group (UK versus Malaysian) and gender identity (women versus men) included as between-subject variables. BMI and age were entered as covariates due to the significant mean differences across the two national groups. For gastric IS, the results indicated that BMI,  $F(1, 185) = 1.37, p = .241, \eta_p^2 = .01$ , and age,  $F(1, 185) = 0.09, p = .786, \eta_p^2 < .01$ , were not significant covariates. There were significant main effects of national group,  $F(1, 185) = 9.04, p = .003, \eta_p^2 = .05$ , and gender,  $F(1, 185) = 13.14, p < .001, \eta_p^2 = .07$ , where mean UK consumption was significantly greater than mean Malaysian consumption, and men's mean consumption was greater than women's mean consumption (see Table 20 for descriptive statistics). However, the interaction between national group and gender was not significant,  $F(1, 185) = 0.75, p = .387, \eta_p^2 < .01$ .

For gastric IAcc, the results indicated that BMI,  $F(1, 185) = 0.84, p = .360, \eta_p^2 < .01$ , and age,  $F(1, 185) = 2.86, p = .093, \eta_p^2 = .01$ , were not significant covariates. The main effects of national group,  $F(1, 185) = 0.64, p = .424, \eta_p^2 < .01$ , and gender,  $F(1, 185) = 0.22, p = .639, \eta_p^2 < .01$ , were also not statistically significant. Likewise, the interaction between national group and gender was also not statistically significant,  $F(1, 185) = 0.12, p = .732, \eta_p^2 < .01$ .

For gastric magnitude, the results indicated that BMI,  $F(1, 185) = 2.79, p = .096, \eta_p^2 = .02$ , and age,  $F(1, 185) = 0.08, p = .773, \eta_p^2 < .01$ , were not significant covariates. The main

effects of national group  $F(1, 185) = 0.19, p = .667, \eta_p^2 < .01$ , and gender,  $F(1, 185) = 1.37, p = .245, \eta_p^2 < .01$ , were also not statistically significant. However, the interaction between national group and gender was statistically significant,  $F(1, 185) = 7.86, p = .006, \eta_p^2 = .04$ , with Malaysian men reporting greater gastric magnitude than UK men, but UK women reporting greater gastric magnitude than Malaysian women (see Table 20 for descriptive statistics).

For negative gastric affect, the results indicated that BMI,  $F(1, 185) = 0.46, p = .497, \eta_p^2 < .01$ , and age,  $F(1, 185) = 0.82, p = .366, \eta_p^2 < .01$ , were not significant covariates. The main effects of national group,  $F(1, 185) = 0.80, p = .777, \eta_p^2 < .01$  and gender,  $F(1, 185) = 0.87, p = .353, \eta_p^2 < .01$ , were also not statistically significant. Likewise, the interaction between national group and gender was also not statistically significant,  $F(1, 185) = 0.01, p = .936, \eta_p^2 < .01$ .

Table 20

*Descriptive Statistics for the Analyses of Covariance for the WLT-II indices and the body image indices.*

Variable	National group	Gender	<i>N</i>	<i>M</i>	<i>SD</i>
GISt (ml)	UK	Women	54	520.94	213.03
		Men	37	627.11	325.19
		Total	91	564.11	267.91
	Malaysian	Women	50	361.54	211.37
		Men	50	531.12	274.47
		Total	100	446.33	258.19
	Total	Women	104	444.31	225.86
		Men	87	571.94	299.11
		Grand average	191	502.45	268.72
GIAcc (%)	UK	Women	54	61.84	12.56
		Men	37	60.15	15.30
		Total	91	61.16	13.69
	Malaysian	Women	50	62.64	21.16
		Men	50	62.18	14.16
		Total	100	62.41	17.91
	Total	Women	104	62.23	17.16
		Men	87	61.32	14.61
		Grand average	191	61.81	16.01
Gastric magnitude	UK	Women	54	4.42	1.24
		Men	37	3.64	1.54
		Total	91	4.10	1.31
	Malaysian	Women	50	3.84	1.44
		Men	50	4.14	1.31
		Total	100	3.99	1.38
	Total	Women	104	4.14	1.28
		Men	87	3.93	1.43
		Grand average	191	4.04	1.35
Negative gastric affect	UK	Women	54	1.01	1.61

Body appreciation		Men	37	1.20	1.49
		Total	91	1.08	1.56
	Malaysian	Women	50	1.04	1.59
		Men	50	1.26	1.62
		Total	100	1.15	1.60
	Total	Women	104	1.01	1.59
		Men	87	1.24	1.56
		Grand average	191	1.12	1.58
	UK	Women	54	3.62	0.65
		Men	37	3.60	0.72
		Total	91	3.61	0.67
	Malaysian	Women	50	4.09	0.56
		Men	50	4.10	0.62
		Total	100	4.10	0.59
	Total	Women	104	3.85	0.65
		Men	87	3.89	0.70
		Grand average	191	3.87	0.67
Functionality appreciation	UK	Women	54	4.39	0.47
		Men	37	4.34	0.58
		Total	91	4.37	0.52
	Malaysian	Women	50	4.45	0.47
		Men	50	4.55	0.50
		Total	100	4.50	0.49
	Total	Women	104	4.42	0.47
		Men	87	4.46	0.54
		Grand average	191	4.44	0.50

*Note.* GIST = Gastric interoceptive sensitivity; GIAcc = Gastric interoceptive accuracy; UK = United Kingdom.

For body appreciation, the results indicated that BMI was a significant covariate,  $F(1, 185) = 19.03, p < .001, \eta_p^2 = .09$ , but age was not,  $F(1, 185) = 2.76, p = .098, \eta_p^2 = .01$ . The main effect of national group was statistically significant,  $F(1, 185) = 23.06, p = .001, \eta_p^2 = .11$  (Malaysian participants had significantly higher body appreciation than UK participants; see Table 20 for descriptive statistics), but the main effect of gender was not,  $F(1, 185) = 0.01, p = .926, \eta_p^2 < .01$ . The interaction between national group and gender was also not statistically significant,  $F(1, 185) = 0.05, p = .829, \eta_p^2 < .01$ .

Finally, for functionality appreciation, the results indicated that BMI,  $F(1, 185) = 9.01, p = .003, \eta_p^2 = .05$ , and age,  $F(1, 185) = 4.72, p = .031, \eta_p^2 = .03$ , were both significant covariates. However, the main effects of national group,  $F(1, 185) = 2.81, p = .096, \eta_p^2 = .02$ , and gender,  $F(1, 185) = 0.18, p = .673, \eta_p^2 < .01$ , were not statistically significant. The interaction between national group and gender was also not statistically significant,  $F(1, 185) = 1.31, p = .253, \eta_p^2 < .01$ .

In light of these results, I elected to compute a series of correlations and regressions separately for each national group, before computing analyses for the positive body image variables with the total sample.

### **7.3.2. Correlations and regressions for UK participants**

I computed bivariate correlations between all positive and negative variables for the total UK sample (see the lower diagonal of Table 21). I also computed partial correlations controlling for BMI (see the upper diagonal of Table 21). In terms of the positive body image variables, results indicated that neither gastric IS nor gastric IAcc were significantly correlated with the positive body image variables, but negative gastric affect and gastric magnitude both had significant (small) positive correlations with body appreciation. There was also a significant (small) positive correlation between gastric magnitude and

functionality appreciation. There was also a small statistically significant correlation between negative gastric affect and body appreciation after controlling for BMI.

For the negative body image variables, there were significant (small) negative correlations with gastric IS, but only the correlation between gastric IS and overweight preoccupation remained statistically significant after controlling for variance in BMI. Gastric IAcc was not significantly associated with the negative body image variables. In terms of the correlations between self-report WLT indices and the negative body image variables, there was a significant (small) negative correlation between gastric magnitude and overweight preoccupation, and this association remained statistically significant after controlling for variance in BMI.

Next, I examined the amount of variance that the WLT-II indices accounted for in each of the body image variables using regression analyses. Specifically, I computed four hierarchical regressions, with body appreciation, functionality appreciation, body shame, and overweight preoccupation entered as criterion variables, respectively. For all analyses, the effects of BMI and gender identity were controlled for in the first step, and then gastric interoceptive sensitivity, negative gastric affect, and gastric magnitude were entered simultaneously in the second step. Gastric IAcc scores were not included due to the dependence on gastric IS scores (see Section 3.2.2) and because gastric IAcc was not significantly correlated with any of the body image variables. Prior to conducting the analyses, it was ascertained that all relevant parametric assumptions were met.

Table 21

*Bivariate Correlations between All Variables (Lower Diagonal) and Partial Correlations Controlling for Body Mass Index (Upper Diagonal) for Adults in the United Kingdom.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GIST		.30**	.11	-.23*	-.06	.03	.12	.28**
(2) GIAcc	.37**		-.13	.03	.05	.13	< .01	< .01
(3) Negative gastric affect	-.01	-.01		-.17	.23*	.03	-.06	-.01
(4) Gastric magnitude	-.15	.02	-.18*		.16	.16	-.17	-.27**
(5) Body appreciation	-.11	.03	.24*	.23*		.56**	-.39**	-.17
(6) Functionality appreciation	-.12	.10	.05	.25**	.56**		-.19*	-.03
(7) Body shame	.20*	.02	-.04	-.13	-.41**	-.23*		.51*
(8) Overweight preoccupation	.29**	.07	-.07	-.18*	-.26**	-.12	.55**	
(9) Body mass index	.26**	.12	< .01	-.14	-.31**	-.17	.17*	.33*

*Note.*  $N = 91$ ; \* $p < .05$ . \*\* $p < .01$ . GIST = Gastric interoceptive sensitivity; GIAcc = Gastric interoceptive accuracy.

The full regression results for the positive body image variables are reported in Table 22. As can be seen, for body appreciation, the WLT-II indices were statistically significant predictors, together accounting for 6.0% of the variance in body appreciation, after accounting for variance associated with gender identity and BMI. At the univariate level, only negative gastric affect emerged as a statistically significant predictor, with the direction of the associations indicating that participants with greater changes in the self-reported intensity of WLT-related sensations across the drinking stages tended to report higher levels of body appreciation. For functionality appreciation, the three WLT-II indices did not account for a statistically significant improvement in explanatory power, after accounting for variance associated with gender identity and BMI.

The full regression results for the negative body image variables are reported in Table 23. As can be seen, for overweight preoccupation, the WLT-II indices were statistically significant predictors, together accounting for 16.6% of the variance in overweight preoccupation after accounting for variance associated with gender and BMI. At the univariate level, both gastric IS and gastric magnitude emerged as statistically significant predictors, with the direction of the associations indicating that participants who required greater gastric stimulation (consumption in ml) tended to report more overweight preoccupation, and that participants who reported lower changes in the intensity of WLT-related sensations across the drinking stages tended to report more overweight preoccupation. Inspection of the squared semi-partial correlation coefficients indicated that gastric IS and gastric magnitude uniquely accounted for approximately 6.9% and 8.3% of the variance in overweight preoccupation, respectively, after the variance in BMI and gender was accounted for. For body shame, the three WLT-II indices did not account for a statistically significant improvement in explanatory power, after accounting for variance associated with gender and BMI.

Table 22

Results of Multiple Hierarchical Regression Analyses for the Prediction of Body Appreciation and Functionality Appreciation in Adults in the United Kingdom.

Step	Variable	Body appreciation					Functionality appreciation				
		B	SE	$\beta$	<i>t</i>	<i>p</i>	B	SE	$\beta$	<i>t</i>	<i>p</i>
1		$F(2, 88) = 3.74, p = .028, \text{Adj. } R^2 = .06$					$F(2, 88) = 0.20, p = .820, \text{Adj. } R^2 = .02$				
	BMI	-0.03	0.01	-.28	-2.73	.008	-0.01	0.01	-.07	-0.61	.543
	Gender	0.03	0.14	.02	0.20	.846	0.02	0.11	.02	0.14	.892
2		$F(5, 85) = 3.38, p = .008, \text{Adj. } R^2 = .12 (\Delta F p = .037)$					$F(5, 85) = 0.67, p = .647, \text{Adj. } R^2 = .02 (\Delta F p = .404)$				
	BMI	-0.03	0.01	-.24	-2.23	.023	-0.01	0.01	-.07	-0.62	.536
	Gender	0.09	0.14	.07	0.64	.522	0.02	0.12	.02	0.19	.854
	GIS <sub>t</sub>	< 0.01	< 0.01	-.05	-0.47	.642	< 0.01	< 0.01	.07	0.57	.569
	Gastric magnitude	0.11	0.06	.20	1.88	.064	0.08	0.05	.19	1.68	.097
	Negative gastric affect	0.11	0.04	.25	2.49	.015	0.02	0.04	.05	0.46	.645

Note. *N* = 91, BMI = Body mass index, GIS<sub>t</sub> = Gastric interoceptive sensitivity.

Table 23

*Results of Multiple Hierarchical Regression Analyses for the Prediction of Overweight Preoccupation and Body Shame in Adults in the United Kingdom.*

Step	Variable	Overweight preoccupation					Body shame				
		B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
1		$F(2, 88) = 10.33, p < .001, \text{Adj. } R^2 = .17$					$F(2, 88) = 3.75, p = .027, \text{Adj. } R^2 = .06$				
	BMI	0.06	0.02	.36	3.68	< .001	0.03	0.01	.24	2.28	.025
	Gender	0.54	0.20	.27	2.79	.006	0.24	0.15	.17	1.60	.113
2		$F(5, 85) = 10.11, p < .001, \text{Adj. } R^2 = .34 (\Delta F p = < .001)$					$F(5, 85) = 2.86, p = .020, \text{Adj. } R^2 = .09 (\Delta F p = .099)$				
	BMI	0.05	0.02	.29	3.23	.002	0.03	0.01	.20	1.88	.064
	Gender	0.81	0.18	.40	4.44	< .001	0.36	0.16	.24	2.27	.026
	GIST	< 0.01	< 0.01	.28	3.06	.003	<0.01	< 0.01	.13	1.19	.239
	Gastric magnitude	-0.25	0.08	-.31	-3.34	.001	-0.13	0.06	-.21	-1.97	.052
	Negative gastric affect	0.04	0.06	-.06	-0.73	.468	-0.04	0.05	-.09	-0.86	.391

*Note.*  $N = 91$ , BMI = Body mass index, GIST = Gastric interoceptive sensitivity.

### **7.3.3. Correlations and regressions for Malaysian participants**

I computed bivariate correlations between the gastric interoception indices and the positive body image variables for the total sample (Table 24 lower diagonal) and partial correlations controlling for BMI (Table 24 upper diagonal). After controlling for BMI, there was a significant (small) correlation between gastric IS and body appreciation. However, gastric IAcc was not significantly associated with body appreciation or functionality appreciation. Regarding the self-report WLT indices, there were significant (small-to-moderate) correlations between gastric magnitude and body appreciation and functionality appreciation, respectively, and these associations remained statistically significant after controlling for BMI.

Next, I examined the amount of variance that the WLT-II indices accounted for in the positive body image variables using regression analyses (consistent with the approach in Section 7.3.2). The full regression results are reported in Table 25. For body appreciation, the WLT-II indices accounted for a statistically significant proportion (9.6%) of the variance, after the variance associated with gender identity and BMI had been accounted for. At the univariate level, gastric IS emerged as a statistically significant negative predictor – where participants who felt satiated with a smaller volume of water reported greater body appreciation – and gastric magnitude emerged as a statistically significant positive predictor, where participants who reported greater changes in the intensity of gastric stimuli across the drinking stages reported greater body appreciation. Similarly, for functionality appreciation scores, the WLT-II indices accounted for a statistically significant proportion (5.2%) of the variance, after the variance associated with gender identity and BMI had been accounted for. Again, at the univariate level, gastric IS emerged as a statistically significant negative predictor and gastric magnitude emerged as a statistically significant positive predictor.

Table 24

*Bivariate Correlations between All Variables (Lower Diagonal) and Partial Correlations Controlling for Body Mass Index (Upper Diagonal) for Adults in Malaysia.*

	(1)	(2)	(3)	(4)	(5)	(6)
(1) GIST		.44**	.19*	.11	-.17*	-.15
(2) GIAcc	.42**		.08	.01	.13	.11
(3) Negative gastric affect	.22*	.02		.18*	.05	.04
(4) Gastric magnitude	.11	.04	.16		.28**	.20*
(5) Body appreciation	-.11	.14	-.01	.34**		.68**
(6) Functionality appreciation	-.15	.06	.07	.26**	.66**	
(7) Body mass index	-.03	-.06	.03	-.16	-.19*	-.25**

*Note.*  $N = 100$ ; \* $p < .05$ . \*\* $p < .01$ . GIST = Gastric interoceptive sensitivity; GIAcc = Gastric interoceptive accuracy.

Table 25

*Results of Multiple Hierarchical Regression Analyses for the Prediction of Body Appreciation and Functionality Appreciation for Adults in Malaysia.*

Step	Variable	Body appreciation					Functionality appreciation				
		B	SE	$\beta$	<i>t</i>	<i>p</i>	B	SE	$\beta$	<i>t</i>	<i>p</i>
1		$F(2, 97) = 3.96, p = .022, \text{Adj. } R^2 = .06$					$F(2, 97) = 4.87, p = .010, \text{Adj. } R^2 = .07$				
	BMI	-0.03	0.01	-.28	-2.82	.006	-0.03	0.01	-.28	-2.93	.004
	Gender	0.02	0.11	.02	0.20	.840	0.12	0.09	.12	1.22	.225
2		$F(5, 94) = 4.54, p = .001, \text{Adj. } R^2 = .15 (\Delta F p = .005)$					$F(5, 94) = 3.84, p = .003, \text{Adj. } R^2 = .13 (\Delta F p = .037)$				
	BMI	-0.03	0.01	-.22	-2.35	.021	-0.02	0.01	-.26	-2.66	.009
	Gender	0.07	0.12	.06	0.56	.576	0.16	0.10	.17	1.69	.094
	GIS <sub>t</sub>	< 0.01	< 0.01	-.20	-2.03	.045	< 0.01	< 0.01	-.23	-2.28	.025
	Gastric magnitude	0.13	0.04	.31	3.17	.002	0.07	0.03	.19	1.99	.049
	Negative gastric affect	-0.02	0.04	-.06	-0.70	.489	0.01	0.03	.03	0.33	.740

*Note.*  $N = 100$ , BMI = Body mass index, GIS<sub>t</sub> = Gastric interoceptive sensitivity.

#### 7.3.4. Cross-national group analyses

Fisher's  $r$ -to- $z$  transformation was computed to examine whether there were statistically significant differences in the patterns of correlation coefficients for associations between gastric interoception and the positive body image indices across the national groups. The full results are reported in Table 26, with comparison of the zero-order coefficients displayed in the lower diagonal and comparison of the partial coefficients (controlling for BMI) in the upper diagonal. There was only one marginally but statistically significant difference within the correlations between the WLT-II indices and the positive body image indices, namely the zero-order correlation between body appreciation and negative gastric affect,  $z = 1.73$ ,  $p = .042$  (UK  $r = .24$ , Malaysian  $r = -.01$ ), but this association was not significantly different across the two national groups after controlling for BMI,  $z = 1.25$ ,  $p = .106$  (UK  $r = .23$ , Malay  $r = .05$ ).

Next, two hierarchical regressions were computed, with body appreciation and functionality appreciation included as criterion variables, respectively. For both analyses, the effects of BMI and gender identity were controlled for in the first step, then national group was entered in the second step, and finally gastric IS, negative gastric affect, and gastric magnitude were entered simultaneously in the third step. The full results for body appreciation and functionality appreciation are reported in Table 27. For body appreciation, national group accounted for a statistically significant 8.6% of the variance, after controlling for BMI and gender identity. After accounting for variance associated with all three variables (i.e., BMI, gender, and national group), the WLT-II indices were statistically significant predictors, together accounting for 5.3% of the variance in body appreciation. At the univariate level, only gastric magnitude emerged as a statistically significant predictor, with the direction of the associations indicating that participants who reported greater changes in the intensity of WLT-related sensations across the drinking stages tended to report higher

levels of body appreciation. Examination of the squared partial correlation coefficient indicated that gastric magnitude uniquely accounted for approximately 5.9% of the variance in body appreciation.

For functionality appreciation, national group did not significantly account for additional variance, after accounting for variance in BMI and gender identity. Conversely, the WLT-II indices were statistically significant predictors, together accounting for 3.7% of the variance in functionality appreciation, after accounting for variance in gender identity, BMI, and national group. At the univariate level, only gastric magnitude emerged as a statistically significant predictor, with the direction of the associations indicating that participants who reported greater changes in the intensity of WLT-related sensations across the drinking stages tended to report higher levels of functionality appreciation. Examination of the squared partial correlation coefficient indicated that gastric magnitude uniquely accounted for approximately 5.1% of the variance in functionality appreciation.

Table 26

*Fischer's  $z_{\text{observed}}$  Values and Associated  $p$ -values for National Group Comparison of the Zero-order Correlation Coefficients (lower diagonal) and Partial Correlations Controlling for Body Mass Index (Upper Diagonal).*

	(1)	(2)	(3)	(4)	(5)	(6)
(1) GISt		1.11	0.56	2.34*	0.76	1.23
(2) GIAcc	0.40		1.43	0.14	0.55	0.14
(3) Negative gastric affect	1.59	0.20		2.40**	1.25	0.07
(4) Gastric magnitude	1.78*	0.14	2.33*		0.86	0.28
(5) Body appreciation	0.00	0.75	1.73*	0.81		1.33
(6) Functionality appreciation	0.21	0.27	0.14	0.07	1.09	
(7) BMI	2.01*	1.16	0.14	0.14	0.87	0.57

*Note.*  $N = 191$ ; \* $p < .05$ . \*\* $p < .01$ . GISt = Gastric interoceptive sensitivity; GIAcc = Gastric interoceptive accuracy; BMI = Body mass index.

Table 27

*Results of Multiple Hierarchical Regression Analyses for the Prediction of Body Appreciation and Functionality Appreciation in the Total Sample after Controlling for National Group.*

Step	Variable	Body appreciation					Functionality appreciation				
		B	SE	$\beta$	$t$	$p$	B	SE	$\beta$	$t$	$p$
1		$F(2, 188) = 11.70, p < .001, \text{Adj. } R^2 = .10$					$F(2, 188) = 4.22, p = .016, \text{Adj. } R^2 = .03$				
	BMI	-0.04	0.01	-.33	-4.82	<.001	-0.02	0.01	-.20	-2.85	.005
	Gender	0.05	0.09	.04	0.58	.561	0.05	0.07	.05	0.66	.508
2		$F(3, 187) = 15.57, p < .001, \text{Adj. } R^2 = .19 (\Delta F p < .001)$					$F(3, 187) = 3.27, p = .022, \text{Adj. } R^2 = .04 (\Delta F p = .244)$				
	BMI	-0.03	0.01	-.27	-4.09	<.001	-0.02	0.01	-.19	-2.57	.011
	Gender	0.01	0.09	.01	0.15	.885	0.04	0.07	.04	0.54	.589
	National group	0.41	0.09	.31	4.57	<.001	0.09	0.07	.09	1.17	.244
3		$F(6, 184) = 10.98, p < .001, \text{Adj. } R^2 = .24 (\Delta F p = .002)$					$F(6, 184) = 3.45, p = .003, \text{Adj. } R^2 = .07 (\Delta F p = .017)$				
	BMI	-0.03	0.01	-.23	-3.57	<.001	-0.01	0.01	-.15	-2.14	.034
	Gender	0.07	0.09	.05	0.74	.459	0.07	0.07	.07	0.94	.349
	National group	0.39	0.09	.29	4.36	<.001	0.09	0.07	.08	1.14	.256
	GIST	< 0.01	< 0.01	-.12	-1.74	.084	< 0.01	< 0.01	-.06	-0.80	.427
	Gastric magnitude	0.11	0.03	.22	3.40	.001	0.08	0.03	.22	3.13	.002
	Negative gastric affect	0.04	0.03	.08	1.32	.189	0.01	0.02	.02	0.22	.824

*Note.*  $N = 191$ , UK  $n = 91$ , Malaysian  $n = 100$ , BMI = body mass index, GIST = Gastric interoceptive sensitivity.

## 7.4. Discussion

The present study examined associations between gastric interoception and body image in UK and Malaysian adults. Broadly speaking, I identified significant associations between facets of gastric interoception and positive body image, where greater levels of gastric IS were associated with more positive body image in both national groups. This is consistent with my hypotheses and with previous findings of positive associations between self-reported components of interoception (IAw) and positive body image (Daubenmier, 2005; Oswald et al., 2017; see also Section A). I also found that facets of gastric interoception were significantly associated with facets of negative body image in UK women and men, where lower levels of gastric IS were associated with more negative body image. This is consistent with my hypotheses, and with previous findings from Luxembourgian women (van Dyck et al., 2016). As a final contribution to knowledge, the present research demonstrated that associations between gastric interoception and positive body image exist in both Western and non-Western samples.

As I have previously outlined (see Section 1.3.1), scholars have suggested that a reduced sensitivity to interoceptive stimuli could constitute a risk factor for the development of more negative body image, due to an over-reliance upon exteroceptive stimuli such as visual appearance-related characteristics (Badoud & Tsakiris, 2017). For example, individuals with a lower sensitivity to interoceptive stimuli might prioritise visual perceptions of the body (e.g., bodily shape or size) over sensations from internal stimuli. Applying this hypothesis to the present research, it seems plausible that a lower sensitivity to gastric signals might render an individual more reliant upon external eating cues (e.g., portion sizes, time of day). This reliance upon external cues could promote a state of disconnect from the body – where it is viewed from an external, appearance-based perspective – which could foster negative body image (Frederickson & Roberts, 1997). Inversely, a greater sensitivity to

gastric signals might increase awareness of the positive functions that the body performs and facilitate the ability to respond to the body's needs, both of which could promote positive body image (Andrew et al., 2016; Cook-Cottone, 2018; Wood-Barcalow et al., 2010).

Of course, it is also equally plausible that facets of body image could have a top-down impact on the perception of gastric stimuli, whereby individuals who have a positive body orientation (i.e., greater body and functionality appreciation) are more willing and – perhaps because of continued practise – more able to attend to gastric sensations and therefore honour their bodily signals by responding to them (e.g., eating when hungry, and stopping when satiation is perceived), rather than relying on exteroceptive cues (Augustus-Horvath & Tylka, 2011; Avalos & Tylka, 2006). Furthermore, it could be the case that the relationships are mediated by other factors, such as appraisals of interoceptive stimuli (Oswald et al., 2017) or self-compassion (Braun et al., 2016). Indeed, an important limitation of the present work is that it was not possible to ascertain whether there are causal relationships between gastric interoception and body image due to the cross-sectional nature of the research, and future work should seek to address this issue using experimental or longitudinal approaches.

Considering the univariate findings more closely, I identified varying associations between the behavioural and self-reported facets of gastric interoception and the positive and negative body image variables; that is, not all the measures were consistently associated. As an example, in the UK sample, gastric IS did not significantly account for any unique variance in body appreciation, but negative gastric affect did. Conversely, both gastric IS and gastric magnitude significantly accounted for unique variance in overweight preoccupation. These divergent findings could reflect wider distinctions in the constructs of interoception and body image (i.e., self-assessments of IAW do not necessarily reflect the extent to which an individual can objectively detect interoceptive stimuli, and, similarly, while negative body image and positive body image are often correlated, the two have also been associated with

outcome variables in unique ways; see Sections 1.1.1 and 1.2.1). Indeed, for the UK sample, the zero-order correlations between gastric IS and negative gastric affect and gastric magnitude, respectively, were not statistically significant. It is possible that, for UK adults, only the self-reported component of gastric interoception is associated with positive body image. However, given the novelty of the present work, it is difficult to offer more in-depth theorising as to why this might be the case. A growing body of evidence has documented associations between self-reported facets of IAW and facets of positive body image (e.g., Studies 1 to 4; see also Daubenmier, 2005; Oswald et al., 2017), but only one previous study has considered the association between a behavioural component of interoception (IAcc in the cardiac domain) and positive body image (Duschek et al., 2015). As such, the associations between positive body image and behavioural components of interoception (e.g., IAcc) are an area that require further examination in future research.

I also identified differences in the patterns of univariate associations across the UK and Malaysian samples. For the Malaysian sample, the positive body image variables were significantly associated with both gastric IS and gastric magnitude, whereas for the UK sample significant associations were identified between body appreciation and negative gastric affect, but not gastric IS or gastric magnitude, after accounting for gender identity and BMI. Furthermore, there were significant associations between the WLT-II indices and functionality appreciation in the Malaysian sample, after accounting for gender identity and BMI, but none of these WLT-II indices were significantly associated with functionality appreciation for the UK sample. In the absence of further data, it is not possible to conclusively resolve the matter of why these differences exist. Possible sources of variance include additional constructs that were not measured in the present work, such as the extent to which interoceptive signals are trusted as a reliable source of information (i.e., the IAW facet

*body trust*; Mehling et al., 2012), which has been associated with positive body image previously (i.e., Studies 1 to 4).

#### **7.4.1. Limitations**

While the present work extends the extant literature in several ways, this study also had several noteworthy limitations. First, all of the results were based upon the gastric IS index because the gastric IAcc index was not significantly correlated with either of the body image measures in either sample. The gastric IS index is equivalent to a single-stage WLT and scores from single-stage WLTs have been found to correlate with other facets of interoception in previous research (e.g., individuals who consume more water tend to evidence lower cardioceptive accuracy; Herbert et al., 2012). Nevertheless, one problem associated with single stage WLTs is that they may be confounded by differences in stomach capacity (van Dyck et al., 2016). While I controlled for gender identity and BMI in the analyses, it is possible that differences in stomach size – which were not measured in the present research – could account for some of the variance that we have attributed to gastric IS. A second limitation is that the Malaysian sample was ethnically homogenous, but the UK sample was ethnically heterogeneous. As such, there was an additional source of variance in the UK sample and it is not clear whether the present findings are generalisable to other ethnic groups in Malaysia. Relatedly, a more general limitation was that the sample was relatively small and comprised of university students. Therefore, future research with larger, more diverse samples is necessary to replicate the present findings.

#### **7.4.2 Conclusion**

These limitations notwithstanding, the present work indicates that there are significant associations between facets of gastric interoception and positive body image, and that associations can be identified in both UK and Malaysian samples. These findings, in turn, could hold promise for practitioner-based interventions. For example, it is possible that

increasing awareness of satiation-related stimuli could promote body and functionality appreciation, and reduce body shame and overweight preoccupation. The findings are also important theoretically because they demonstrate the value of extant models of interoception and body image beyond the few Western countries where research had been previously conducted, hence extending the generalisability of current theorising (e.g., Badoud & Tsakiris, 2017). Nevertheless, an important task for future researchers is to ascertain whether a causal relationship exists between facets of interoception and body image.

## **8. Study 6: An examination of associations between body image and implicit components of interoception**

### **8.1. Introduction**

At its core, interoception is a physiological process of signal transmission between viscera and the central nervous system (Vaitl, 1996). Accordingly, psychophysiological measures of visceral-afferent signal transmission are a central component of interoception as a construct (Forkmann et al., 2016). Such indicators can be considered implicit measures of interoception, as they do not necessarily require conscious perception of internal bodily sensations (although, attention toward one's heartbeat can modulate the cortical representation of afferent signals related to the cardiac cycle; Petzschner et al., 2019; Villena-González et al., 2017).

In the extant literature (and across Studies 1-5), associations between body image and explicit (i.e., consciously experienced) facets of interoception are well-documented (for an overview, see Sections 1.3.2 to 1.3.3). However, at present, studies have not examined the direct associations between implicit components of interoception and body image. The closest body of related literature concerns studies that have examined neural components of interoception in groups with presumed body image disturbances, such as samples of individuals with disordered eating. For example, Lutz and colleagues (2019) found the amplitude of the heartbeat evoked potential (HEP; see section 8.1.2, below) to be significantly larger in participants with anorexia nervosa in comparison to a group of healthy matched control participants ( $d = 1.06$ ). However, research has indicated that HEPs increase in amplitude after short-term food deprivation (Schulz, Ferreira de Sà, et al., 2015), which may mean that the findings of Lutz and colleagues (2019) are attributable to long-term fasting in anorexia nervosa. Another study indicated that the HEP is associated with aspects of bodily self-consciousness, such as self-identification and self-location (Park et al., 2016).

Specifically, modulations of HEP amplitude covaried with altered states of bodily self-consciousness induced by a full body illusion, as well as with participants' subjective ratings of illusion strength (Park et al., 2016). Overall, while these studies suggest that there may be an association between body image and interoception at the implicit level (i.e., visceral-afferent signal transmission), this possibility has not yet been directly examined.

To address the aforementioned paucity of literature, the aim of Study 5 was to examine whether there are associations between indices of negative and positive body image, respectively, and implicit components of interoception originating in the cardiac and gastric organ systems: the HEP and gastric-alpha phase-amplitude coupling (PAC). These bodily domains were selected for two reasons. First, in contrast to other organs, the heart and the stomach both continuously and independently produce oscillatory electrical activity, even when disconnected from the central nervous system (Furness, 2012; Suzuki et al., 1986; Zeng et al., 2018). These visceral signals are transmitted to the brain via afferent pathways to provide information about current bodily states (Khalsa et al., 2018). Crucially, a recent body of evidence indicates that these oscillatory signals have an additional function: they are coupled with, and are in some instances the drivers of, brain dynamics and cognition (Azzalini et al., 2019; Richter et al., 2017). The second reason for focusing on the cardiac and gastric domains is that there is a body of literature documenting direct associations between facets of body image and explicit behavioural indices of cardiac perceptual accuracy (e.g., Ainley & Tsakiris, 2013; Duschek et al., 2015; Emanuelsen et al., 2014) and gastric interoception (Study 5; van Dyck et al., 2016). Therefore, it is plausible that associations could exist between body image and implicit indices of cardiac and gastric interoception.

### **8.1.1. Electroencephalography**

Electroencephalography (EEG) is an electrophysiological method for recording brain activity. EEG electrodes on the scalp detect electrical potentials, which represent the summed

signals from excitatory post-synaptic electrical fields (that is, the temporary changes in the polarisation of nerve cells that make them more likely to fire) from aligned neuronal dendrites (Banich & Compton, 2018). Electrical potentials are recorded as waves, which can be analysed in terms of both amplitude (i.e., the size of the signal, measured in voltage) and frequency (i.e., the rate of oscillation, measured in Hertz). EEG has excellent temporal resolution and can show changes in brain activity with millisecond resolution (Banich & Compton, 2018; cf. Burle, et al., 2015).

### **8.1.2. The heartbeat evoked potential**

The HEP is an event-related potential component that reflects the cortical response to cardiac signals (Schandry et al., 1986). The physiological pathways underlying the HEP have not yet been fully ascertained, and it is likely that they are multifaceted (for a review, see Park & Blanke, 2016). For example, neural signals initiated by baroreceptors (i.e., stretch receptors, which continually detect pressure changes when located in the heart) at the aortic arch and carotid arteries have been suggested as one possible source of the HEP (Garfinkel & Critchley, 2016). The afferent signals from baroreceptors are transmitted to the brainstem and thalamus via the vagus nerve (Garfinkel & Critchley, 2016). Research also indicates that direct neural pathways between the heart and the brain may contribute to HEP generation (Tahsili-Fahadan & Geocadin, 2017). Specifically, there are cardiac afferent neurons that detect chemical and mechanical changes in the heart, which relay afferent information directly to the brainstem via the vagal nerve or the spinal cord (Craig, 2003). Once afferent cardiac sensory information reaches the brainstem, (and thalamus, in the case of the first suggested pathway), the information is projected to viscerosensory cortices, including the insula, the amygdala, and the cingulate cortex (Park & Blanke, 2016).

HEP amplitude has been found to be significantly correlated with cardiac IAcc scores ( $r = .28-.34$ ; Fittipaldi et al., 2020; Pollatos et al., 2005; Pollatos & Schandry, 2004; for

reviews, see Coll et al., 2020; Park & Blanke, 2019). Furthermore, attention toward one's heartbeat can modulate the HEP, with a significantly higher amplitude observed when focusing on one's heartbeat compared to exteroceptive stimuli (Petzschner et al., 2019; Villena-González et al., 2017; for a recent review and meta-analysis, see Coll et al., 2020). This modulation appears to be dependent upon cardiac IAcc (Yuan et al., 2007).

To compute the HEP, electrical activity in the brain is measured using EEG, and electrical activity of the heart muscle is measured using electrocardiography (ECG). The EEG is then aligned and averaged to the occurrence of the R-wave of the QRS complex in the ECG. The QRS complex indicates ventricular depolarisation which triggers *ventricular systole* (that is, ventricular contraction), and the R-wave specifically signifies the voltage of the electrical signal as it passes through the main portion of the ventricular walls within the conduction system of the heart (Ashley & Niebauer, 2004). The HEP is commonly detected in frontal and central EEG electrode fields (for a review, see Park & Blanke, 2019). While there is some variability in the existing literature regarding the timing of the HEP (Park & Blanke, 2019), several authors have reported the HEP as a negative deflection within a time-range of 200-400 ms after the R-wave (Pollatos et al., 2005) and as a positive deflection within 455-595 ms after the R-peak (Müller et al., 2015; Schulz et al., 2013; Schulz, Ferreira de Sà et al., 2015; Schulz, Köster et al., 2015).

### **8.1.3. Gastric-alpha phase-amplitude coupling**

Phase-amplitude coupling (PAC) is a key feature of the temporal organisation of neural activity (Florin & Baillet, 2015; Osipova et al., 2008; Roux et al., 2013; Weaver et al., 2016). Specifically, PAC refers to couplings between neural oscillations, where the amplitude of a higher frequency oscillation varies according to the phase of a lower frequency oscillation (Bragin et al., 1995; Buzsaki, 2010; Canolty et al., 2006; Schroeder & Lakatos, 2009). Recently, Richter and colleagues (2017) found that the rule of PAC can be extended to

brain-viscera interactions. Specifically, significant PAC between electrical activity in the stomach and brain was identified (Richter et al., 2017).

The stomach can be considered as an electrical pacemaker: cells within the stomach (i.e., the interstitial cells of Cajal; Sanders et al., 2006; Sanders et al., 2014) produce an electrical slow wave at a rate of three cycles per minute ( $\sim 0.05$  Hz). This rhythm is constantly generated and relayed to the interoceptive areas in the brain (including the insula, the ventral anterior cingulate cortex, and the somatosensory cortex) via afferent sensory neurons (Critchley & Harrison, 2013; Furness et al., 2013; Ito, 2002; Mayer, 2011). As such, the stomach provides a continuous slow oscillatory input, which Richter and colleagues (2017) suggested could constrain resting-state brain dynamics. Indeed, Richter and colleagues (2017) found that the phase of gastric slow waves accounted for 8% of the variance in amplitude fluctuations in the cortical alpha rhythm (i.e., the dominant brain rhythm when resting).

To compute gastric-alpha PAC, the electrical activity in the brain and gastric myoelectrical activity are recorded simultaneously (Richter et al., 2017). Gastric myoelectrical activity can be measured using electrogastrography (EGG; Yin & Chen, 2013). The degree of coupling between EEG power and EGG phase can then be represented by a modulation index (Richter et al., 2017; Tort et al., 2010). A low MI indicates a uniform distribution; that is, no systematic association between EEG power and EGG phase (Richter et al., 2017; Tort et al., 2010). A larger MI indicates that the PAC profile deviates from a uniform distribution; that is, EEG power differs systematically across EGG phase.

#### **8.1.4. Aims and hypotheses**

As indicated above, the aim of Study 6 was to examine whether there are associations between the HEP and gastric-alpha PAC, respectively, and indices of positive and negative body image. Specifically, body appreciation and functionality appreciation were selected to provide coverage of positive body image because recent evidence suggests that they are core

facets of the construct (Swami, Furnham, et al., 2020). Furthermore, in the extant literature (e.g., Oswald et al., 2017) and across Studies 1 to 5, body appreciation and functionality appreciation have been significantly associated with explicit components of interoception. Likewise, body shame and overweight preoccupation were selected to provide coverage of negative body image because they have been previously associated with explicit components of interoception in the extant literature (for an overview, see Sections 1.3.2. and 1.3.3) and across Studies 1, 4, and 5.

Given the novelty of the present work, there were no direct sources of data to draw upon when generating hypotheses. Preliminarily, it was expected that the direction of the associations between facets of body image, the HEP, and gastric-alpha PAC, respectively, would be largely consistent with previously-identified associations between body image and behavioural measures of interoception in the cardiac and gastric domains (for an overview, see Sections 1.3.2. and 1.3.3). More specifically, building on the findings of van Dyck and colleagues (2016) and the findings from Study 5, I expected to identify a negative association between gastric-alpha PAC and the negative body image indices, with a lower MI associated with more negative body image. Based on the findings of Ainley and Tsakiris (2013) and Emanuelson and colleagues (2014), I also expected that there would be a negative association between the HEP and the negative body image variables, with a lower HEP amplitude associated with more negative body image.

Taking into consideration the previously-identified associations between a positive body image index and cardiac IAcc (Duschek et al., 2015), and between the HEP and cardiac IAcc scores (Fittipaldi et al., 2020; Pollatos et al., 2005; Pollatos & Schandry, 2004), I also expected there would be a positive association between the HEP and the positive body image indices, where a higher HEP amplitude is associated with more positive body image.

Regarding gastric-alpha PAC, while behavioural data from an index of gastric interoception

were significantly associated with the positive body image indices in a sample of Malaysian adults (Study 5), the associations were not statistically significant in a sample of UK adults. Nevertheless, self-reported gastric magnitude was significantly associated with facets of positive body image across both Malaysian and UK adults. Given the complexity of these previous findings at the univariate level, it was initially unclear whether there would be significant associations between gastric-alpha PAC and the positive body image variables. As a preliminary hypothesis, a positive association between the gastric-alpha PAC and the positive body image indices was predicted, with a higher MI associated with more positive body image.

## **8.2. Method**

### **8.2.1. Participants**

The participants of this study were 36 right-handed citizens of the UK enrolled at Anglia Ruskin University (men  $n = 15$ , women,  $n = 21$ ). The participants ranged in age from 19 and 40 years ( $M = 23.78$ ,  $SD = 5.71$ ) and in BMI from 19.69 to 30.45kg/m<sup>2</sup> ( $M = 24.67$ ,  $SD = 2.94$ ). The majority of participants self-reported their ethnicity as British White (80.6%; mixed = 11.1%; British Asian = 8.3%). None of the participants reported any previous history of neurological or psychiatric conditions in a screening questionnaire prior to the study (see Procedure, below).

### **8.2.2. Measures**

**Body appreciation.** Participants were asked to complete the 10-item Body Appreciation Scale-2 (BAS-2; Tylka & Wood-Barcalow, 2015), as described previously. In the present study,  $\omega$  for body appreciation scores was .86 (95% CI = .77, .91).

**Functionality appreciation.** To assess a second facet of positive body image, participants were asked to complete the 7-item Functionality Appreciation scale (FAS; Alleva

et al., 2017), as described previously. In the present study,  $\omega$  for functionality appreciation scores was .85 (95% CI = .73, .91).

**Body shame.** To measure a facet of negative body image, participants were asked to complete the 8-item Body Shame subscale from the Objectified Body Consciousness Scale (McKinley & Hyde, 1996), as described previously. In the present sample,  $\omega$  for body shame scores was .83 (95% CI = .71, .89).

**Overweight preoccupation.** To measure a second facet of negative body image, participants were asked to complete the Overweight Preoccupation subscale from the Multidimensional Body-Self Relations Questionnaire Appearance Scales (MBSRQ-AS; Cash, 2000), as described previously. In the present sample,  $\omega$  for overweight preoccupation scores was .78 (95% CI = .58, .88).

**Demographics** Participants were asked to complete a demographic questionnaire, which included items related to gender, age, and ethnicity. These details were used for descriptive purposes.

### 8.2.3. Data acquisition

A BrainAmp amplifier system (Brain Products GmbH, Germany) was used to record the data. Thirty-two active scalp electrodes (FP1, FP2, F7, F3, FZ, F4, F8, FC5, FC1, FC2, FC6, T7, C3, CZ, C4, T8, TP9, CP5, CP1, CP2, CP6, TP10, P7, P3, PZ, P4, P8, PO9, O1, OZ, O2, PO10) were positioned in accordance with the 10-20 System. The electrogastrogram (EGG) and electrocardiogram (ECG) were recorded simultaneously with the EEG data. For the EGG, six disposable cutaneous electrodes were positioned across the lower abdomen in accordance with the 6-lead layout described by Chen and colleagues (1999). To ensure that impedances were kept below 10 K $\Omega$ , participants were asked to clean and exfoliate the skin on their abdomen with a skin preparation gel prior to electrode positioning (Yin & Chen, 2013). For the ECG, three disposable cutaneous electrodes were positioned in standard 3-lead

configuration. The ECG and EGG electrodes shared the same ground electrode. All data were collected at a sampling rate of 1000 Hz, with a low-pass filter at 330 Hz, and BrainVision Recorder software (Brain Products GmbH, Germany) was used to monitor signal acquisition.

#### **8.2.4. Procedure**

Prior to data collection, ethics approval was obtained from the relevant ethics committee (approval code: FST/FREP/17/75). Exclusion criteria for the study included diagnosis of a physical disorder (e.g., diabetes or Crohn's Disease) or present use of medications that affect diet or weight (Wolpert et al., 2020), diagnosis of a neurological or psychiatric condition, pregnancy, and left-hand dominance (consistent with Richter et al., 2017). Participants were required to fast for a minimum of three hours before the study and to refrain from drinking for two hours before the study (Wolpert et al., 2020), and all participants reported adhering to these requirements in a screening questionnaire. The body image measures were completed in a separate session (as part of Study 4) that was scheduled seven days prior to the session for the current study.

Upon arrival, participants were presented with an information sheet and provided written informed consent. Participants were then taken to a Faraday cage for the data recording. Participants were positioned in a semi-reclined sitting position. Data was recorded for 12 minutes, during which time participants were instructed to avoid any voluntary movements and to keep their eyes open (aside from blinking). Participants were asked to let their mind wander and to avoid any structured mental strategies during the recording, such as counting or mentally reciting a text. All participants received written debriefing information and had the opportunity to ask any questions at the end of the study. Participants were offered a £14 Amazon voucher or course credits as remuneration for their time. Participation (including positioning of the electrodes) took an average of 90 minutes.

#### **8.2.5. Data Processing**

**8.2.5.1. HEP data processing.** The data were analysed using MATLAB software (MathWorks, USA) and EEGLAB (Delorme & Makeig, 2004). The data were resampled to 250 Hz and then filtered between 1-40 Hz using the FIR band-pass filter. QRS complexes in the ECG channels were automatically detected and labelled within the ECG and EGG data using the fMRIB EEGLAB plug-in (Centre for Functional Magnetic Resonance Imaging of the Brain, UK). The data for each participant was then subjected to an Independent Component Analysis. Components were manually inspected to remove eye blinks and cardiac artefacts. For three participants, channels with excessive noise (PO9 for one participant and P8 for two participants) were interpolated using the EEGLAB interpolation function. Next, epochs were extracted from the processed EEG data using the R peak of the QRS complex as a temporal reference, with the epoch length spanning from 200ms before each R peak to 800ms after each R peak. The data was then re-referenced to the average of all EEG channels. Epochs with voltage exceeding  $\pm 120 \mu\text{V}$  in any of the channels within the regions of interest (FP1, F7, F3, FC5, FZ, FC1, FC2, CZ, FP2, F8, F4, FC6) were rejected ( $M = 15.58$ ;  $SD = 22.19$ ). HEP amplitudes were collapsed across electrodes to create three equal-sized frontocentral electrode regions of interest (left: FP1, F7, F3, FC5, midline: FZ, FC1, FC2, CZ, right: FP2, F8, F4, FC6). These regions of interest (ROIs) were based upon a large body of previous research that has identified the HEP deflection in the frontal and central electrode fields (for a review see Park & Blanke, 2019). A time-window of 455-595 ms after the R peak was selected, during which the overlap between the HEP amplitude and the electrocardiac field is considered to be minimal (Gray et al., 2007; Schulz et al., 2013; Schulz, Ferreira de Sà et al., 2015). Finally, mean HEP amplitude was calculated for each participant within the time-window for each of the three ROIs.

**8.2.5.2. Gastric-alpha PAC data processing.** The EGG preprocessing steps are in line with recent best-practise guidelines (Wolpert et al., 2020). Specifically, for the EGG

data, gastric frequency in each participant was first determined as the frequency of the largest spectral peak within the normogastric range (0.033–0.066 Hz; Wolpert et al., 2020). The data were low-pass filtered below 5 Hz and down sampled from 500 Hz to 10 Hz. Spectral density was estimated via Hann tapered FFT for each EGG channel over the continuous EGG signal using Welch’s method, with 200 s time windows moving with 150 s overlap. The electrode exhibiting the largest spectral peak in the  $0.05 \pm 0.01$  Hz range was selected for further analysis.

The preprocessing for the gastric-alpha PAC was based upon both the procedure described by Richter and colleagues (2017), and the data-driven approach described by Mikkuta and colleagues (2019). The EEG and EGG raw data were high-pass filtered below 40 Hz and down-sampled from 500 Hz to 250 Hz. EGG Data from the selected channel were then bandpass-filtered to isolate the signal related to the gastric basal rhythm (linear phase finite impulse response filter, designed with the Matlab function FIR2). The data were centred at the EGG peak frequency and then filtered with a bandwidth of  $\pm 0.015$  Hz of the peak EGG frequency and a transition width between the passband and stopband of 15% of the upper and lower passband frequencies (filter order of 5). The data were filtered in the forward and backward directions to avoid phase distortions. The filtered EGG signal was then Hilbert transformed, and the analytic phase was derived. No specific artefact gradient procedure was necessary because the gastric frequency ( $\sim 0.05$  Hz) is free from known cardiac and respiratory artefacts (Glerean et al., 2012; Rebollo et al., 2018).

Instantaneous amplitude was estimated from the analytic signals. To calculate the MI, the phase of the slow oscillation was divided into  $B = 18$  bins (each covering  $20^\circ$ ) (Mikutta et al., 2019). The mean power of the spindle frequency oscillations enveloped within each bin was estimated. The statistical determination of significant clusters of phase amplitude coupling was a 2-step process. First, for each participant, chance-level PAC at each channel

and frequency was estimated. Then, at the group level, channels and frequencies where a significant difference between observed coupling and chance-level coupling differed were determined. The level of PAC expected by chance was estimated in addition to the corresponding chance-level MI for each participant, channel and frequency. For each participant, channel and frequency, a distribution of surrogate MI values was obtained by creating 200 surrogate data sets and computing the associated MIs. For each surrogate data set, the mean  $\mu_{surr}$  and standard deviation  $\sigma_{surr}$  were computed in addition to MI  $z$ -scores, which were defined as:  $Z_{surr} = \frac{PAC_{measure} - \mu_{surr}}{\sigma_{surr}}$  (Penny et al., 2008). The chance level for each participant, channel and frequency was defined as the median of surrogate MI values. A cluster-based permutation procedure (Maris & Oostenveld, 2007) was computed in FieldTrip (Oostenveld et al., 2011) to examine whether empirical MI  $z$ -scores differed significantly from chance level MI at the group level. Briefly, this procedure entailed comparing empirical MI  $z$ -scores with the corresponding chance level MI value across participants using a  $t$ -test at each channel and frequency. Candidate clusters were defined in space as channels exceeding the first level  $t$ -threshold ( $p < 0.05$ , two-sided) and that were connected to at least two neighbouring channels that also exceeded the threshold, and across adjacent frequencies that exceeded the first level  $t$ -threshold. Each candidate cluster was characterised by a summary statistic corresponding to the sum of the  $t$ -values across the channels and frequencies defining the cluster. The second-level statistic (i.e., whether a given sum of  $t$ -values in the candidate cluster could be obtained by chance) was determined by computing the distribution of cluster statistics under the null hypothesis. The labels ‘empirical’ and ‘chance’ were randomly shuffled 10,000 times and the clustering procedure was applied. The largest positive and negative clusters from each permutation were retained. Across the 10,000 permutations, the distribution of cluster statistics under the null hypothesis was built and then used to assess the observed clusters for significance. Because the largest

positive and negative clusters were retained at each permutation, this method intrinsically controls for multiple comparisons over channels and frequencies (Maris & Oostenveld, 2007). This data-driven approach resulted in four final ROIs: (1) left frontal: FP1, F7, F3; (2) right frontal: FP2, F8, F4; (3) left centroparietal: T7, CP1, CP5, P3; and, (4) right centroparietal: T8, CP2, CP6, P4.

### 8.3. Results

**8.3.1. HEP.** Bivariate correlations were computed between HEP amplitude in the three regions of interest (see Figure 4) and all four body image variables. FDR was controlled for using the Benjamini and Hochberg (1995) procedure, which was computed using the *Stats* package in *R*. The full results are reported in Table 28. In the following summary of correlation coefficients, interpretation thresholds are consistent with those proposed by Cohen (1992; i.e., small:  $r = .1$ ; medium:  $r = .3$ ; large:  $r = .5$ ). As can be seen, statistically significant and medium associations were observed between mean HEP amplitude in the midline electrode field and the two negative body image variables (i.e., body shame and overweight preoccupation). The direction of both associations was negative, whereby greater body shame and overweight preoccupation were associated with a more negative HEP amplitude, and lower body shame and overweight preoccupation were associated with a more positive HEP amplitude (see Figure 5). Conversely, there were no statistically significant associations between the positive body image indices and HEP amplitude in any of the ROIs.



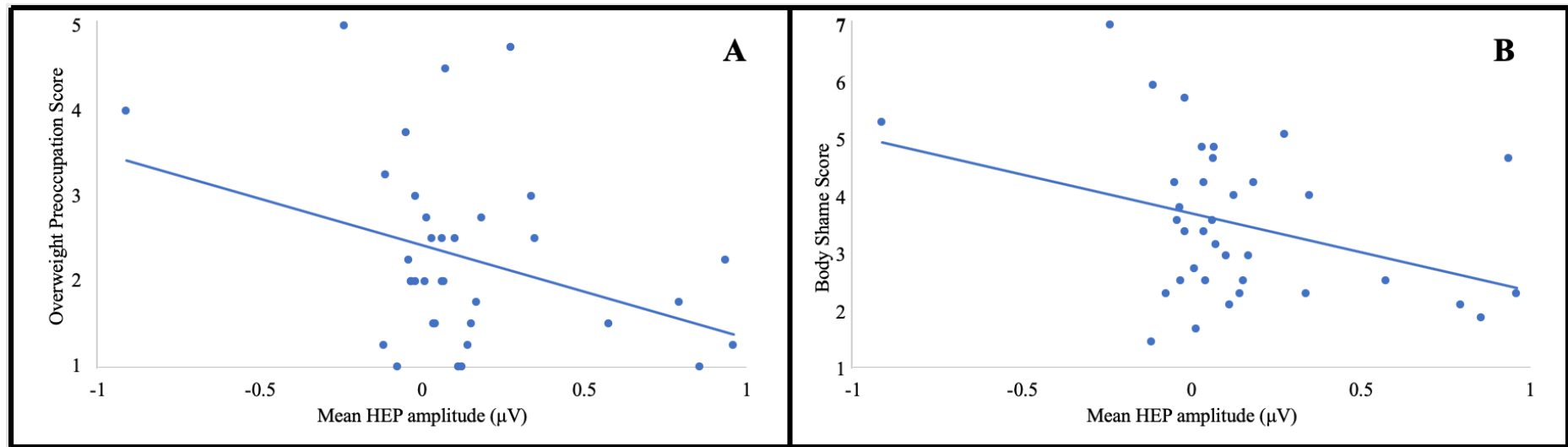
Figure 4. Grand average heartbeat evoked potential (HEP) amplitude across all participants for the left, midline, and right electrode fields. The dashed line indicates the R-peak, and the blue rectangle indicates the time-window of interest.

Table 28

*Bivariate Correlations between Mean Heartbeat Evoked Potential Amplitude and All Body Image Variables.*

	Left electrode field	Midline electrode field	Right electrode field
Body appreciation	-.06	.16	-.14
Functionality appreciation	.20	-.05	.08
Body shame	-.21	-.36*	-.20
Overweight preoccupation	< .01	-.36*	< .01

Note. \* $p < .05$ .



*Figure 5.* Scatterplots to show the correlations between mean heartbeat evoked potential amplitude in the midline frontocentral electrode field in a time-window of 455-595 ms after the R peak and overweight preoccupation scores (panel A) and body shame scores (panel B). HEP = Heartbeat evoked potential.

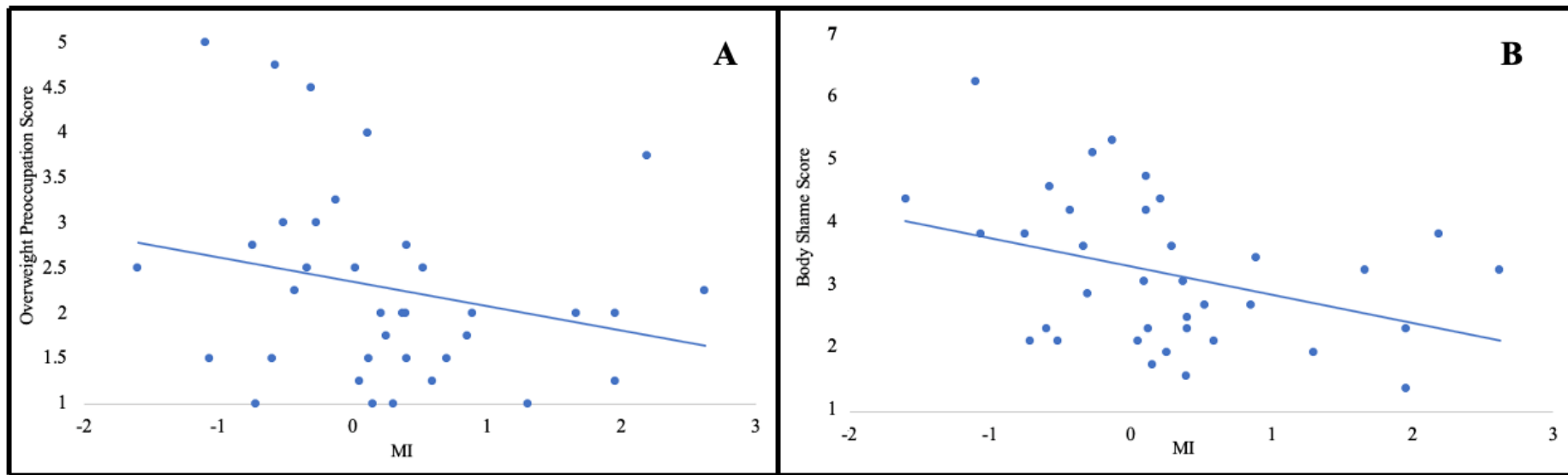
**8.3.2. Gastric-alpha PAC.** Bivariate correlations were computed between the MI for gastric-alpha PAC in the four regions of interest and all four body image variables. Again, the statistical significance threshold was FDR-corrected. As can be seen in Table 29, a statistically significant and large association was observed between overweight preoccupation and the MI for gastric-alpha PAC in the left centroparietal ROI. The direction of the association was negative, whereby a lower MI for gastric-alpha PAC was associated with higher overweight preoccupation score (see Figure 6, panel A). Furthermore, a statistically significant and medium association was observed between body shame and the MI for gastric-alpha PAC in the left centroparietal ROI. Again, the direction of the association was negative, whereby a lower MI for gastric-alpha PAC was associated with a higher body shame score (see Figure 6, panel B). Conversely, there were no statistically significant associations between the positive body image indices and the MI for gastric-alpha PAC in any of the ROIs.

Table 29

*Bivariate Correlations between the Modulation Index for Gastric-Alpha Phase-Amplitude Coupling and All Body Image Variables.*

	Left frontal	Right frontal	Left centroparietal	Right centroparietal
Body Appreciation	< .01	-.13	.30	.09
Functionality	.03	.05	.14	-.03
Appreciation				
Body Shame	-.29	-.21	-.45**	-.12
Overweight Preoccupation	-.16	-.18	-.59**	-.28

*Note.* \*\* $p < .01$



*Figure 6.* Scatterplots to show the correlations between the modulation index for gastric alpha phase-amplitude coupling and overweight preoccupation scores (panel A) and body shame scores (panel B). MI = modulation index.

**8.3.3. Additional correlations.** The correlations between HEP amplitude and the MI for gastric-alpha PAC are reported in Appendix IV. The effect sizes were generally small, and none of the correlations were statistically significant (all  $r$  values  $\leq .21$ , all  $p$  values  $\geq .243$ ). The correlations between all of the body image indices are also reported in Appendix IV. Of note, the correlations between the negative and positive body image indices were small-to-medium, and negative (ranging from  $r = -.12$  to  $-.45$ ). Body appreciation was significantly correlated with both of the negative body image indices, but functionality appreciation was not.

## **8.4. Discussion**

In this chapter, I examined associations between facets of negative and positive body image and two implicit components of interoception: the HEP and gastric-alpha PAC. Overall, significant negative associations were identified between the indices of negative body image and the interoception variables; that is, a more negative HEP amplitude in the midline ROI and a lower MI for gastric-alpha PAC in the left centroparietal ROI were both associated with greater body shame and overweight preoccupation. In contrast, no statistically significant associations were identified between the interoception variables and the indices of positive body image (i.e., body appreciation and functionality appreciation).

The negative body image findings are consistent with the hypotheses. These findings also extend previous research, which has indicated associations between facets of negative body image and behavioural components of interoception in the cardiac (Ainley & Tsakiris, 2013; Emanuelsen et al., 2014) and gastric (van Dyck et al., 2016; Study 5 in the present thesis) domains. As previously discussed (see Section 1.3.1), according to current theorising, less accurate interoceptive perception (e.g., cardiac IAcc) could result in exteroceptive (i.e., visual) cues being utilised as the primary basis for bodily awareness (Tajadura-Jiménez & Tsakiris, 2014; Tsakiris et al., 2011), which could, in turn, result in an excessive focus on the

aesthetic characteristics of the body (Badoud & Tsakiris, 2017) and foster negative body image (Frederickson & Roberts, 1997). Applying this hypothesis to the present HEP findings, previous research has indicated that a lower HEP amplitude is associated with reduced cardiac IAcc (for a recent review and meta-analysis, see Coll et al., 2020; see also Fittipaldi et al., 2020; Pollatos et al., 2005; Pollatos & Schandry, 2004; Yuan et al., 2007). Furthermore, the brain's processing of cardiac signals that is indexed by the HEP has been shown to be functionally relevant for both bodily self-consciousness (Park et al., 2016; and see Aspell et al., 2013) and visual perception (Park et al., 2014). As such, a possible mechanism that might explain the present findings is that a lower HEP amplitude may indicate that an individual has a less robust self-representation, which is more susceptible to the influence of exteroceptive visual inputs (Park et al., 2014, 2016). It is also possible that individuals with a less robust self-representation might be more susceptible to broader social influences, such as sociocultural appearance ideals, which could in turn foster negative body image, but this possibility remains to be examined experimentally.

Regarding the association between gastric-alpha PAC and negative body image, emerging evidence indicates that stimuli from the stomach have an ascending influence on resting state brain dynamics. Specifically, in the initial identification of gastric-alpha PAC, transfer entropy (i.e., analysis of the direction of information transfer) indicated that gastric-alpha coupling is attributable to an ascending influence from the stomach to the brain (Richter et al., 2017). In a recent extension of this work, fMRI data indicated that the coupling between the gastric rhythm and resting-state brain dynamics extended across a large cortical network — the gastric network — which is temporally organised according to the phase of the gastric cycle (Rebollo et al., 2018). The network comprises multiple regions with convergent functional properties involved in mapping bodily and external space. In particular, it includes several regions of the brain that are known to contain neural

representations of body parts, such as the extrastriate body area, which is activated when viewing bodies or body parts (Orlov et al., 2010). As such, it is possible that ascending gastric inputs might influence the extent to which an individual is reliant upon exteroceptive visual cues as a basis for bodily awareness, which might constitute a risk factor for developing negative body image (Badoud & Tsakiris, 2017; Frederickson & Roberts, 1997). Another possible mechanism could be that a weaker connection between the stomach and the brain (i.e., a lower MI for gastric-alpha PAC), could result in a less accurate perception of bodily cues, which could lead to high levels bodily uncertainty (e.g., regarding the perception of hunger and satiety signals, the perception of bodily dimensions). Excessive levels of bodily uncertainty could, in turn, lead to weight- and shape-related anxiety (see Barca & Pezzulo, 2020). However, given the novelty of this field of research, these hypotheses also remain to be tested experimentally.

It is noteworthy that the negative body image findings were consistent across the HEP and gastric-alpha PAC, despite the lack of statistically significant correlations between the two implicit components of interoception. As discussed previously (see Section 1.1.1), interoceptive processing is not yet fully understood, with domain-specific (i.e., where the processing of gastric and cardiac signals occurs in specialised, discrete neural circuits; see, Spunt & Adolphs, 2017), functionally coupled (for a discussion, see Azzalini et al., 2019), and unitary accounts of interoceptive processing all plausible (Khalsa et al., 2018). Nevertheless, it is possible to integrate both the distinction between the two implicit components of interoception, and the commonality of the negative body image findings: at the neural level, the transmission of interoceptive information follows common pathways (e.g., afferent information is relayed to the brainstem via the vagal nerve and the spinal cord; Craig, 2003) before being projected to insular and cingulate cortices, but different receptors also support the transduction of interoceptive signals across interoceptive domains (e.g.,

Craig, 2003). These neuroanatomical pathways can therefore be considered consistent with both the domain-specific and unitary accounts (Murphy et al., 2018). As such, one possible interpretation of the present findings is that the processing of cardiac and gastric interoceptive stimuli may be domain-specific, but there is, nonetheless, a generalised association between implicit components of interoception and negative body image, where a weaker connection between the brain and internal organs is associated with a more negative body image. As discussed above, a possible mechanism could be that a weaker connection between viscera and the brain could result in a less accurate perception of one's bodily dimensions, which could lead to weight- and shape-related anxiety.

In contrast to the negative body image findings, the positive body image findings were not consistent with the hypotheses. A statistically significant association between gastric-alpha PAC and facets of positive body image was predicted on the basis of the findings from Study 5. Likewise, significant associations between HEP amplitude and facets of positive body image were expected on the basis of previously identified associations between positive body image and cardiac IAcc (Duschek et al., 2015), and between HEP amplitude and cardiac IAcc scores (Fittipaldi et al., 2020; Pollatos et al., 2005; Pollatos & Schandry, 2004). In summary, the present work indicates that there are associations between implicit facets of interoception and negative body image, but no associations between implicit facets of interoception and positive body image. This finding could stem from the divergence between the constructs of positive and negative body image: while negative body image and positive body image are often negatively correlated (Tylka, 2018) — indeed, in the present study correlations between the positive and negative body image indices ranged from  $r = -.12$  to  $-.45$  — the two constructs are also theoretically distinct (Tylka, 2018). For example, they have been associated with outcome variables in unique ways (e.g., Davis et al., 2019; Gillen, 2015; Thomas & Warren-Findlow, 2019). It is possible that the implicit

components of interoception are associated with negative body image because there is an emphasis on the appearance of physical characteristics of the body (e.g., body size, shape, and weight) within the negative body image construct, particularly within the facets of body shame and overweight preoccupation (Cash, 2000; McKinley & Hyde, 1996). Conversely, there is a wider focus on ‘holistic’ appearance within the positive body image construct, which might include aspects of appearance that are less likely to be based on the physiological condition of the body, such as personal grooming/style choices or unique body characteristics. In addition, the implicit components of interoception under examination within the present work can be considered as markers of low-level processing (Azzalini et al., 2019), but positive body image encompasses many components that are contingent upon higher-order processing skills, such as filtering incoming information in a body-protective manner (Wood-Barcalow et al., 2010).

#### **8.4.1. Limitations**

While EEG provides the necessary temporal resolution for examining time-locked components, a known limitation of EEG is that the spatial resolution is relatively poor (Banich & Compton, 2018). In the present work, ROIs for the HEP and gastric-alpha PAC were determined using a combination of the extant literature and data-driven approaches (see Sections 8.2.5.1 and 8.2.5.2). That is, cortical areas where the HEP (Park & Blanke, 2019) and significant gastric-alpha PAC (Richter et al., 2017; Rebollo et al., 2018) have been detected, and areas that have been associated with components of body image (e.g., Gaudio & Quattrocchi, 2012) were considered alongside the present data to predict where significant associations between the interoception and body image variables might be identified. Broadly speaking, the areas where significant associations were identified appear to be consistent with previous literature. For example, significant associations were identified between gastric-alpha PAC and negative body image in the centroparietal region, which overlaps with the

findings of Richter and colleagues (2017) – where gastric-alpha PAC was localised to occipitoparietal regions – and is consistent with the findings of Gaudio and Quattrocchi (2012), in which perceptual and affective components of negative body image were associated with activity in parietal regions. However, for both gastric-alpha PAC and the HEP findings, significant associations with the body image indices were limited to one ROI (for each respective measure), with significant associations identified in the midline electrode field for the HEP, and the left centroparietal region for gastric-alpha PAC. Given the novelty and cross-disciplinary nature of the present work, and the aforementioned spatial limitations of EEG (i.e., it is difficult to determine the source of the activity within the brain; Banich & Compton, 2018), it is not possible at present to offer more in-depth theorising as to why significant associations were identified in some regions but not others. Future research could seek to address this issue using imaging techniques such as fMRI, which can more accurately localise the neural correlates for the associations between facets of negative body image and the HEP and gastric-alpha PAC, respectively (e.g., building upon the procedure described by Rebollo et al., 2018).

Additional limitations of the present work are that the present sample was homogenous in terms of both national identity and handedness, and there was relatively little range in age or BMI. Therefore, it is unclear whether the findings from the present study will generalise to more diverse populations or clinical groups. For example, EGG parameters are different for individuals with higher BMI values, and are altered by several medications (for a review, see Wolpert et al., 2020). Additionally, it was not possible to determine whether causal relationships exist between implicit components of interoception and facets of body image due to the correlational design employed in the present study. Indeed, it is possible that the associations identified in the present work are mediated by other factors. For example, the HEP has been associated with various psychological disorders (for reviews, see Coll et al.,

2020; Park & Blanke, 2019), including generalised anxiety disorder (Pang et al., 2019) and depression (Terhaar et al., 2012). Specifically, HEP amplitude has been found to be significantly smaller for depressed patients in comparison to healthy matched controls ( $\eta^2 = 0.18$ ; Terhaar et al., 2012), and a more negative HEP amplitude has been associated with greater severity of anxiety symptoms (Pang et al., 2019). Therefore, while a previous diagnosis of a neurological or psychiatric condition was included within the exclusion criteria, it is possible that sub-clinical depression and anxiety symptomology could account for some of the variance in the negative association between HEP amplitude and negative body image, and future work should seek to examine this possibility. Relatedly, future experimental work is also required to determine whether the ability to divide attention across interoceptive and exteroceptive stimuli has a direct impact on body image. This work could be initiated with the use of novel tasks that force participants to switch between focusing on interoceptive stimuli (e.g., counting heartbeats) and exteroceptive stimuli (e.g., counting auditory tones, or taps on the skin).

#### **8.4.2. Conclusion**

In summary, the present work provides novel evidence of significant associations between implicit components of cardiac and gastric interoception and facets of negative body image. However, neither of the interoception measures were significantly associated with facets of positive body image. When considered within the context of the extant literature, the present findings indicate that the associations between interoception and affective components of negative body image are present across different hierarchical levels of interoceptive processing: from bottom-up, unconscious visceral-afferent signal transmission to consciously experienced components, such as heart rate and satiety (e.g., Ainley & Tsakiris, 2013; Emanuelson et al., 2014; van Dyck et al., 2016; Study 5), to top-down regulatory elements of interoceptive attention, such as body trust (e.g., Studies 1 – 4).

The identification of associations between HEP, gastric-alpha PAC, and facets of negative body image could have important clinical applications. For example, the HEP and gastric-alpha PAC both have potential to serve as biomarkers (that is, biological indicators) of negative body image states and body image disturbances (Khalsa et al., 2018; Khalsa & Lapidus, 2016). This, in turn, could help to improve the diagnosis of body image disorders, and provide indications of treatment efficacy. However, future work is required to determine whether the findings from the present work can be generalised to more diverse samples, and to determine whether there are causal associations between implicit components of interoception and negative body image.

## **9. General Discussion of Studies 5 and 6**

Across Studies 5 and 6, I examined relationships between facets of body image and explicit and implicit components of interoception across gastric and cardiac domains. The overarching aims of the two studies were to expand the available literature concerning relationships between interoception and body image (see Sections 1.3.2 and 1.3.3) by: (1) examining associations between body image and explicit interoception in a previously overlooked bodily domain (i.e., the gastric system); (2) examining associations between body image and implicit components of interoception; (3) exploring associations across facets of both positive and negative body image, and; (4) exploring the associations between the constructs in samples that are more diverse in terms of gender, and cultural and national identity. To that end, Study 5 examined associations between facets of positive and negative body image and IS and IAcc in the gastric domain in samples of UK and Malaysian women and men, and Study 6 examined associations between facets of positive and negative body image and implicit components of gastric and cardiac interoception in UK women and men.

While the methods utilised across Studies 5 and 6 are distinct (see Section 1.1.1), there were, nevertheless, two key trends in the findings across both studies. First, at the broadest level, statistically significant associations between interoception and body image were observed across several different components of interoception. Second, the components of interoception were consistently associated with facets of negative body image, but had only small-to-negligible associations with facets of positive body image. In this section, I will briefly discuss each of these findings in turn, before turning to discuss the overarching limitations of Studies 5 and 6.

### **9.1. Statistically significant associations between interoception and body image were observed across several different components of interoception**

Across Studies 5 and 6, statistically significant associations between interoception and body image were identified across several different components of interoception, including: explicit gastric magnitude (i.e., the self-reported intensity of gastric distension); explicit gastric IS (i.e., a behavioural measure of satiation perception), and; implicit components of gastric and cardiac interoception (i.e., indicators of visceral-afferent signal transmission). As I previously outlined in Section 1.4, prior to the present series of studies, associations between interoception and body image had been predominantly examined singular facets of IAw and IAcc. In the case of IAcc, research had exclusively focused on the cardiac domain, which was problematic for several reasons, as previously discussed in Sections 1.1.1. and 1.4. Furthermore, the associations between implicit components of interoception and body image had not been directly examined (for an overview, see Section 8.1).

Thus, the findings from Studies 5 and 6 represent a significant and novel contribution to knowledge in indicating that associations between body image and interoception are present in previously neglected components of interoception. In particular, the present findings support the idea that the previously identified association between body image and cardiac IAcc (e.g., Ainley & Tsakiris, 2013; Duschek et al., 2015; Emanuelsen et al., 2014; Pollatos et al., 2008) can be generalised to another bodily domain (namely, the processing of interoceptive stimuli in the gastric system). More broadly, when considered in the context of previous research, the findings from Studies 5 and 6 indicate that associations between interoception and affective components of negative body image are present across different hierarchical levels of interoceptive processing, from bottom-up, unconscious visceral-afferent signal transmission to consciously experienced components, to top-down regulatory elements of IAw.

The identification of novel associations between interoception and body image could have important ramifications for potential practitioner-based interventions. In particular, the

findings from Studies 5 and 6 indicate that behavioural interventions aimed at increasing awareness of satiation-related stimuli or cardiac stimuli (e.g., biofeedback training programmes; Li et al., 2017; Ledoux et al., 2014; Meyerholz et al., 2019; Piech et al., 2017; Sugawara et al., 2020) could represent viable interventions for the reduction of negative body image. In addition, the HEP and gastric-alpha PAC both have potential to serve as biomarkers of negative body image states and body image disturbances (Khalsa et al., 2018; Khalsa & Lapidus, 2016).

## **9.2. Behavioural and implicit components of interoception are more closely associated with facets of negative body image in comparison to facets of positive body image**

A second finding across Studies 5 and 6 was that the interoception variables explained a relatively greater proportion of the variance for the negative body image variables in comparison to the positive body image variables. In particular, in Study 6, there were no significant associations with facets of positive body image for either of the implicit components of interoception, but both components had significant associations with facets of negative body image (correlations ranged from  $r = -.36$  to  $-.59$ ). In Study 5 the distinctions between the positive and negative body image findings were more nuanced, but nonetheless in line with this general trend. For example, in UK adults, (behavioural) gastric IS was significantly associated with overweight preoccupation. In the same sample, only negative gastric affect (a self-reported variable) was weakly associated with body appreciation, and there were no significant associations between gastric IS and the positive body image variables. In Malaysian adults, gastric IS had significant but weak associations with facets of positive body image, but these were below the recommended minimum for a practically significant effect (Ferguson, 2009). In the same sample, gastric magnitude (that is, the self-reported intensity of gastric sensations during the WLT) had significant, small ( $r = .20$  to  $.28$ ) associations with facets of positive body image. In the cross-national analyses, only gastric

magnitude emerged as a statistically significant univariate predictor of the positive body image variables.

Overall, these findings align with the previously discussed conceptual distinction between positive body image and negative body image (for an overview, see Section 1.2.1). Specifically, it is possible that behavioural and implicit components of interoception are more closely associated with negative body image because there is an emphasis on the appearance of physical characteristics of the body (e.g., body size, shape, and weight) within the negative body image construct, and these physical characteristics are likely to be intertwined with the physiological condition of the body. In contrast, the positive body image construct encompasses broader aspects of appearance (such as personal grooming/style choices or unique body characteristics) that are not associated with the physiological condition of the body (Tylka, 2018). In addition, positive body image encompasses many components that are contingent upon higher-order processing skills, such as filtering incoming information in a body-protective manner (Wood-Barcalow et al., 2010), which contrasts with both the HEP and gastric-alpha PAC, which are considered to be markers of low-level processing (Azzalini et al., 2019).

### **9.3. General limitations of Studies 5 and 6**

While a strength of Studies 5 and 6 was the inclusion of both men and women from diverse cultural and national groups, both studies were nonetheless limited by the reliance on relatively small university samples that were fairly homogenous (within national groups) in terms of age and ethnicity. Accordingly, an important task for future research is to replicate Studies 5 and 6 in more diverse samples to ascertain whether findings generalise to more diverse populations or clinical groups. Relatedly, while a previous diagnosis of a neurological or psychiatric condition was included within the exclusion criteria for both studies, it is possible that sub-clinical depression and anxiety symptomology could account for some of

the variance that has been attributed to the interoception variables in Studies 5 and 6, and future work should seek to examine this possibility.

An additional limitation of Studies 5 and 6 relates to the bodily domains that were examined. While the present work extends previous research by examining the gastric domain in addition to the cardiac domain, it still remains unclear whether the association between interoception and body image is generalisable across other bodily domains. As previously discussed (see Section 8.1) the heart and the stomach can be distinguished from other bodily organs on the basis that they both continuously and independently produce oscillatory electrical activity, even when disconnected from the central nervous system (Furness, 2012; Suzuki et al., 1986; Zeng et al., 2018). Furthermore, some researchers have suggested that there may be a degree of functional coupling in the neural representation of the two organ systems (see Azzalini et al., 2019). As such, it remains unclear whether the interoception measures utilised in the present work are representative of a ‘generalised’ interoceptive ability that could be detected in other organ systems, such as the respiratory system. Indeed, previous research has highlighted distinctions in interoceptive ability across cardiac and respiratory domains (e.g., Garfinkel et al., 2016).

Finally, Studies 5 and 6 were also limited by the use of a cross-sectional design. As such, it is not currently possible to determine whether the identified relationships are stable longitudinally, or whether a causal relationship between the investigated components of interoception and body image exists. Thus, an important direction for future research is to experimentally examine the identified relationships, with a particular focus on whether the ability to divide attention across interoceptive and exteroceptive stimuli has a direct impact on body image. This possibility could be examined using novel tasks that force participants to switch between focusing on interoceptive stimuli (e.g., counting heartbeats) and exteroceptive stimuli (e.g., counting auditory tones, or taps on the skin). The question of

causality could also be further examined as part of assessments of the potential therapeutic interventions described above (e.g., biofeedback), which have been previously demonstrated to improve awareness of components of interoception ( $d = 1.21$ ; Meyerholz et al., 2019).

## **10. Final discussion and conclusion**

Prior to the studies presented in this doctoral thesis, previous research had identified associations between interoception and body image in both clinical and community samples (for overviews, see Sections 1.3.2 and 1.3.3). Broadly speaking, this body of work had indicated that interoception and body image are inversely associated, with people who have lower levels of IAw and IAcc tending to report more negative body image. However, I hypothesised that the interactions between the two constructs were likely to be more complex than the extant literature articulated, because both interoception and body image are multidimensional (see Sections 1.1.1 and 1.2.1) and several demographic variables are known to interact with both constructs independently (see Sections 1.1.2 – 1.2.4 and Sections 1.2.2 – 1.2.4). In particular, at the point of PhD commencement, there were four key areas that the available literature had not adequately addressed (see Section 1.4): (1) almost all of the extant research focused on the relationship between interoception and facets of negative body image (in particular, a psychopathological focus on body image disturbances), neglecting facets of positive body image; (2) the extant self-report research exclusively considered the perceptual aspect of IAw, neglecting elements of regulation, appraisal, and adaptive and maladaptive modes of attention towards bodily signals; (3) the extant physiological research focused on the cardiac domain of IAcc, neglecting other bodily domains, and; (4) all of the available research had been conducted in North America and Western Europe, and most studies relied on small samples of young female university students and young female clinical samples. I sought to address these limitations across the six studies presented in this doctoral thesis, specifically considering whether associations are robust across different components of interoception and body image, and whether associations are robust after accounting for key demographic variables.

The research presented in this doctoral thesis is cross-disciplinary and multi-method. In Studies 1 to 4, I employed self-report measures to investigate associations between facets of IAw and facets of positive and negative body image in samples of UK adults and adolescents and a sample of Malaysian adults. In Studies 5 and 6, I used techniques from behavioural sciences and neurophysiology to examine relationships between facets of body image and explicit and implicit components of interoception across gastric and cardiac domains. The key findings and limitations of each study have been discussed in the preceding sections, with the trends in findings and limitations within each of the two groups of studies (Studies 1-4 and 5-6) further considered in Sections 6 and 9. Thus, in this final discussion, I will summarise three conclusions from the series of studies (Section 10.1) and the implications of these findings (Section 10.2), in addition to the overall limitations of the present work, and suggested directions for future research (Section 10.3).

## **10.1. Conclusions from the series of studies**

### **10.1.1. Statistically significant associations between interoception and body image exist across dimensions of body image and hierarchical levels of interoceptive processing**

The research presented in this doctoral thesis evidences novel associations between body image and several different components of interoception. Interestingly, the components of interoception examined in the present work span different hierarchical levels of perceptual processing: from bottom-up, unconscious visceral-afferent signal transmission (i.e., the HEP, gastric-alpha PAC: Study 6) to consciously experienced components (i.e., satiety: Study 5), to top-down regulatory elements of interoceptive attention, such as body trust and attention regulation (i.e., Studies 1-4). This is a significant extension of the extant literature, which had previously identified direct associations between interoception and body image primarily within the cardiac domain of IAcc and the perceptual component of IAw (see Sections 1.3.2 and 1.3.3). Importantly, all of the components of interoception examined in the present body

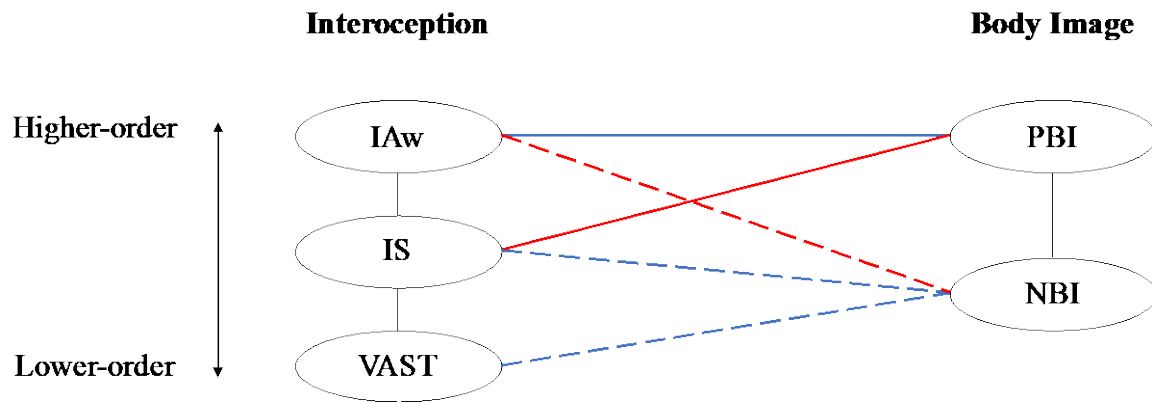
of research were found to be significantly associated with at least one facet of body image, for at least one of the samples (with the exception of the gastric IAcc index; see Study 5). In light of these findings, it is possible to conclude from the present body of research that associations between body image and interoception are robust across components of interoception. However, it is also important to note that the pattern of associations between interoception and body image varied (e.g., in magnitude) across different components of interoception and dimensions of body image (a point that I address in Section 10.1.2) and at the univariate level across the participant groups (a point that I address in Sections 10.1.3 and 10.2.2).

Novel associations between interoception and body image were also identified across different dimensions of body image, with statistically significant associations between interoception and body image identified across multiple facets of positive body image (body appreciation, functionality appreciation, and body pride), negative body image (overweight preoccupation, body shame, actual-ideal weight discrepancy, drive for muscularity) and constructs related to body image (body surveillance, appearance orientation). This is a significant extension of the extant literature, which had predominantly examined interoception in relation to facets of negative body image, with a particular psychopathological focus on body image disturbances. In the few studies that had provided coverage of the relationship between interoception and positive body image (Daubenmier, 2005; Duschek et al., 2015; Oswald et al., 2017), only singular facets of positive body image had been examined. Given the convergence of the findings from the present work (i.e., statistically significant associations with body image were identified for a broad range of body image facets), it could be concluded that associations between body image and interoception are robust across dimensions of body image. However, I also found that the

nature of associations between interoception and body image varied in direction and magnitude across dimensions of positive and negative body image (see Section 10.1.2).

### **10.1.2. The nature of the association between interoception and body image is dependent on the components of interoception and body image being examined**

As I have summarised above, at the point of PhD commencement, previous research had broadly indicated that interoception and body image are inversely associated, where lower levels of IAw and IAcc are associated with more negative body image. The findings from the present series of studies contribute to extant knowledge on the topic by indicating more complex relationships between components of interoception and body image. Specifically, I found that the distinctions between the constructs of interoception (i.e., the divergence between IAw and IAcc; see Section 1.1.1) and body image (i.e., the divergence between positive and negative body image; see Section 1.1.2) were reflected in the associations between the two constructs (see Figure 7). On the one hand, I found that self-reported facets of IAw had medium-to-strong, positive associations with facets of positive body image, but tended to explain only a small proportion of the variance in facets of negative body image (Studies 1-4, see Section 6 for a discussion). Conversely, I found that behavioural and implicit components of interoception (i.e., gastric IS, and gastric and cardiac measures of visceral-afferent signal transmission) had small-to-large inverse associations with facets of negative body image, but small-to-negligible associations with facets of positive body image (Studies 5-6, see Section 9 for a discussion).



*Figure 7.* An overview of the associations between components of interoception and body image identified across Studies 1 to 6. IAw = Interoceptive awareness; IS = Interoceptive sensitivity; VAST = Visceral-afferent signal transmission; PBI = Positive body image; NBI = Negative body image. Blue lines signify a stronger association and red lines signify a weaker association. Dashed lines signify an inverse association.

The nuances in the associations between interoception and body image that have been identified in the present series of studies align with the theoretical distinctions between the constructs of negative and positive body image (see Section 1.1.2). Specifically, negative body image measures tend to examine evaluations of the body’s physical characteristics (e.g., body size, shape, and weight), which are tied to the physiological condition of the body. Accordingly, the negative body image variables tended to be most closely associated with the lower-level, physiological components of interoception (i.e., unconscious visceral-afferent signal transmission, gastric IS; see Studies 5 and 6, and Section 9 for further discussion). Conversely, measures of positive body image assess a much broader construct, encompassing evaluations of global (i.e., holistic) appearance. In this way, positive body image includes evaluations of aspects of appearance that are less likely to be based on the physiological condition of the body, such as personal grooming/style choices or unique body characteristics (Tylka, 2018, see also Tylka & Wood-Barcalow, 2015a). In addition, the positive body image construct encompasses many components that are contingent upon higher-order processing skills, such as filtering incoming information in a body-protective manner (i.e., rejecting negative body-related information and accepting positive information; Wood-Barcalow et al.,

2010). Correspondingly, I found that associations with positive body image were strongest for the components of interoception that are also contingent upon higher-order (top down) processing, specifically body trust and attention regulation (see Studies 1 – 4, and Section 6 for further Discussion).

### **10.1.3. Statistically significant associations between interoception and body image exist in several demographically distinct samples**

As I have summarised above, prior to the present series of studies, all of the available research had been conducted in North America and Western Europe. In addition, most studies relied on small samples of young female university students and young female clinical samples. This was an important limitation of the extant literature, particularly because there are several variables that interact with both interoception and body image in complex ways, including gender, age, and cultural and national contexts (for overviews, see Section 1). The findings from the present series of studies evidence that associations between interoception and body image can be identified in subgroups of each of the aforementioned demographic variables. That is, statistically significant associations were identified in both women and men; in a sample of adolescents, and samples of adults that ranged in age from 18 to 76, and; in samples of adults from two different national and cultural contexts (i.e., the UK and Malaysia). Furthermore, using hierarchical regression analyses (Studies 1-5) I was also able to determine that components of interoception significantly predicted unique portions of the variance in facets of body image after controlling for these variables. In addition, in Study 3, I was able to determine that a mediational model for the pathway between body trust and body appreciation is invariant across both UK and Malaysian adults, and across women and men (see Figure 3). Altogether, it is possible to conclude from these findings that associations between interoception and body image are robust after accounting for the effects of culture, age, and gender.

An important caveat to this conclusion is that I also identified more complicated patterns of univariate findings, which indicate nuanced associations between interoception and body image for each of the examined groups. As an example, the magnitude of the correlation coefficients for several of the univariate associations between the MAIA variables and the body image variables significantly differed across: Malaysian women and men (Study 2), Women from the UK and Malaysia (Study 3), and adolescent girls and boys (Study 4). Similarly, the magnitude of the correlation coefficients for the associations between the gastric interoception variables and body appreciation differed significantly across adults from the UK and Malaysia.

## **10.2. Implications**

The implications of the present work are twofold: the findings make an incremental contribution to the theoretical understanding of associations between interoception and body image, and also reveal potential clinical avenues for practitioner-based interventions.

### **10.2.1. Theoretical implications**

Previous theoretical accounts of the associations between interoception and body image have focused on the division of attentional resources across interoceptive and exteroceptive stimuli (Badoud & Tsakiris, 2017; Stanghellini et al., 2015; for an overview, see Section 1.3.1). Specifically, it has previously been suggested that, for people with lower IAcc and IAw, the precision of interoceptive information may be deemed to be less reliable and, consequently, neural representations of the body may be more reliant on exteroceptive inputs (Ainley et al., 2016; Badoud & Tsakiris, 2017). This reliance could, in turn, result in a greater focus on the extent to which appearance-related characteristics of the body meet sociocultural beauty standards (Mussap & Salton, 2006), and predispose individuals to negative body image (Badoud & Tsakiris, 2017). Many of the findings from the studies presented in this doctoral thesis align with this theoretical account. For example, in Study 5, I

found significant negative associations between components of interoception (i.e., gastric IS, gastric magnitude) and facets of negative body image (i.e., overweight preoccupation and body shame), indicating that participants who were less sensitive to gastric stimulation tended to report more overweight preoccupation. The findings from Study 6 also extend the account beyond the IAcc component of interoception, by indicating that participants who had a weaker connection between viscera and the brain (i.e., lower HEP amplitude, lower MI for gastric-alpha PAC) also reported more negative body image (see Study 6).

However, several of the findings from the present series of studies also indicate that it is necessary to refine the theoretical account to encompass the multidimensionality of interoception and body image. For example, as discussed in Section 10.1.2, I found that facets of IAW were not consistently associated with facets of negative body image, and that – in the instances where significant associations were identified – the associations tended to be small, particularly in comparison to the proportion of variance accounted for by demographic variables (for further discussion, see Section 6). One possible explanation for this finding is that the components of IAW under examination do not reflect the *precision* of interoceptive signalling (Murphy et al., 2020). That is, the facets of IAW captured by the MAIA are primarily elements of regulation, appraisal, and adaptive and maladaptive modes of attention towards bodily signals (Mehling, 2016; Mehling et al., 2009, 2012; see Section 1.1.1), which are reflective of a higher level of perceptual processing.

The extant theoretical accounts are also insufficient with regard to the consideration of relationships between facets of interoception and positive body image, which should not be regarded as the absence or opposite of negative body image (Tylka, 2018; see Section 1.2.1). Based on the findings from Studies 1-4, I suggest that the ability to notice and sustain attention towards interoceptive stimuli might directly increase awareness of the positive functions that the body performs and facilitate the ability to respond to the body's needs, both

of which could promote positive body image (Andrew et al., 2016; Cook-Cottone 2018; Wood-Barcalow et al., 2010). As I outlined in Section 4.1, this hypothesis is based on the embodiment model (Menzel & Levine, 2011), which suggests that participating in embodying activities (i.e., activities that encourage awareness of and attentiveness to the body) promotes integration between the body and the mind, which directly fosters a more positive body image (e.g., Langdon & Petracca, 2010; Swami & Tovée, 2009). It is also grounded in previous research, which has demonstrated that focusing on body functionality is related to greater body appreciation (Alleva et al., 2015; Alleva et al., 2018a, 2018b; Avalos & Tylka, 2006; Wood-Barcalow et al., 2010). In particular the findings from Study 3 provide support for this hypothesis, by evidencing that the pathway between the IAW facet of body trust and body appreciation is partially mediated by functionality appreciation, and that this model is invariant across both men and women, and across adults from the UK and Malaysia.

### **10.2.2. Clinical implications**

The findings from this series of studies have potential implications for practitioner-based interventions. These clinical implications reflect the divergence in the associations between interoception and body image across the constructs of positive and negative body image as well as self-reported and physiological measures of interoception (see Figure 7). On the one hand, behavioural interventions that aim to increase awareness of bodily sensations (e.g., biofeedback training programmes) might be viable therapeutic strategies for reducing negative body image. Based on the present body of work, the biofeedback programmes could specifically focus on promoting awareness of gastric or cardiac sensations (e.g., Li et al., 2017; Ledoux et al., 2014; Meyerholz et al., 2019; Piech et al., 2017; Sugawara et al., 2020). In addition, the HEP and gastric-alpha PAC both have potential to serve as biomarkers of negative body image states and body image disturbances (Khalsa et al., 2018; Khalsa &

Lapidus, 2016), which could help to improve the diagnosis of body image disorders, and provide indications of treatment efficacy.

Conversely, higher-level interventions that tap the regulation of interoceptive attention and appraisals of interoceptive stimuli may be particularly viable tools for promoting positive body image. It is possible that this could take the form of a mindfulness-based programme. For example, body scan meditations have been previously been evidenced to improve components of interoception (Fischer et al., 2017; Kok & Singer, 2017; for a review see Gibson, 2019). In particular, previous research has demonstrated that regulatory facets of IAW (such as attention regulation and self-regulation) are improved via body scan meditation (Bornemann et al., 2015), which is significant in light of the strong associations between these components of IAW and facets of positive body image that were identified in Studies 1 to 4.

Considered together, the approaches for the negative body image and positive body image interventions could also be combined by adapting methods from Cognitive Behavioural Therapy. The cognitive aspect might entail identifying and reconstructing maladaptive appraisals of interoceptive stimuli (e.g., that they are untrustworthy), and the behavioural aspect might entail a combination of the biofeedback training and body scan meditation techniques, to enhance awareness of interoceptive stimuli, and promote positive attention toward/appraisals of bodily stimuli. A combined approach might be particularly valuable because, as Tylka (2018) indicated, attention toward alleviating symptoms of negative body image, without considering facets of positive body image, results in clinical practices that are inadequate for the promotion of health and well-being as they relate to embodiment. Thus, developing therapies aimed at reducing symptoms of negative body image in tandem with attempting to enhance aspects of positive body image, remains an important task for researchers (Guest et al., 2019; Tylka, 2018).

### **10.3. Directions for future research**

As I have previously discussed in my reporting of Studies 1 to 6, the present work was not without limitation, and raises several questions for future research. Most notably, it is not currently possible to determine whether the relationships identified in the present series of studies are stable longitudinally, or whether a causal relationship between the investigated components of interoception and body image exists. As I have summarised in Section 1.3.2, previous longitudinal work has indicated that early IAw impairments are associated with later development of body image disturbances (e.g., Killen et al., 1996; Leon et al., 1995; Lilenfeld et al., 2006). An important direction for future research will be to use longitudinal approaches to determine whether components of interoception (including IAw, IS, IAcc, and indices of visceral-afferent signal transmission) might be predictive of body image longitudinally, with particular attention to facets of positive body image. Based on the findings from Studies 1-4, it is possible that higher levels of IAw in early life might be associated with later development of positive body image. Conversely, based on the findings from Studies 5-6, it is possible that early impairments in IS, and weaker connections between viscera and brain, might lead to later development of negative body image.

Future research using experimental methods will also help to establish whether causal associations are present between facets of interoception and body image. As discussed previously, biofeedback training programmes could be used to manipulate IS/IAcc in the cardiac and gastric domains (e.g., Li et al., 2017; Ledoux et al., 2014; Meyerholz et al., 2019; Piech et al., 2017; Sugawara et al., 2020). Based upon the findings from the present work, it could be hypothesised that such interventions might lead to reductions in levels of negative body image. An equally important research question is whether the ability to divide attention across interoceptive and exteroceptive stimuli has a direct impact on body image. This question could be examined using novel tasks that force participants to switch between

focusing on interoceptive stimuli (e.g., counting heartbeats) and exteroceptive stimuli (e.g., counting auditory tones, or taps on the skin). Previous research suggests that low cardiac IAcc is associated with a significantly poorer performance on tasks that require selective and divided attention (e.g., Matthias et al., 2009). Considering this finding in the context of the results from the present research, it could be hypothesised that participants who are less adept at regulating attention across interoceptive and exteroceptive stimuli might experience more negative body image. The ability to divide and regulate attention could also be a mediating variable, whereby individuals with low IS/IAcc are more likely to attend to exteroceptive cues, and also more likely to struggle with regulating attention across salient interoceptive and exteroceptive stimuli.

Another possible route for establishing causality is to explore the potential utility of non-invasive brain stimulation techniques such as transcutaneous vagus nerve stimulation, which has been previously evidenced to enhance cardiac IAcc (Villani et al., 2019). Research on this topic could firstly examine whether transcutaneous vagus nerve stimulation has impacts on other components and domains of interoception, such as the HEP, gastric-alpha PAC, and gastric IS. These components of interoception are all likely to be transmitted in the body by visceral afferent nerve fibres such as the vagus, which is connected to both the heart and the digestive tract (Critchley & Harrison, 2013; see Section 1.1). Thus, it is plausible that transcutaneous vagus nerve stimulation could enhance HEP, gastric-alpha PAC, and gastric IS. Research in this field should also examine whether altering physiological components of interoception has an impact on state and/or trait body image. Based on the findings from the present work, it could be predicted that enhancing components of interoception such as the HEP, gastric-alpha PAC, gastric IS might result in less negative body image.

Relatedly, previous theorising and research indicates that participating in embodying activities promotes integration between the body and the mind, which directly fosters a more

positive body image (Menzel & Levine, 2011; see also Langdon & Petracca, 2010; Swami & Tovée, 2009). Future research could seek to empirically examine whether embodying activities (e.g., dance, yoga) leads to stronger associations between the brain and viscera, which could be measured using indicators such as the HEP and gastric-alpha PAC.

While a strength of the present series of studies was the inclusion of both women and men from diverse cultural and national groups, and adolescent girls and boys, it is not clear whether the findings are generalisable to other cultural and national groups, and other social identity groups, and future research should seek to examine this further. In particular, the participants from the present series of studies were recruited from largely urbanised sites. Previous research has indicated that living in a rural, low SES context might be conducive to positive body image development and a protective factor against negative body image development, while living in urban, high SES context might have a harmful effect on positive body image and be conducive to negative body image development (Swami et al., 2010, 2011). Considered alongside the findings from the present series of studies, it is plausible that associations between interoception and body image might differ in magnitude across rural low SES contexts and urban high SES contexts.

Finally, all of the measures used in the present work were originally developed in the West using samples of Western adults. While the measures have been validated (and adapted where necessary) for each of the target populations, it is possible that they may not adequately capture aspects of interoception and body image that are specific to other cultural contexts or other developmental stages (e.g., adolescence). In particular, previous qualitative research has indicated that there are elements of IAW and positive body image that may be unique to specific cultural groups (e.g., McHugh et al., 2014; Freedman et al., 2020). Future research could address this issue by qualitatively examining the ways in which the associations between interoception and body image are understood and experienced in

different demographic groups. Such work could also provide an indication of whether associations between interoception and body image are mediated by unique factors in different demographic groups.

#### **10.4. Final conclusion**

Overall, the findings from this doctoral thesis advance knowledge on the associations between interoception and body image, by demonstrating that – while the association can be broadly generalised to wider facets of interoception and body image, and samples that are more demographically diverse than had been considered previously – the associations between interoception and body image are also more nuanced than had been previously articulated. Specifically, I found that the nature of associations between interoception and body image is dependent on the components of interoception and body image being examined. Self-reported facets of IAW tend to have medium-to-strong, positive associations with facets of positive body image, but explain only a small proportion of the variance in facets of negative body image. Conversely, physiological measures of interoception have small-to-large inverse associations with facets of negative body image, but small-to-negligible associations with facets of positive body image. It is hoped that these findings will contribute to the theoretical understanding of associations between interoception and body image, and lead to the development of practitioner-based interventions aimed at reducing negative body image and promoting positive body image.

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## Appendices

### Appendix I. Measurement invariance analyses for Study 3

The MAIA data were neither univariate (Shapiro Wilk's  $p < .001$ ) nor multivariate normal (Mardia's skewness = 624.35,  $p < .001$ ; Mardia's kurtosis = 33.17,  $p < .001$ ), so parameter estimates were again obtained using the robust maximum likelihood method with the Satorra-Bentler correction (Satorra & Bentler, 2001). I used indicative fit indices summarised by Swami and Barron (2019) to assess the baseline model fit. In addition, I used  $\Delta CFI < .01$  as an indicator of metric invariance (Cheung & Rensvold, 2002). For scalar invariance, Chen (2007) suggested that invariance is supported when  $\Delta CFI < .01$  and  $\Delta RMSEA < .015$  or  $\Delta SRMR < .030$ , although other scholars have suggested that  $\Delta CFI < .01$  is sufficient (Cheung & Rensvold, 2002; Meade et al., 2008). Because full scalar invariance may be an unrealistic goal (Davidov et al., 2014), I also allowed for partial scalar invariance, which involves freeing constraints that are not equivalent between groups at any previous stage. Partial scalar invariance allows for comparison of latent means across groups (Davidov et al., 2012).

The fit of the 1-factor model for the total sample was adequate across most indices:  $SB\chi^2(2) = 30.31$ ,  $SB\chi^2_{\text{normed}} = 15.16$ , robust RMSEA = .098 (90% CI = .076, .123), SRMR = .026, robust CFI = .982, robust TLI = .954. The fit for each of the national samples was also adequate, UK:  $SB\chi^2(2) = 12.28$ ,  $SB\chi^2_{\text{normed}} = 6.14$ , robust RMSEA = .089 (90% CI = .049, .135), SRMR = .027, robust CFI = .987, robust TLI = .961; Malaysia:  $SB\chi^2(2) = 7.95$ ,  $SB\chi^2_{\text{normed}} = 3.98$ , robust RMSEA = .082 (90% CI = .026, .148), SRMR = .020, robust CFI = .992, robust TLI = .976.

Next, I tested for measurement invariance across the UK and Malaysian participants. Configural and metric invariance were supported, but scalar invariance was not (see Supplementary Table 1). After fixing the intercept for Item 3, partial scalar invariance was supported across UK and Malaysian adults based upon the  $\Delta\text{SRMR} < .30$  criterion.

Supplementary Table 1.

*Measurement Invariance Across National Group for the MAIA Trusting subscale*

Measure	Model	$\text{SB}\chi^2$	$df$	Robust CFI	Robust RMSEA	SRMR	Model Comparison	$\Delta\text{SB}\chi^2$	$\Delta df$	$\Delta\text{Robust CFI}$	$\Delta\text{Robust RMSEA}$	$\Delta\text{SRMR}$
BAS	Configural	18.63	4	.987	.090	.039						
	Metric	79.82	7	.978	.116	.058	Configural vs metric	61.19	3	.009	.026	.019
	Scalar	153.28	10	.912	.140	.114	Metric vs scalar	73.46	3	.066	.024	.056
	Partial scalar	122.39	9	.960	.136	.079	Metric vs partial scalar	42.57	2	.018	.020	.021

## **Appendix II. Pilot study and measurement invariance analyses for Study 4**

The MAIA, FAS, and BASES-AP had not been validated for use with adolescents. Therefore, I recruited 24 participants (14 girls and 10 boys) aged 13-16 ( $M = 14.33 \pm 1.13$ ) for a pilot study to assess the understanding and appropriateness of each measure with this younger cohort. This is the recommended sample size for pilot studies exploring conceptual, item, and semantic equivalence (Beaton et al., 2000) and is a much larger sample than those used for similar pilot studies (e.g., Halliwell et al., 2017).

Participants completed a paper-and-pencil questionnaire in which they were asked to consider each item from the measures mentioned above, and respond to the following open-ended questions (adapted from Halliwell et al., 2017): “Does this statement make sense to you?”; “Do you think this statement would make sense to other adolescents your age?”; “Could you respond to this statement on the [appropriate response scale for each instrument, e.g., the ‘strongly disagree’ to ‘strongly agree’ scale]?”; and “Do you think I need to make any changes to this statement?” The majority of participants (20/24) responded positively to all items, across all three measures. For the remaining participants, negative responses were logged for items within the MAIA only, but no item attracted more than two negative responses. Therefore, I made no adjustments to the wording of the items or response scale.

I then computed CFA analyses for the MAIA, the FAS, and the BASES-AP data to assess whether the factor structures from the parent models were an appropriate fit for the adolescent sample. For all three scales, the data were neither univariate (Sharipo-Wilks,  $p < .001$ ) nor multivariate normal (MAIA: Mardia’s skewness = 7843.784,  $p < .001$ , Mardia’s kurtosis = 57.905,  $p < .001$ ; FAS: Mardia’s skewness = 683.142,  $p < .001$ , Mardia’s kurtosis = 30.67,  $p < .001$ ; BASES-AP: Mardia’s skewness = 282.800,  $p < .001$ , Mardia’s kurtosis = 20.883,  $p < .001$ ). Therefore, parameter estimates were obtained using the robust maximum likelihood method with the Satorra-Bentler correction (Satorra & Bentler, 2001).

For the MAIA, fit indices for a 6-factor structure were as follows:  $SB\chi^2(284) = 574.886$ ,  $SB\chi^2_{\text{normed}} = 2.02$ , robust RMSEA = .075 (90% CI = .066-.084), SRMR = .061, robust CFI = .901, robust TLI = .887, BL89 = .876. As fit indices were less than ideal, suggested modification indices were consulted to improve model fit, with modifications being based on correlations among like items from the same factor. Error covariances were freed for Items 3 and 4 of the Self-Regulation subscale (MI = 69.782; Likelihood ratio:  $\chi^2(1) = 64.356$ ,  $p < .001$ ), and Items 4 and 5 of the Emotional Awareness subscale (MI = 49.432; Likelihood ratio:  $\chi^2(1) = 43.552$ ,  $p < .001$ ). In the final modified model, fit indices were acceptable,  $SB\chi^2(282) = 494.472$ ,  $SB\chi^2_{\text{normed}} = 1.75$ , robust RMSEA = .064 (90% CI = .55-.074), SRMR = .058, robust CFI = .916, robust TLI = .916, BL89 = .900.

For the FAS, fit indices for a unidimensional structure were as follows:  $SB\chi^2(14) = 28.935$ ,  $SB\chi^2_{\text{normed}} = 2.07$ , robust RMSEA = .86 (90% CI = .040-.130), SRMR = .047, robust CFI = .960, robust TLI = .940, BL89 = .945. Since fit indices were less than adequate, modification indices were consulted to free error covariances. Error covariances were freed for Items 2 and 3 (MI = 26.845; Likelihood ratio:  $\chi^2(1) = 20.586$ ,  $p < .001$ ). In the final modified model, fit indices were good,  $SB\chi^2(13) = 19.410$ ,  $SB\chi^2_{\text{normed}} = 1.49$ , robust RMSEA = .056 (90% CI = .001-.104), SRMR = .036, robust CFI = .984, robust TLI = .975, BL89 = .973. Finally, for the BASES-AP, fit indices for a unidimensional structure were good,  $SB\chi^2(9) = 18.047$ ,  $SB\chi^2_{\text{normed}} = 2.01$ , robust RMSEA = .083 (90% CI = .022-.139), SRMR = .028, robust CFI = .986, robust TLI = .977, BL89 = .980.

### **Appendix III. EFA analyses for the WLT-II questionnaire for Study 5**

To explore the dimensionality of the WLT-II questionnaire data, I conducted principal-axis exploratory factor analyses (EFAs) with oblimin rotation using the *Psych* Package (Revelle, 2019) in *R* (*R* development Core Team, 2014). For the UK sample, Bartlett's test of sphericity returned a significant result,  $\chi^2(28) = 148.65$ ,  $p < .001$ , and the

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy = .79, indicating that the WLT-II questionnaire items had adequate common variance for factor analysis. The number of factors to be extracted was based upon a comparison between eigenvalues in the current dataset and parallel analysis, with only values that are  $> 1.0$  and greater than those from the parallel analysis being retained (Horn, 1965). Inspection of the scree plot suggested one primary factor, with a steep cut-off to one secondary factor, and a gradual slope to the remaining six factors. Correspondingly, there were two factors with  $\lambda > 1.0$ , and the results of parallel analysis suggested that both factors from the actual data had  $\lambda$  greater than the criterion  $\lambda$  generated from the random data (*i.e.*,  $\lambda_1 2.72 > 1.47$ ;  $\lambda_2 1.55 > 1.26$ ). Item retention was based on Comrey and Lee's recommendation that items with loadings  $\geq .33$  should be retained (Comrey & Lee, 1992). Factor loadings are reported in Supplementary Table 2. Item #8 did not load onto either factor, and was therefore eliminated from the model. Items #4, 5, 6, and 7 all loaded onto the primary factor. These items largely overlap with the "negative affect" factor described by van Dyck and colleagues (2016), so I decided to term the factor negative gastric affect.  $\omega$  for negative affect scores was .78 (95% CI = .70, .84). Items #1, 2, and 3 all loaded onto a second factor, which I termed gastric magnitude, because all of the items refer to the intensity of the sensations elicited by the WLT-II (Khalsa et al., 2018).  $\omega$  for gastric magnitude scores was .72 (95% CI = .66, .79).

For the Malaysian sample, Bartlett's test of sphericity returned a significant result,  $\chi^2(28) = 166.67, p < .001$ , and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy = .78, indicating adequate common variance for factor analysis. Inspection of the scree plot suggested one primary factor, one secondary factor, and a steep cut-off to the remaining six factors. The EFA results indicated that there were two factors with  $\lambda > 1.0$ , and the results of parallel analysis suggested that both factors from the actual data had  $\lambda$  greater than the criterion  $\lambda$  generated from the random data (*i.e.*,  $\lambda_1 3.18 > 1.47$ ;  $\lambda_2 1.40 > 1.26$ ).

Factor loadings are reported in Supplementary Table 2. Item #8 did not load onto either factor and was therefore eliminated from the model. Items #4, 5, 6, and 7 all loaded onto the negative gastric affect factor, and  $\omega$  for negative gastric affect scores was .83 (95% CI = .75, .87). Items #1, 2, and 3 all loaded onto the gastric magnitude factor, and  $\omega$  for gastric magnitude was .75 (95% CI = .62, .80).

Tucker's congruence coefficients for the EFA-derived models with the UK and Malaysian samples was .96 for the negative gastric affect factor and .97 for the gastric magnitude factor, suggestive of factor structure similarity.

#### Supplementary Table 2.

*Water Load Test Questionnaire Items in English and (in Italics) in Bahasa Malaysia (Malay) and Associated Item-Factor Loadings.*

Item	UK sample		Malay sample	
	F1	F2	F1	F2
1. My stomach feels full / <i>Perut saya terasa penuh.</i>	<.01	<b>.75</b>	-.03	<b>.81</b>
2. My stomach feels tense / <i>Perut saya terasa tegang.</i>	.29	<b>.46</b>	.14	<b>.57</b>
3. I feel thirsty / <i>Saya rasa dahaga.</i>	.23	<b>-.43</b>	.01	<b>-.39</b>
4. I feel guilty / <i>Saya rasa bersalah.</i>	<b>.38</b>	-.23	<b>.53</b>	.06
5. I feel nauseous / <i>Saya rasa mual.</i>	<b>.68</b>	-.10	<b>.83</b>	-.08
6. I feel sluggish / <i>Saya rasa tidak aktif.</i>	<b>.72</b>	-.04	<b>.67</b>	.08
7. I feel discomfort / <i>Saya rasa tidak selesa.</i>	<b>.85</b>	.09	<b>.88</b>	.07
8. I feel sated / <i>Saya rasa berpuas hati.</i>	-.14	.31	-.26	.16

*Note.* Items in bold indicate items associated with each factor. F = Factor.

#### Appendix IV. Supplementary correlational analyses for Study 6

Supplementary Table 3.

*Correlations between the Modulation Index for Gastric-Alpha Phase-Amplitude Coupling and Mean Heartbeat Evoked Potential Amplitude.*

	PAC left frontal	PAC right frontal	PAC left centroparietal	PAC right centroparietal
HEP left	.16	.21	.07	.10
HEP midline	-.19	-.11	.03	.03
HEP right	-.06	.01	-.08	-.04

*Note.* HEP = Heartbeat evoked potential; PAC = phase-amplitude coupling.

Supplementary Table 4.

*Bivariate Correlations between All Body Image Variables.*

	Body Appreciation	Functionality Appreciation	Body Shame	Overweight Preoccupation
Body appreciation		.43*	-.45*	-.37*
Functionality appreciation	.43*		-0.12	-0.13
Body shame	-.45*	-0.12		.63**
Overweight preoccupation	-.37*	-0.13	.63**	

*Note.* \* $p > .05$ , \*\* $p > .001$