Belief updating about Interoception and Body Size Estimation in Anorexia Nervosa

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Abstract

Anorexia Nervosa (AN) is an eating disorder with high mortality and morbidity rates, partly due to treatment resistance and high relapse rates. Treatment adherence and recovery has been found to be hindered by insight deficits, a lack of appreciation of one's illness, or its consequences, most frequent in restrictive AN. However, to date, insight disturbances in AN have mainly been studied in relation to treatment outcomes rather than explanatory mechanisms. One possibility is that interoception (the sensing, awareness and interpretation of physiological signals) and particularly its metacognitive aspects such as prospective (self-efficacy) and retrospective (insight) beliefs about one's interoceptive abilities may be affected in AN. To our knowledge however such aspects of global metacognition, and their relation to key interoceptive and body perception impairments, have not been assessed in AN. Here in two experiments (n_{AN}=51 and 28, $n_{AN\text{-}WR}$=47 and 21, n_{HC}=63 and 34, respectively), we tested, (a) how women with and weight-restored from AN (AN-WR), in comparison to healthy controls (HCs), formulate explicit interoceptive self-efficacy beliefs (i.e., estimates of performance in a cardiac perception task) prospectively and then update them following performance and then following explicit feedback and (b) how they formulate prospectively and then update following feedback two types of body-size beliefs (estimates about the envisioned body, '*How thin it looks*' vs the emotional body, '*How thin it feels*'). Results of *Experiment 1* confirmed our hypotheses that the AN (but not the AN-WR) group formulated more pessimistic interoceptive self-efficacy beliefs in comparison to HCs both before and after otherwise comparable performance. In *Experiment 2* we found that the AN group envisioned and felt (also the AN-WR group) their body size to be bigger than it really is in comparison to controls. Post-feedback, the AN but not AN-WR group significantly overestimated both their envisioned and emotional body and they also updated their emotional body size estimates at a slower rate than the HCs. These observed group differences in belief updating about interoceptive self-efficacy and body size estimates warrant further studies in interoceptive metacognition and belief updating in AN, and their relation with insight deficits, particularly at the acute stages of the disease.

Keywords: Interoception, Anorexia Nervosa, Self-Efficacy, Belief Update, Metacognition, Body Image

Introduction

Anorexia Nervosa (AN) is an eating disorder that remains poorly understood (Kaye et al., 2009). AN is more prevalent in females than in males (Arcelus et al., 2011; Hoek, 2006), although this gender difference may be at least partly explained by past diagnostic criteria and assessments leading to an underdiagnosis in men (e.g., Andersen et al., 1990; Crosscope-Happel et al., 2000). According to psychiatric categorical classifications, AN is characterised by (a) restricted caloric intake relative to individual requirements, leading to extremely low body weight with respect to the individual's age, sex, developmental trajectory and physical health, (b) an intense fear of gaining weight or becoming fat, or a persistent behaviour interfering with weight gain despite the individual's low weight, and (c) a disturbed view of one's own weight or body shape, undue influence of weight and shape on self-evaluation, or denial of the seriousness associated with current low body weight (Diagnostic and Statistical Manual 5, DSM-5; American Psychiatric Association, APA, 2013).

Despite recent advances in psychological and pharmacological treatments for AN, treatment outcomes remain poor, as low adherence to treatment and high relapse rates are frequently observed (Carter et al., 2004; Halmi et al., 2005; Roux et al., 2016). As such, AN has the highest mortality and morbidity rates among psychiatric disorders (Arcelus et al., 2011). Poor treatment compliance in AN has in part been associated with resistance to treatment and the disorder's 'ego-syntonic' nature (Gregertsen et al., 2017; Serpell et al., 1999). The term ego-syntonicity is used in this context to describe the fact that patients with AN may regard their restrictive eating as adaptive to their psychological needs and their identity, while disregarding the illness' negative consequences on their body and health (Serpell et al., 1999). Ego-syntonicity may be linked with impaired 'insight', i.e., a lack of appreciation of one's illness. Insight deficits have been found to be a maintaining factor in AN, hindering treatment adherence and recovery (Abbate-Daga et al., 2013; Konstantakopoulos et al., 2012) and they are more frequently observed in restrictive AN in comparison to the binge-eating/purging subtype and in patients with Bulimia Nervosa (Greenfeld et al., 1991; Konstantakopoulos et al., 2011).

However, to date, insight disturbances in AN have mainly been studied in relation to treatment outcomes rather than explanatory mechanisms. To our knowledge, there is only one pilot study on insight in AN that suggests a potential association between insight deficits and impairments in other abilities, such as metacognition – the ability to reflect upon and monitor one's own cognition (Arbel et al., 2013; Flavell, 1979). While further experimental studies and mechanism-based accounts of insight deficits are lacking in AN, work on other pathologies (e.g., in schizophrenia; Beck et al., 2004; Lysaker et al., 2021) also suggests that clinical insight could be dependent on other higher-order abilities, such as metacognition, including for example, patients' ability to judge the veracity of their own perceptions or beliefs. This metacognitive dimension of insight is also termed 'cognitive insight' (Beck et al., 2004; Lysaker et al., 2021) and several psychiatric studies have explored the relation between clinical and cognitive insight (for review see Camp et al., 2017). However, as aforementioned, cognitive insight and metacognition have not been experimentally addressed in AN research. This will be one of the aims of the present study.

Moreover, metacognition itself is a multifaceted ability. One dimension of interest here is the difference between 'local' (e.g., retrospective judgements on specific, isolated cognitions, such as confidence judgements on the accuracy of a percept) versus more abstract and 'global' aspects of metacognition, such as overall retrospective beliefs about one's performance across many trials or tasks, or prospective judgements about one's capabilities in different contexts. The latter aspect also relates to the concept of self-efficacy beliefs, defined by Bandura (1977) as one's beliefs in their capacity to succeed in a certain situation, influencing how one thinks, behaves, and feels. Individuals with high self-efficacy are more confident in their ability to perform at a certain level or control the outcome of a task (Weerdmeester et al., 2020; Zulkosky, 2009). On the other hand, poor self-efficacy beliefs may be involved in the development of mental health symptoms (Seow et al., 2021). In eating disorders, self-efficacy influences drive for thinness, body dissatisfaction, and treatment outcomes (Keshen et al., 2017; Toray & Cooley, 1997). This aspect of metacognition however has only been assessed with questionnaires in AN, as in most other psychopathologies. Indeed, hitherto most experimental psychiatric research on metacognition has focused on local metacognition. It is only recently that global aspects of metacognition have been found to relate more closely to everyday neuropsychiatric symptoms and their awareness (Kirsch et al., 2021; Seow et al., 2021). To our knowledge, aspects of global metacognition, and their relation to key interoceptive and body perception impairments have not been assessed in AN. Thus, assessing both local and global beliefs about one's perceptual ability in different modalities will also be one of the aims of the present study.

Interoception and Metacognition

One of the domains of interest in AN is interoception. Interoception refers to the sensing, perceiving and interpreting of the physiological state of the body (Craig, 2002; Khalsa et al., 2009). Perceiving and interpreting the physiological state of the body at least partly depends on the ability to sense afferent signals, including respiratory, gastrointestinal, and cardiac signals (Cameron, 2001; Critchley & Garfinkel, 2017). In addition to sensation, interoception can be examined at different levels of signal processing, including at least three dimensions such as interoceptive accuracy, interoceptive sensibility and interoceptive awareness, or metacognitive insight; (Critchley & Garfinkel, 2017; Garfinkel et al., 2015; see Brewer et al., 2021; Khalsa et al., 2018a; Murphy et al., 2019 for further dimensions). Interoceptive accuracy (IAcc) is considered as an objective measure of one's conscious sensitivity to interoceptive signals, typically measured via behavioural testing, e.g., performance on counting heartbeats (Heartbeat Counting Task, HCT; Schandry, 1981; see Desmedt et al., 2020; Murphy et al., 2018a, 2018b; Zamariola et al., 2018 for critical reviews of this methodology). Interoceptive sensibility (IS) is a subjective measure of how well a person thinks they perceive interoceptive signals in everyday life and is typically assessed via self-report questionnaires. Finally, interoceptive awareness is the metacognitive evaluation of one's interoceptive performance, or ability, e.g., via confidence-accuracy correspondence between the aforementioned objective (IAcc) and subjective (IS) interoceptive measures.

Impairments in these different dimensions of interoception have been associated with several mental health conditions, including AN (e.g., Fassino et al., 2004; Fisher et al., 2016; Herbert & Pollatos, 2014; Jenkinson et al., 2018; Khalsa et al., 2018a, 2018b; Pollatos et al., 2008; Pollatos et al., 2009). First, the ability to sense a depleted nutritional body state to encourage food-seeking behaviours relies on interoception (for review see Maniscalo & Rinaman, 2018; Martin et al., 2019). Individuals with AN often report prolonged fullness, and one in three individuals with AN will report satiety and lack of hunger cues even when on an empty stomach (Bluemel et al., 2017). Difficulty in perceiving such signals could be attributed to poor interoception. Moreover, some studies have found that patients with AN have a deficit in cardiac IAcc (Pollatos et al., 2008; Pollatos et al., 2016) and many other domains and levels of interoception (Ambrosecchia et al., 2017; Crucianelli et al., 2016; Eshkevari et al., 2014; Kerr et al., 2016; Khalsa et al., 2015; Kinnaird et al., 2020; Lutz et al., 2019; Richard et al., 2019). For instance, Khalsa and colleagues (2015) tested changes in the perception of interoception before, during and after meal consumption and found that patients with AN, in comparison to controls, had dysfunctional interoceptive responses during meal anticipation. That could be explained by pre-meal anxiety and related emotional responses (Khalsa et al., 2018), metacognitive or interoceptive awareness biases (Crucianelli et al., 2021), indexed by confidence ratings or questionnaires (Kinnaird et al., 2020). However, to our knowledge no study has tested directly the role of anticipatory metacognitive beliefs about interoception in eating disorders. This will be the aim of the present study.

More specifically, we followed certain theoretical approaches to interoception and mental health (e.g., Stephan et al., 2016), that take into account both retrospective and prospective aspects of interoceptive metacognition, such as prospective, self-efficacy beliefs about interoceptive abilities and retrospective beliefs about one's interoceptive accuracy in a specific task. Thus, we investigated how individuals with AN in comparison to HCs update their prospective beliefs about their ability to detect their heartbeats after engaging in a modified HCT (Schandry, 1981) and receiving feedback about their performance in the HCT. Under a Bayesian Learning Framework (Friston, 2003; Mathys et al., 2011), we regarded individuals' (1) initial, prospective beliefs about how well they will do in the task as 'prior beliefs', (2) their subsequent estimates after the task as 'posterior retrospective beliefs' and (3) their final, retrospective beliefs on how well they did following false performance feedback from the experimenter (i.e., they were told they performed better or worse than the other participants, irrespective of their actual IAcc scores) as 'post false-feedback retrospective' beliefs. In this context, the term 'prior beliefs' refers to the beliefs (or, probability distributions) the individual has before taking into account some new information. After the integration of this new information, these beliefs are referred to as 'posterior beliefs', and this change from prior beliefs to posterior beliefs is known as belief updating.

We predicted that the AN group would anticipate performing worse in the HCT, i.e., have low prior beliefs in their ability to perform well in the HCT in comparison to the HCs (*Hypothesis 1*), given previous findings of affected interoceptive anticipation (Khalsa et al., 2015). However, we expected that IAcc scores of both the AN and AN weight-restored (AN-WR) groups would be similar to that of the HCs, i.e., the accuracy of reporting felt heartbeats would not differ between the groups (*Hypothesis 2*), given previous related findings on group-differences in IAcc (Eshkevari et al., 2014; Lutz et al., 2019; Richard et al., 2019). Moreover, we expected that the AN group would provide lower ratings on their retrospective beliefs in comparison to HCs when asked to evaluate their performance on the HCT (as in some previous studies measuring confidence following HCT; Kinnaird et al., 2020), despite an otherwise successful performance (*Hypothesis 3*). We also hypothesised that individuals with AN, in comparison to HCs, would rely more on their prior beliefs rather than their Performance (IAcc) when providing a rating on their retrospective beliefs (given the hypotheses seen in the aforementioned literature regarding low confidence and self-esteem in AN and relation to interoception; *Hypothesis 4)*. Hence, we expected that a greater discrepancy between Performance and prior beliefs (Prediction Error) in the AN group compared to HCs would explain the AN group's lower retrospective beliefs regarding their

Performance. Additionally, in a control *Hypothesis 5* we examined how false-feedback within each group influenced participants' post false-feedback retrospective beliefs. We wanted to examine if patients with AN have difficulty changing their prior beliefs based on all kinds of feedback (here, indexed by external false-feedback), or whether these difficulties were specific to (interoceptive) performance. Hence, we provided false feedback on their performance (i.e., we divided each group arbitrarily into subgroups and gave them false-feedback of high vs low performance). We expected that participants in the negative false-feedback subgroup would provide lower false-feedback retrospective performance estimates, in comparison to those in the positive false-feedback subgroup, and this would be observed in all three of our groups. This would suggest that any difficulties in the retrospective beliefs in the AN group (i.e., *Hypotheses 3* and *4* above) would be specific to embodied performance and not any kind of feedback.

Finally, we used self-report measures to assess whether relevant key traits previously associated with AN would predict group differences in prior beliefs and IAcc, separately. Specifically, we focussed on eating disorder psychopathology, alexithymia, body awareness, and trait anxiety, separately. We expected that greater eating psychopathology, alexithymia and trait anxiety, and poorer body awareness would predict pessimistic prior beliefs and IAcc across all groups, and in particular in the two clinical groups. We also explored how dimensions of an exploratory measure of insight (awareness on illness severity, consequences and prognosis) could explain our findings on prior beliefs and IAcc in each clinical group separately, given that one cannot test insight into one's illness in healthy controls that do not have an illness (see Methods and Supplementary Material).

However, difficulty in perceptual belief updating is not unique to perception of interoceptive states, and as we see in our second experiment, may also be studied in the domain of body image and how individual estimates of body size may be influenced by feedback.

Body Image and Body Size Estimation

Perceptual and attitudinal differences between individuals with AN and HCs have also been observed regarding one's body image. A universally accepted definition of body image and related body image disturbances (BID) is lacking (Glashouwer et al., 2019); early accounts referred to body image as 'the picture we have in our minds of the size, shape, and form of our bodies, and to our feelings concerning these characteristics and our constituent body parts (Slade, 1988, p.20)'. This definition is reflected in work that has initially focused primarily on the visually perceived body size and shape (Garner et al., 1987; Slade & Russel,

1973) as well as the affective component of our body image (i.e., feelings towards one's own body appearance, such as body image dissatisfaction; Cash & Green, 1986; Cooper & Fairburn, 1992; Rosen, 1990). More contemporary research has highlighted the multidimensional nature of body image, including multisensory perception (Apps & Tsakiris, 2014; Gaudio et al., 2014) and the evaluative, behavioural, and social components of body image (e.g., Banfield & McCabe, 2002; Carraça et al., 2011; Casale et al., 2021; Cash et al., 2004; Gaudio & Quattrocchi, 2012; Yamamotova et al., 2017).

Studies in AN have found disturbances in most of these different aspects of body image. For instance, individuals with AN may estimate their body as larger than it is in reality in comparison to HCs (e.g., Gardner & Brown, 2014; Guardia et al., 2010; Mölbert et al., 2017). These biased estimations are considered as perceptual BID, sometimes referred to as body image distortions, a term we will use here too. Individuals with AN are also likely to use their weight and shape as indicators of their worth, showing overvaluation, dissatisfaction and various other aberrant cognitive and emotional attitudes towards their body image. Indeed, some studies have found no differences in the perceptual component of BID between participants with an eating disorder and HCs but have instead found differences in the attitudinal component of BID (Nico et al., 2010; Provenzano et al., 2020). For example, the accuracy of body size estimates within clinical populations has been found to be influenced by factors such as body dissatisfaction and the disparity between the actual and ideal body, and these factors are often influenced by drive for thinness and dissatisfaction (Cash & Deagle, 1997; Hagman et al., 2015; Henninghausen et al., 1999). More generally, some studies suggest that BID in eating disorders could be the result of underlying top-down beliefs linked to attitudinal and emotional disturbances (e.g., overvalued ideas of thinness; Epstein et al., 2001; Konstantakopoulos et al., 2012), rather than perceptual disturbances. For example, some patients may be aware of their actual body size, i.e., be aware of their low weight, but hold on to their negative feelings and beliefs about the body (e.g., Gadsby, 2019). However, to the best of our knowledge, the way in which beliefs about body size are held and updated in eating disorders has not been systematically investigated.

More specifically, no study on body size belief updating in AN has directly assessed how one's perceptual and attitudinal body size beliefs may change following personalised feedback on body size. Studies in subclinical samples have shown that individuals with more severe BID give thinner ideal- and average body size estimates following exposure to thin bodies (in comparison to body size estimates prior to being exposed to a thin or large body; Glauert et al., 2009). Others have found that exposure to a large body was linked with perceptual body image distortions and a reduced ideal body size in an AN group in comparison to HCs (Cazzato et al., 2016). These two studies offer some insight into body size belief updating relative to general norms and ideals within the female population (the stimulus before reporting a post-exposure body size estimate was of another body), but potential changes in body size estimation after receiving feedback about one's own body remain unclear.

To this end, we have developed a novel paradigm to study belief updating about body size, following personalised feedback. We categorised potential BID into two components: the perceptual component of body image (hereafter referred to as Envisioned body image, i.e., estimates of body size as the person thinks their body image looks *in reality*), and the affective components (hereafter referred to as Emotional body image; an estimate of body size as the person feels their body image to be *in their mind*; see also Fotopoulou et al., 2011 for findings in dissociations between these two components in another domain of body awareness). Participants were asked to provide a baseline body size estimate for both modes. Then, participants received feedback on their body size (actual BMI in the Envisioned mode), or second-person feedback based on how another person may 'see' their body as accurately as they can (in this case, the clinician; Emotional mode) and were asked to provide two more body size estimates following feedback (one per mode). For control purposes participants were also asked to provide a size estimate of a printed balloon picture, before and after receiving feedback on the size of the balloon. Participants' balloon size estimates were added as control variables in our analyses (see more in *Methods*, *Experiment 2*).

Our first set of hypotheses focused on how individuals with AN might misestimate different body image components, and related belief updating failures. Both AN and AN-WR groups were expected to provide less accurate body size estimates relative to their actual BMI prior to receiving any feedback, as suggested by the aforementioned studies on perceptual BID (*Hypothesis 1*). We expected this misestimation to be present both for Envisioned and Emotional body size estimates, with greater misestimation in the Emotional mode when comparing within-group, given by the findings on the aforementioned studies on attitudinal and emotional BID, and greater emotional misestimation in the AN vs AN-WR group. The presence of this misestimation in both the AN and AN-WR groups, and for both the Envisioned and Emotional body size estimates, would indicate that body size misestimation is a broad, enduring trait rather than a feature of the acute AN state only. However, we expected such broad body size misestimations to be present only in the acute AN patients after receiving feedback on their Envisioned body size estimates relative to HCs (*Hypothesis*

2). We also expected both clinical groups to misestimate their body size more than HCs following feedback on their Emotional body size estimates, in comparison to HCs (*Hypothesis 3*).

Our second set of hypotheses examined whether there would be any between-group differences at the rate at which participants updated their estimates regarding their body size (in each mode separately). In this paper we define these rates as 'Envisioned Updating Rate' and 'Emotional Updating Rate' (see *Methods* for more details). While we did not expect significant differences in the Updating Rate in the Envisioned mode (*Hypothesis 4*), we expected that the two clinical groups would have a lower Updating Rate in the Emotional mode in comparison to the HCs, given the aforementioned hypotheses in the literature regarding belief updating in AN (*Hypothesis 5*; Konstantakopoulos et al., 2012; Gadsby, 2019).

Taken together, our two studies aimed to examine how females with AN, compared to gender-, age-, and nationality-matched AN-WR individuals, and HCs form and update metacognitive beliefs about interoceptive accuracy following feedback about their performance (Experiment 1) and how they update perceptual estimates about their body size after visual feedback (Experiment 2). Our multiple samples allowed us to disentangle state (i.e., present only during the acute AN phase) from trait mechanisms (i.e., pre-morbid deficits present in at-risk individuals, or deficits that endure beyond the acute phase and are present during remission). This approach allows identification of both aetiological traits and risk factors for AN as well as secondary consequences to prolonged malnutrition, comorbidities, and pharmacological treatment. Accordingly, effects present across our samples would suggest that deficits in interoception and perceived body size are premorbid risk factors of AN rather than the expression of a categorical disease state like acute AN.

Methods

Experiment 1: Interoceptive (Cardiac) Belief Updating

Participants

Our convenience sample included a total of N=161 female participants (n=51 AN, n=47 AN-WR, and n= 63 HCs), out of which 27 AN patients, 21 AN-WR patients, and 34 HCs also took part in *Experiment 2.* Patients with AN and AN-WR were recruited from the Psychiatric Daycare Unit of Sao Paolo General Hospital (ASST Santi Paulo e Carlo) in Milan, from Comunità Villa Miralago in Cuasso al Monte (VA) and from Casa di Cura Villa Margherita in Arcugnano, Italy. HCs were Italian volunteers recruited from the University of

Milan and University College London (UCL). Patients with AN met DSM-5 criteria (APA, 2013) for restrictive subtype AN, as diagnosed by an experienced clinician, using standard clinical measures (patient history and psychometric questionnaires and a physical assessment), and had a BMI <18.5. The weight-restoration criteria in AN are debated (Khalsa et al., 2017; Wierenga et al., 2015), hence we chose a combination of objective and clinical criteria to best represent the patients' clinical reality. Those in the AN-WR group no longer met DSM-5 restrictive subtype AN criteria according to their psychiatrist, and met at least two of the following: (i) BMI >16.5, (ii) clinical and behavioural signs of AN recovery (e.g. no restrictive eating patterns) for at least 6 months, or (iii) a global Eating Disorders Examination Questionnaire (EDE-Q; Fairburn & Beglin, 1994) score <4. All HCs had a healthy BMI between 18.5 and 25. HCs were not included if they had a history of an eating disorder, or a first-degree relative with a history of an eating disorder. All participants were aged between 18 and 45 years, with no history of neurological disease, brain damage, drug dependence or severe psychiatric disease (e.g., psychosis; see Table 1 for other clinical characteristics including comorbidities and pharmacological treatment). Other exclusion criteria included being male, being pregnant, substance and/or alcohol abuse.

Institutional ethics approval was granted and written informed consent was obtained from all participants prior to their participation. All procedures were conducted in accordance with the World Medical Association Declaration of Helsinki. HCs and AN-WR participants received either monetary compensation at a fixed rate of £7.5/hour, or university course credits. The AN group received £10 Amazon vouchers.

Table 1

Summary of participant profiles for the Anorexia Nervosa (AN), Weight-Restored Anorexia Nervosa (AN-WR), and Healthy Control (HC) groups. Multiple comorbidities include at least two of the following: OCD, Mood Disorder, Borderline Personality Disorder, Panic/Anxiety Disorder.

	AN	**AN-WR**	**HC**
Age (*SD*)	26.51 (*9.48*)	25.38 (*6.23*)	25.14 (*4.77*)
BMI (*SD*)	15.80 (*1.53*)	19.89 (*2.46*)	21.17 (*2.98*)
Years of Illness (*SD*)	8.21 (*8.45*)	4.36 (*3.85*)	N/A
Age of Onset (*SD*)	16.65 (*3.54*)	17.59 (*4.24*)	N/A

Years from Weight Restoration (*SD*)	N/A	3.47 (*5.40*)	N/A
Psychiatric Comorbidities	5 OCD 7 Mood Disorder 3 Panic/Anxiety Disorders 0 Borderline Personality Disorder 4 Personality Disorder 0 Trichotillomania 15 Multiple Comorbidities	2 OCD 8 Mood Disorder 10 Panic/Anxiety Disorder 2 Borderline Personality Disorder 0 Personality Disorder 1 Trichotillomania 9 Multiple Comorbidities	4 Subclinical Anxiety Symptoms
Psychiatric Treatment during the acute stage	16 Antidepressants 3 Mood Stabilisers 13 Antipsychotics 11 Sedatives	21 Antidepressants 3 Mood Stabilisers 4 Antipsychotics 5 Sedatives	1 Sedatives (*4y prior to participation in the study*)

Design

An existing cardiac perception task (HCT; Schandry, 1981) was adapted to create a well-controlled experimental task for belief updating. The adapted task included the traditional measure of interoceptive accuracy (IAcc), hereafter referred to as Performance, and three additional measures. These measures include participants' (1) Prospective Performance Estimates (i.e., prior beliefs on the task they will be asked to complete), (2) their Retrospective Performance Estimates (i.e., posterior beliefs about performance on the task they completed) (3) Post false-feedback Retrospective Performance Estimates (i.e., posterior beliefs about performance following false feedback regarding their performance). Prospective Performance Estimates were assessed by asking participants '*How well do you think you will do [on the task] on a scale of 0 (very poorly) to 100 (very well)*? For Retrospective Performance Estimates the experimenter asked the participant '*How well did you do on the task on a scale of 0 (very poorly) to 100 (very well)*'. Participants gave their answer verbally. The experimenter gave false feedback to each participant by telling them they performed better or worse than the other participants and Post False-feedback Retrospective

Performance Estimates were obtained by asking participants: '*Now, if I were to ask you again, how well do you think you did on the task on a 0 (very poorly) to 100 (very well) scale?*'.

The IVs were Group (AN, AN-WR, and HC) and false feedback (positive and negative). The DVs were the Prospective Performance Estimates, Performance, Prediction Error (difference between Performance and Prospective Performance Estimates), Retrospective Performance Estimates, and Post False-feedback Retrospective Performance Estimates.

Psychometric Measures

Depression, Anxiety, Stress Scale (DASS-21; Lovibond and Lovibond, 1995): The DASS-21 was only used in a subset of the sample (AN=27, AN-WR= 23, HC=33) due to clinical time constraints. The DASS-21 is a reliable scale (Cronbach's α can range between 0.86 and 0.90; Gloster et al., 2008) and has 21 items used to assess any symptoms relating to negative mood and emotions on a 4-point Likert scale (0 – *Did not apply to me to all* to 3 – *Applied to me very much*). It has three subscales to assess depression, anxiety, and stress, with higher scores relating to higher levels of depression, anxiety, and stress, with cut-offs being 5, 4, and 8, respectively. The DASS-21 has positive psychometric properties in samples of adults with anxiety and depression. Our sample showed an excellent internal consistency, Cronbach's α= .958.

Body Awareness Questionnaire (BAQ; Shields et al., 1989): The BAQ was used to measure self-reported interoceptive sensibility (Garfinkel et al., 2015). Due to clinical time constraints the BAQ was only completed by a subset of our sample (AN=24, AN-WR=22, HC=26). The BAQ is an 18-item scale measuring attentiveness to normal, internal bodily processes and sensations, with good internal consistency as shown both in an undergraduate student sample, Cronbach's α = .82 (Shields et., 1989) and a clinical sample (Cronbach's α = .786; Unal et al., 2020). In this experiment, the BAQ demonstrated a high internal consistency, with Cronbach's α =.851 in the present sample. The BAQ has four factors: the ability to note responses in body processes, and predict bodily sensations, sleep-wake cycle, and onset of illness. All responses are measured on a 7-point likert scale of 0 (*Not at all true about me*) to 7 (*Very true about me*), with higher scores indicating greater body awareness.

Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994): The TAS-20 was used as a measure of alexithymia as it is the most commonly used self-report questionnaire, with demonstrated good reliability and factorial validity in both clinical and non-clinical populations (González-Arias et al., 2018). All participants, except for two AN and one AN-

WR, completed the TAS-20, which consists of 20 items rated on a 5-point likert scale of 1 (*strongly disagree*) to 5 (*strongly agree*). Total scores may range from 20 to 100 (sum of the three subscale scores), and a total score of 61 or above is generally indicative of alexithymia (Honkolampi et al., 2001; Franz et al., 2008). In the present experiment we used the total score in our analysis, and not each subscale scores in separate analyses due to the relatively small sample sizes and subsequent power-related issues. In the current experiment, the TAS-20 showed an excellent internal consistency, Cronbach's α= .913.

Insight into Illness: Finally, a subset of our AN and AN-WR patients completed an insight into illness questionnaire developed by the authors (Table 2), given that to the best of our knowledge, there is no questionnaire that focusses only on insight in eating disorders. Specifically, in AN, there is one self-report measure (Konstantakopoulos et al., 2011; Konstantakopoulos et al., 2020) developed largely for clinical, psychiatric use. However, at the time of study design and recruitment it had not yet been validated, its content was too general for the current experiment's scope, and its completion also did not fit within the time limits of the present experiment. Instead, participants from the two clinical groups answered five questions on different dimensions of restrictive, anorexic symptom awareness. We focussed on three dimensions, namely on the (i) General, Allocentric Perspective of Self, (ii) Health Consequences, and (iii) Future Perspectives: Hopes and Fears. The self-report items measure patients' awareness of their emaciated appearance and illness, severity, the negative consequences of their insight disordered eating and fears and beliefs regarding behaviours which may hinder prognosis. Each question was rated on a 0 (*not at all*) to 10 (*very much*) likert scale, and each participant's clinician (both for AN and AN-WR groups) also rated symptom and illness severity on these questions based on their professional evaluation of the individual's symptoms and the individual's medical files. Individual scores were averaged to obtain a 'subjective' global clinical insight score, with higher scores suggesting more insight into illness, while clinician scores were averaged to obtain an objective score, with higher scores indicating greater illness severity.

Table 2

Items of the insight into illness questionnaire used in the current pilot experiment's analyses

	Item	Dimension of insight
1	*How severe is your condition*?	***General, Allocentric Perspective of Self***
	Do you think that your eating behaviour could have	

2	*negative consequences for your health?*	
3	*Do you think that your body weight and shape could have negative consequences for your health?*	***Health Consequences***
4	*Are you afraid of losing control of your eating behaviour?*	
5	*Do you believe that the severity of your condition will improve in the future?*	***Future Perspectives: Hopes and Fears***

Experimental Measures and Procedure

All participants provided informed consent and were given written task instructions prior to completing the HCT and were also given the opportunity to ask the experimenter clarification questions. Demographic data and self-report, standardised questionnaire measures were completed prior to the HCT. Heart rate (both for baseline measurements and the counting phases of the HCT) were recorded using the Polar wrist worn heart rate monitor (model RS 800CX, see Emanuelsen et al., 2015; Fishcher et al., 2016).

Before completing the HCT, a baseline measurement for heart-rate was obtained. Participants were asked to sit and relax, while the experimenter recorded their heart-rate for 5-minutes using the Polar monitor. Then, participants were asked to provide a Prospective Performance Estimate. Next, participants were asked to silently count their heartbeats to measure their Performance. Performance was measured as one's ability to detect their own heartbeats, without feeling their chest or taking their pulse (Schandry, 1981). All participants were asked to remove any accessories from their wrists, roll up their sleeves, and to sit down with their wrist gently resting on the band of the heart rate monitor which was located on the table in front of them. Participants were allowed to keep their eyes opened or closed, whichever felt more comfortable, but with their legs uncrossed. The experimenter then asked the participant to concentrate only on their heartbeats, without trying to take their pulse or attempting any other physical manipulations which could facilitate detection. The participant was prompted with 'Go' and 'Stop' signals at the start and end of each counting phase, respectively. After each 'Stop', participants verbally reported the number of felt heartbeats. This was repeated for the three counting phases of 25s, 45s, and 65s, with 30s rest breaks in between. The order of the counting phases was randomised between all participants. Information about the length of the counting phases or participant performance was not given at this stage.

Upon completion of the three counting phases, participants were asked to give a Retrospective Performance Estimate. Finally, participants were told they performed either better or worse than the rest of sample and were asked to provide a Post False-feedback Retrospective Performance Estimate. Once participants gave a verbal answer, they were debriefed and told that this feedback was for experimental purposes only, and in no way was a reflection of their actual performance during the task. Due to clinical time constraints, false-feedback was not given to n=32 participants, hence these participants' Post False-feedback Retrospective Performance Estimates are missing.

Data Analysis

Data were analysed using R (R, Boston, MA). Before conducting our main analyses, we carried out preliminary analyses to see if BMI and age were different between groups, expecting BMI to be significantly different in the AN group compared to the AN-WR and HCs, but not in the AN-WR group compared to the HC group. However, age was not expected to be significantly different across the three groups. As expected, BMI was significantly different between the AN and HC groups, and age was not significantly different across the three groups. The results are available in the Supplementary Material.

We ran a linear regression to assess whether group (IV) predicted Prospective Performance Estimates (DV; *Hypothesis 1*). Control analyses for the effects of age and baseline heart-rate were conducted to examine their effects on Prospective Performance Estimates. However, these two covariates did not significantly affect our main findings (see Supplementary Material). We also applied a linear regression to assess whether group (IV) had an effect on Performance (DV; *Hypothesis 2*). Performance (IAcc) was calculated using the Schandry (1981) transformation:

$$IAcc = \left[1 - \frac{1}{3}\sum \frac{|Recorded\ Heartbeats - Counted\ Heartbeats|}{Recorded\ Heartbeats}\right] * 100 \qquad 1$$

We obtained percentage scores for Performance (IAcc) scores to maintain consistency with participants' Performance Estimates. Performance scores varied between 0 and 100, with a score of 100 implying best performance, i.e., a smaller difference between the recorded and counted (felt heartbeats), and a score closer to 0 indicating worst performance. Control analyses for performance in each time interval separately were also conducted to ensure that overall Performance results were not exclusively driven by any one of the intervals. Control analyses with age and baseline heart rate as predictors were conducted to control for the effects of these factors, however they did not affect our main findings (see Supplementary Material).

Next, for *Hypothesis 3* we ran a linear regression to assess whether the three groups (IV) differed in their Retrospective Performance Estimates (DV) when controlling for their Prospective Performance Estimates and Performance (covariates). For *Hypothesis 4,* we used another linear regression to assess whether the difference between Performance and Prospective Performance Estimates (Prediction Error, PE; IV) of each group predicted their Retrospective Performance Estimates (DV). We also used three separate linear regressions to assess whether the false feedback (IV) predicted participant's Post False-feedback Retrospective Performance Estimates (DV), within each group separately (control *Hypothesis 5*). However, given that false-feedback was randomly given to participants, irrespective of their Performance in the task, we also used three linear regressions with Performance as IV and false-feedback as DV. We ran these analyses to look for possible within-group differences in performance and to control that we did not randomly give positive false-feedback to participants with higher Performance scores and negative false feedback to participants with low Performance scores. We also ran exploratory linear regressions for *Hypotheses 1* and *2* with psychometric measures as IVs as well as *2* with illness duration and severity (AN and AN-WR groups separately) as covariates. However, these variables did not affect our findings, and the output is available in the Supplementary Material. Finally, in the AN group we ran exploratory analyses to explore the relationship between their Prospective Performance Estimates and Performance and their self-reported clinical insight. The output is available in the Supplementary Material since the results were not significant and this analysis was not part of a main hypothesis in the present experiment.

Results

Women with AN, but not AN-WR women, significantly underestimated their performance abilities prior to completing the HCT

Results from the linear regression showed that group was a significant predictor of Prospective Performance Estimates, with the Prospective Performance Estimates of the AN group being significantly lower than those of the HCs (Figure 1; Table 3). That is, women with AN anticipated that they would perform worse in the HCT. The difference in

Prospective Performance Estimates was small and not statistically significant between the AN-WR and HC groups.

HCT performance did not differ significantly between women with AN, AN-WR and healthy women

The three groups did not differ significantly in their actual HCT Performance (IAcc; Figure 2; Table 3). That is, all groups were able to discern felt heartbeats at a similar level of accuracy, with only very small and non-significant differences between groups. BMI was not added as an IV in the linear regression given that it was a criterion for the three groups, but we conducted three separate regressions to examine whether BMI affected Performance within each group, since recent criticisms of the heartbeat counting task suggest that BMI may affect sensitivity to heartbeat detection (Richard et al., 2019), and in turn Performance. However, none of the three within-group analyses yielded significant results, suggesting that in our cohort, Performance was not significantly affected by BMI within each group.

Table 3

Main results for Hypotheses 1 and 2

Main Analyses

Effect: Prospective Performance Estimates	**β(*SE*)**	***t***	***p***	**95% CI**
Intercept (HCs)	53.435(*3.14*)			
AN	-13.635(*4.36*)	*-3.23*	***.002***	
AN-WR	-4.12(*4.50*)	*-0.92*	*.362*	
Adj R^2: 0.06; df(137)				-44.318 – 60.2
Effect: Performance (IAcc)				
Intercept (HCs)	0.601(*0.03*)			
AN	0.030(*0.04*)	0.652	*.516*	
AN-WR	0.050(*0.04*)	1.127	*.262*	
Adj R^2: -0.005; df(135)				-.601 - .371
Effect: Performance (IAcc) per Group ~ BMI				

IAcc_AN ~ BMI	-0.011(*0.02*)	-0.653	.517	
Adj R^2: -0.013; df(45)				-.457 - .351
IAcc_AN-WR ~ BMI	0.002(*0.014*)	0.113	.911	
Adj R^2: -0.025; df(40)				.001 - .911
IAcc_HC ~ BMI	0.012(*0.01*)	1.108	.274	
Adj R^2: 0.005; df(45)				.012 - .274

Women with AN, but not AN-WR women, gave lower retrospective ratings on their HCT performance compared HCs.

Using linear regression, we examined the effect of group on Retrospective Performance Estimates when controlling for Prospective Performance Estimates and Performance. We found that the AN group gave lower Retrospective Performance Estimates compared to HCs (Figure 3; Table 4). The difference between the Retrospective Performance Estimates of the AN-WR group in comparison to the HCs was small and not statistically significant.

Women with AN, but not AN-WR women, are more influenced by their prospective performance beliefs than HCs

Using linear regression, we examined the effect of Prediction Error per group on Retrospective Performance Estimates. We found that the AN group gave significantly lower Retrospective Performance Estimates than the HC group, and we found a small, non-significant difference between the Retrospective Performance Estimates of the AN-WR group and the HCs. We also found a significant Group x Prediction Error interaction, which indicated that Retrospective Performance Estimates were also dependent on different levels of Prediction Error between groups. Specifically, the interaction was influenced by the AN group's higher prediction error (they predicted to perform worse than they actually did). However, the relative difference between the AN-WR and HC groups was not significant.

Table 4

Main results for Hypothesis 3

		Main Analyses		
Effect: Retrospective Performance ~ Prospective Performance +	**β(*SE*)**	***t***	***p***	**95% CI**

Performance + Group				
Intercept (HCs)	2.33(*5.91*)			
Prospective Performance	0.56(*0.07*)	*7.683*	***<.001***	
Performance	33.40(*7.29*)	*4.579*	***<.001***	
AN	-13.11(*3.75*)	*-3.497*	***.001***	
AN-WR	-1.46(*3.78*)	*-0.385*	*.701*	
Adj R^2: 0.48; df(131)				-41.144 – 46.179
Effect: Retrospective Performance ~ Prediction Error x Group				
Intercept (HCs)	51.51(*3.34*)			
AN	-10.56 (*5.30*)	*-1.992*	***.049***	
AN-WR	-2.90(*5.21*)	*-0.557*	*.579*	
Prediction Error (PE)	0.055(*0.12*)	*0.462*	*.645*	
AN x PE	-0.419(*0.17*)	*-2.538*	***.012***	
AN-WR x PE	-0.03(*0.18*)	*-0.184*	*.855*	
Adj R^2: 0.159; df(131)				-49.476 – 67.224

False-feedback resulted in a change in performance evaluation estimates in all groups. Specifically, positive false feedback resulted in higher performance evaluation estimates and Negative false-feedback resulted in lower performance evaluation estimates

We first ran three linear regressions (one per group), to control for potential effects of false-feedback on performance. As expected, we found no statistically significant effect, i.e., the false-feedback that participants received was not based on their performance in the HCT (Table 5).

In the main analyses we conducted to examine whether false-feedback affected participants' post-false feedback performance estimates we found the same pattern of results across the three groups. That is, participants within each group gave significantly higher Post False-feedback Retrospective Performance Estimates if they received positive false-feedback, in comparison to those who received negative false-feedback.

Table 5

Main Analyses for Hypothesis 5

	Control Analyses			
Effect:	**β(*SE*)**	***t***	***p***	**95% CI**

Performance (Per Group) ~ False-Feedback				
Intercept (AN: Negative False-Feedback)	61.32(*3.95*)			
AN: Positive False-Feedback	1.23(*5.16*)	*0.238*	*0.813*	-45.98 – 29.91
Adj R^2: -0.021; df(44)				
Intercept (AN-WR: Negative False-Feedback)	61.14(*4.80*)			
AN-WR: Positive False-Feedback	4.94(*6.88*)	*0.718*	*0.477*	-42.26 – 29.45
Adj R^2: -0.013; df(37)				
Intercept (HC: Negative False-Feedback)	61.45(*5.03*)			
HC: Positive False-Feedback	-4.46(*7.48*)	*-0.596*	*0.554*	-61.45 – 34.62
Adj R^2: -0.013; df(40)				
		Main Analyses		
Effect:	**β(*SE*)**	***t***	***p***	**95% CI**
Post-False Feedback Retrospective Performance Estimate (Per Group) ~ False-Feedback				
Intercept (AN: Negative False-Feedback)	25.37(*5.75*)			
AN: Positive False-Feedback	37.49(*7.44*)	*5.036*	***<.001***	-62.86 – 74.63
Adj R^2: 0.346; df(45)				
Intercept (AN-WR: Negative False-Feedback)	34(*4.22*)			
AN-WR: Positive False-Feedback	33.50(*5.96*)	5.62	***<.001***	-37.50 – 56.00
Adj R^2: 0.44; df(38)				
Intercept (HC: Negative False-Feedback)	43.44(*4.23*)			
HC: Positive False-Feedback	24.72(*6.29*)	*3.93*	***<.001***	-43.44 – 41.57
Adj R^2: 0.26; df(40)				

Figure 1

Prospective Performance Estimates Between the Groups (AN, AN-WR, and HC).

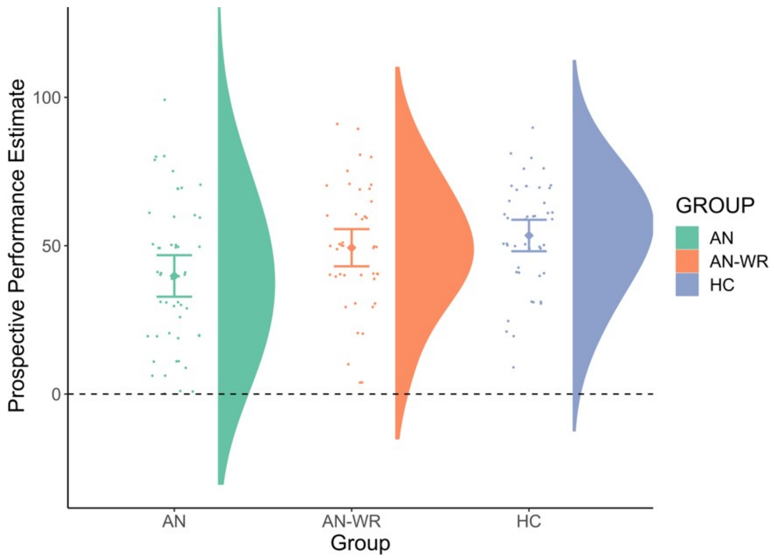


Figure 2

Performance (IAcc) Between the Groups (AN, AN-WR, and HC)

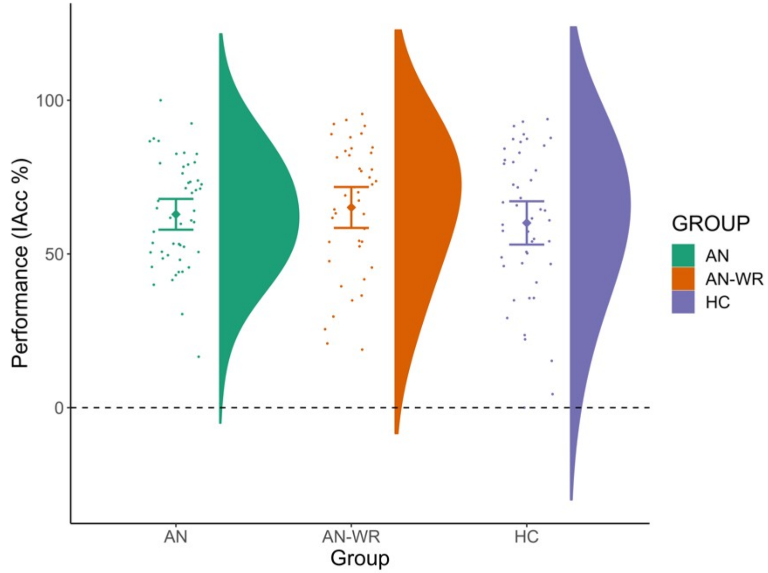


Figure 3

Retrospective Performance Estimates Between Groups (AN, AN-WR, HC)

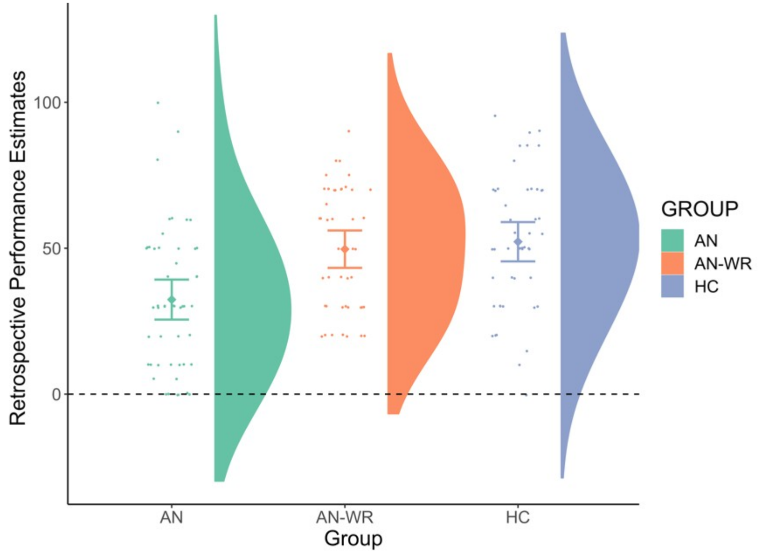
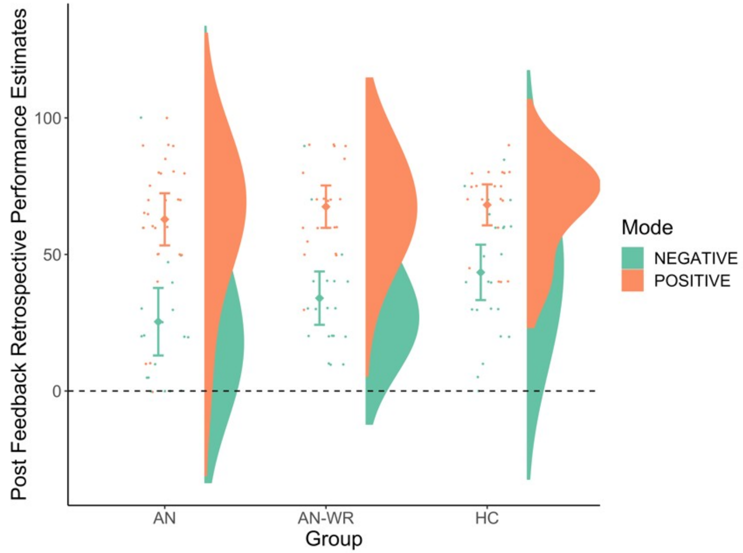


Figure 4

Post Feedback Retrospective Performance Estimates Following on False Feedback



Methods

Experiment 2: Exteroceptive Belief Updating

Participants

For Experiment 2, we used convenience sampling to recruit a total of N=84 female participants (n=28 AN, n=22 AN-WR, and n=34 HCs). The participants were recruited from the same units as in *Experiment 1*. Inclusion and exclusion criteria were identical to those of *Experiment 1* (see *Experiment 1*, *Participants* section). One AN patient was excluded due to comorbid psychosis and one AN-WR patient was excluded due to comorbid bulimia nervosa. The final sample included 27 AN patients, 21 AN-WR, and 34 age- and gender-matched HCs (Table 6). Part of the data from this study were as part of a Master of Science in Clinical Neuropsychiatry (Saramandi, 2020). The analyses conducted in the current research are an elaboration of this previous thesis.

Table 6

Summary of participant profiles for the Anorexia Nervosa (AN), Weight-Restored Anorexia Nervosa (AN-WR), and Healthy Control (HC) groups. The table has been reproduced from Saramandi (2020)

	AN	**AN-WR**	**HC**
Age (*SD*)	25.04 (*8.36*)	26.05 (*7.33*)	25.88 (*4.77*)
BMI (*SD*)	15.82 (*1.64*)	19.82 (*1.74*)	20.78 (*2.12*)
Years of Illness (*SD*)	7.98 (*7.98*)	4.96 (*4.63*)	N/A
Age of Onset (*SD*)	15.98 (*2.66*)	17.71 (*4.45*)	N/A
Months from Weight Restoration (*SD*)	N/A	40.44 (*74.04*)	N/A
Psychiatric Comorbidities	4 OCD 4 Mood Disorder 2 Borderline Personality Disorder 0 Panic/Anxiety Disorder 9 Multiple Comorbidities	0 OCD 3 Mood Disorder 0 Borderline Personality Disorder 6 Panic/Anxiety Disorder 5 Multiple Comorbidities	4 Subclinical Anxiety Symptoms

Psychiatric Treatment during the acute stage	17 Antidepressants 3 Mood Stabilisers 13 Antipsychotics 11 Sedatives	13 Antidepressants 0 Mood Stabilisers 2 Antipsychotics 4 Sedatives	N/A

Design

A 3 (Group: AN, AN-WR, HC) x 2 (Mode: Envisioned, Emotional) design was employed, with one between-subjects factor (Group) and one within-subjects factor (Mode). Mode was manipulated by instruction; in one block participants were asked to give Envisioned body size estimates and in the other block participants were asked to give Emotional body size estimates.

Our dependent variables (DVs), as explained in detail below, were the Pre-feedback Error Rate, Balloon Size Error Rate, Post-feedback Error Rate, Envisioned Belief Update and Emotional Belief Update (see more below). To examine differences between group body size estimates prior to receiving feedback we obtained a Pre-feedback Error Rate. The Pre-feedback Error Rate (DV) was the difference between participants' Pre-feedback body size estimate and actual BMI. Body size estimates were assessed by asking participants to indicate how large they experienced their body to be from an (1) envisioned, and an (2) emotional stance. To account for individual BMI in the error rates, instead of looking at the BMI magnitude differences between groups, the difference between body size estimates and actual BMI was weighted by BMI (see *Supplementary Material* for formula).

We also obtained a Balloon Size Error Rate to examine whether group differences were specific to one's own body size estimates, or also generalisable to other objects (e.g., a balloon). The Balloon Size Error Rate was the difference between the balloon size estimate and the balloon's actual size, weighted by actual size, and this was used as a control factor in the analyses. No statistically significant difference between the Balloon Size Error Rate of the three groups would suggest that participants did not perceive the balloon size differently.

To examine how the groups differed in their Post-feedback body size estimates in comparison to their actual BMI, we calculated two Post-feedback Error Rates (DV): one for the Envisioned and one for the Emotional mode. We did this to examine how Envisioned and Emotional body size estimates may change after receiving feedback with respect to their actual BMI (Feedback: Self-BMI and Clinician-feedback-BMI, respectively; DVs: Envisioned Post-feedback Error Rate, and Emotional Post-feedback Error Rate, respectively).

The Post-feedback Error Rate was the difference between participants' Post-feedback body size estimates and their actual BMI, weighted by BMI.

To assess how groups updated their Envisioned and Emotional body size beliefs following self-BMI feedback and Clinician-feedback-BMI (IVs) respectively, we obtained an Envisioned and an Emotional Belief Update estimate by calculating the difference between the respective Post-feedback and Pre-feedback body size estimates (DVs).

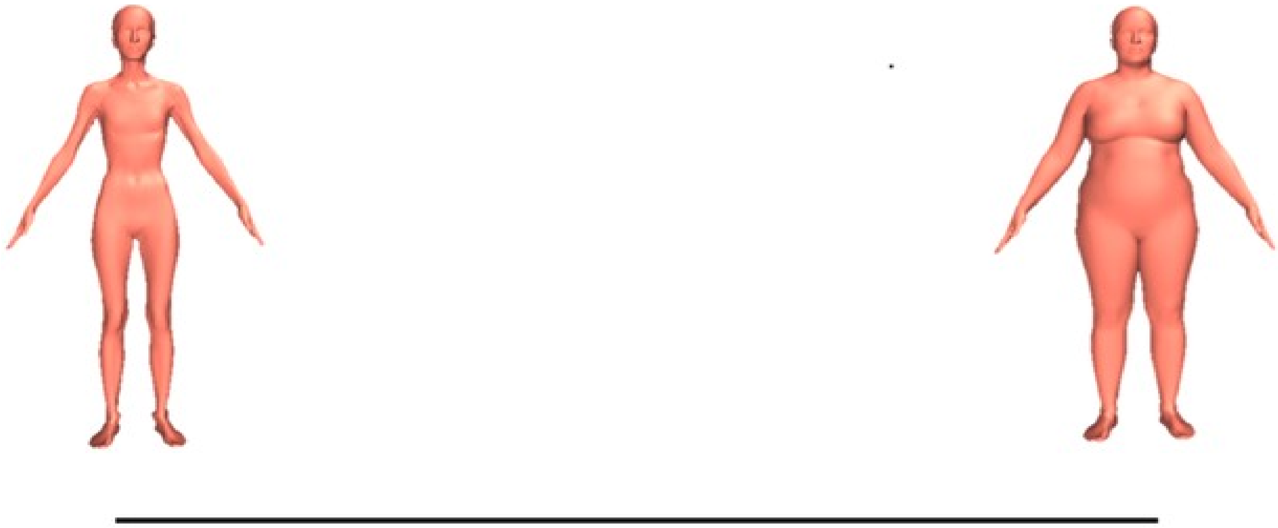
Materials and Measures

Participants completed all three experimental blocks (i.e., envisioned estimates with BMI as feedback, emotional estimates with Clinician-feedback-BMI as feedback, and balloon-size estimates for control purposes with balloon-size as feedback).

Participants were presented with an A4 size paper with a page-wide scale on landscape layout format (22cm long; Figure 5), with two avatar-like images of bodies differing only in BMI (Body 1: BMI=12 and Body 2: BMI=32; see Figure 1), one on each end of the scale. The avatar-like images of bodies were created on Body Visualiser (https://bodyvisualizer.com/) by adjusting the default avatar-like female body (BMI: 23.80, Height: 1.64m, Weight: 64kg, Chest: 93cm, Waist: 76cm, Hips: 102cm, Inseam: 76cm). BMI was calculated as: m/h^2, where m is weight in kg and h is height in metres. To create the avatar with a BMI=12, weight was adjusted to 32kg, while keeping height at 1.64m (Chest: 62cm, Waist: 45cm, Hips: 72cm, Inseam: 77cm). To create the avatar with a BMI=32, weight was adjusted to 86kg and height was kept at 1.64m (Chest: 109cm, Waist: 109cm, Hips: 118cm, Inseam: 74cm). Subsequently, participants were asked to provide pre-feedback and post-feedback envisioned and emotional body size estimates by drawing a cross on the scale corresponding with where they thought they should be positioned (see *Procedure* below).

Figure 5

The scale used for the Envisioned and Emotional body conditions. In this Figure the body with a BMI=12 is positioned on the left end of the scale, and the body with a BMI=32 is positioned on the right end of the scale. The position of the bodies was counterbalanced between participants, i.e., half of them saw the body with a BMI=12 on the right end of the scale, and the body with a BMI=32 on the left end of the scale, and vice versa. This Figure has been reproduced from Saramandi et al. (2020)



In the balloon-block, participants were shown a picture of a blown-up balloon whose size corresponded to 4.9cm from the smaller end of the scale (i.e., side with the smaller balloon). Next, they were given an A4 size paper (landscape layout) with a 22cm long scale which had a small balloon on one end, and a large balloon on the other end and were asked to indicate the balloon's size (balloon positions on the scale were counterbalanced between participants).

Procedure

Participants were given the information sheet and were asked to provide written consent. Next, they completed the demographics section and were explained the difference between an envisioned experience of one's body (based on BMI), and an emotional experience (based on the felt body image).

The order of the Envisioned and Emotional (body) blocks was counterbalanced. In both blocks, the experimenter showed the first visual analogue type scale with the 'thin' and 'large' bodies as anchor points and asked participants to draw a cross on the line to indicate their envisioned and emotional body size. In the Envisioned block participants gave a Pre-feedback envisioned body size estimate and in the Emotional block they gave a Pre-feedback emotional body size estimate. Then, participants received feedback, i.e., were shown their position on a new (second) scale, based on their BMI (Envisioned block) or social, intersubjective feedback based on the experimenter's clinical judgement (Clinician-feedback-BMI; Emotional block). Next, participants gave a Post-feedback Envisioned body size estimate in the Envisioned block and a Post-feedback Emotional body size estimate in the Emotional block on a new, third scale.

In between the two body blocks, participants completed the control (balloon) block. Participants were shown a picture of a blown-up balloon on a piece of paper without a scale. The experimenter showed the scale with the two balloons and asked participants to draw a cross on the line to indicate the size and shape of the balloon (Pre-feedback balloon size estimate). Next, the experimenter gave them feedback, i.e., showed them the balloon's position on a new (second) scale based on the actual size of the balloon in the first picture they had shown to the participant, and asked them to provide a Post-feedback balloon size estimate on a new, third, scale.

Data Analysis

Data were analysed using R (R, Boston, MA). In two instances, the experimenter made an error in the use of the scale and inadvertently gave two participants much larger BMI estimates than intended, hence these participants' Clinician-feedback-BMI, Post-feedback Emotional Error Rates and Post-feedback Emotional body size estimates had to be excluded from the analyses. The experimenter made a note and upon inspection of the data the two participants' estimates were identified as statistical outliers, confirming the experimental error.

Before conducting our main analyses, we carried out preliminary analyses to examine between-group BMI and age differences and as expected, groups different in BMI (AN patients had a significantly lower BMI compared to the AN-WR and HC groups) and age was not significantly different across the three groups. The results are available in the Supplementary Material.

For *Hypothesis 1* we examined the differences of the Pre-feedback Error Rates between group and mode. Since participants completed one trial per mode of instruction (repeated measures), a multilevel model was used to examine the *Pre-feedback Error Rate* between the three groups and the two modes, with participant ID added as a random effect. We then ran Holm-corrected planned contrasts to break down any significant group x mode interactions (we first report between-subject results and then within-subject results). In the model, the Pre-feedback error rate was used as the DV, and Group (AN vs AN-WR vs HC) and mode (envisioned vs emotional) were used as Independent Variables (IVs). We controlled for age and Pre-feedback balloon error rate.

In the Envisioned mode, to assess how the Post-feedback error rate (DV) was predicted by group (IV; *Hypothesis 2*), we ran a multiple linear regression. Age and Pre-feedback Balloon Error Rate were added as control variables.

Similarly, in the Emotional mode, we ran a multiple linear regression to assess how the Post-feedback error rate (DV) was predicted by group (IV; for *Hypothesis 3*), controlling for age and Pre-feedback Balloon Error Rate.

For *Hypotheses 2* and *3* we only ran between-subject, and not within-subject Holm-corrected planned contrasts given that the feedback received after the Pre-feedback body size estimate was different for each of our two modes.

To examine *Hypotheses 4* and *5*, we followed the assumptions of a Bayesian Learning Framework, but analysed our data in the form of a linear regression based on a structural equivalence between the two (this equivalence is explained in detail below), given the constraints of our design that included a single per-person trial. Specifically, we compared the interaction represented by our linear regression (group x pre-feedback) to the equation representing the Bayesian Learning Framework. As such, the slope of the pre-feedback estimate in our linear regression could be interpreted as the Updating Rate of the HCs, while the interaction between group and pre-feedback estimates could be interpreted as the difference in the Updating Rates between the two clinical groups and the HCs. This allowed us to examine how the slope of each clinical group compared to the slope of the HCs (main effect) and therefore compare the rates at which the groups updated their beliefs (these rates here were defined as 'Updating Rates' at the group level, separate for each mode; see further details below). Using this kind of equivalence, we did not expect significant group differences in the Updating Rates of the Envisioned estimates (*Hypothesis 4*), but we expected that the clinical groups would have significantly smaller Updating Rates in the Emotional estimates compared to the HCs (*Hypothesis 5*).

For *Hypothesis 4* we ran a multiple linear regression, using Envisioned Belief Update (difference between Post-feedback and Pre-feedback Envisioned body size estimates) as the DV. For the IVs we used feedback (Self-BMI, i.e., participants' actual BMI), the Pre-feedback estimates, and the interaction between Group and Pre-feedback estimates. However, we did not use the intercept Group effect because there is no fixed bias term in the Bayesian Learning Framework.

Similarly, for *Hypothesis 5* we ran a multiple linear regression, using Emotional Belief Update (difference between Post-feedback and Pre-feedback Emotional body size estimates) as the DV. For the IVs we used feedback (Clinician-feedback-BMI), the Pre-feedback estimates, and the interaction between Group and Pre-feedback estimates. Like in the analysis for *Hypothesis 4*, we did not use the intercept Group effect.

The final model for *Hypotheses 4* and *5* was:

$$Belief\ Update \quad Group\ x\ PreFeedback + Feedback - Group \tag{2}$$

For *Hypothesis 4,* the term "Belief Update" seen in Eq. 2 refers to the Envisioned Belief Update, and the term "feedback" refers to Self-BMI, while for *Hypothesis 5,* "Belief Update" refers to the Emotional Belief Update and "feedback" refers to Clinician-feedback-BMI.

To make the aforementioned comparisons we used the structural equivalence of the following models:

Linear Regression Predictive Equation:

$$Belief\ Update = intercept + slope_b * fb + slope_a * \text{Pre Fb\_Estimate} \tag{3}$$

Bayesian Learning Framework Predictive Equation:

$$Belief\ Update = \text{Updating Rate * fb - Updating Rate + Pre Fb\_Estimate} \tag{4}$$

Equations (3) and (4) have an equivalent structure, and both predict changes in Belief Update (DV), and hence we were able to examine the differences in Updating Rates between the groups by comparing the slopes of the pre-feedback estimate of our three groups. More specifically for the predictive linear regression equations for the groups are:

For HCs:

$$Belief\ Update = b0 + \text{b1\_b * fb + b1\_a * Pre Fb\_Estimate} \tag{5}$$

For ANs:

$$Belief\ Update = b0 + \text{b1\_b * fb + (b1\_a +b2) * Pre Fb\_Estimate} \tag{6}$$

where, b0 is the intercept, b1_a is the coefficient of the Pre-feedback estimate, b1_b is the coefficient of the feedback, b2 is the coefficient of the interaction between Group and Pre-feedback estimates, fb is feedback and pre-fb_estimate is the pre-feedback estimate. The AN equation would apply to the AN-WR group (with the corresponding value for b2).

Using the Bayesian Learning Framework, the following would be the predictive equations for the HC and the AN groups, respectively:

$$Belief\ Update = UR_{hc} * fb - UR_{hc} * \text{Pre Fb\_Estimate} \tag{7}$$

$$Belief\ Update = UR_{an} * fb - UR_{an} * \mathrm{Pre\,Fb\_Estimate} \quad (8)$$

where UR_hc, and UR_an refer to the Updating Rates of the HC and AN groups, respectively. Assuming the Bayesian Learning Framework, we can exploit the above equivalence between equations (5), (6), (7), and (8) to claim that the intercept (b0) should be equal to 0, b1_a would be equal to (-UR_hc) and b1_a+b2 would be equal to (-UR_an). Taken together, the difference between the Updating Rates of the two groups would be the following:

$$UR_{hc} - UR_{an} = -b1_a + b1_a + b2 = b2 \quad (9)$$

where, b2 is the coefficient of the interaction between Group and Pre-feedback estimates. A statistically significant b2 would therefore imply that the difference in the Updating Rates between the groups was significant.

Results

Women with AN misestimated both their envisioned and emotional body size more than healthy women, while AN-WR women misestimated only their emotional body size

Results revealed significant main effects of both group and mode on Pre-feedback Error Rates, and a significant Group x Mode interaction (Table 7). The main effect of group indicated that the AN group misestimated their body size more than HCs, and the main effect of mode indicated that misestimations were greater in the Emotional vs Envisioned mode. These effects remained significant when accounting for age and perceptual bias (i.e., Pre-feedback Balloon Error Rate).

To break down the group x mode interaction we performed planned contrasts (as described above in the Methods, Experiment 2, Data Analysis section). In the between-group planned contrasts (Holm corrections applied), we found that the AN group had significantly higher Pre-feedback Error Rates in the Envisioned mode in comparison to the HC group, but not in comparison to the AN-WR group. The difference in the Envisioned Pre-Feedback Error Rates between the AN-WR and HC groups was small and not statistically significant.

Next, we found that the Emotional Pre-feedback Error Rates of the AN group were significantly higher than the Emotional Pre-feedback Error Rates of both the HC and AN-WR groups, with the AN group showing greater misestimation of their body size. The difference in Emotional Pre-feedback Error Rates between the AN-WR and HC groups was also significant, with the AN-WR group showing greater misestimation than HCs.

When comparing mode (Envisioned vs Emotional Pre-feedback Error Rates) within each group, we found that women with AN had significantly higher error rates for the Emotional mode compared to the Envisioned mode. However, we found a small difference which was not statistically significant within both the AN-WR group and the HC group (Holm corrections applied; Figure 6; Table 8).

Table 7

Main results for Hypothesis 1

	Pre-feedback body size estimate Error Rate					
Effect	**β(*SE*)**	***t***	***p***	**χ^2(df)**	**f^2**	**ICC**
Group	0.11(0.08)		***<.001***	40.65(2)	0.45	0.23
AN vs HC	0.31(*0.04*)	7.23				
AN-WR vs HC	0.11(*0.05*)	2.45				
Mode: Emotional vs Envisioned	0.15(*0.02*)	6.45	***<.001***	33.54(1)	0.14	0.60
Group x Mode			***<.001***	21.58(2)	0.79	0.52

Table 8

Planned Contrasts for Hypothesis 1

	Planned Contrasts on Group x Mode					
Comparison	**β(*SE*)**	***t***	***p***	**df**	**Adj R^2**	**95% CI**
AN Envisioned vs AN Emotional	0.295(*0.07*)	4.019	***<.001***	*52*	*0.222*	-.809 - .638
AN-WR Envisioned vs AN-WR Emotional	0.113(*0.06*)	1.897	*.149*	40	0.060	-.384 - .458
HC Envisioned vs HC Emotional	0.058(*0.03*)	1.904	*.149*	63	0.039	-.264 - .241
AN Envisioned vs HC Envisioned	0.189 (*0.04*	4.525	***<.001***	*58*	*0.248*	*-.441 - .340*

AN-WR Envisioned vs AN Envisioned	-.113(*0.05*)	-2.176	*.139*	*46*	*0.074*	*-.441 - .340*
AN-WR Envisioned vs HC Envisioned	0.076(*0.04*)	2.011	*.149*	52	0.054	*-.315 - .241*
AN Emotional vs HC Emotional	0.425 (*0.06*)	6.837	***<.001***	*57*	*0.441*	*-.809 - .638*
AN Emotional vs AN-WR Emotional	-.295(*0.08*)	-3.532	***.006***	*46*	*0.196*	*-.809 - .638*
AN-WR Emotional vs HC Emotional	0.130(*0.05*)	*2.724*	***.044***	*51*	*0.110*	*-.384 - .458*

Women with AN, but not AN-WR women, misestimated their envisioned body size more than healthy women, after receiving body-size-relevant feedback

We found higher misestimation post-feedback (i.e., higher Post-Feedback Error Rate) in the Envisioned mode when comparing between the AN and HC groups. This difference was smaller and not significant between the AN-WR and HC groups (Table 9; Figure 7). The significant difference between the AN and HC groups remained even after Holm corrections on the *p* value, and when controlling for age and perceptual bias (i.e., Balloon Error Rate). Planned contrasts showed small and not statistically significant differences between the Envisioned Post-Feedback Error Rates of the AN and AN-WR groups (Table 10).

Women with AN, but not AN-WR women, misestimated their emotional body size more than healthy women, after receiving body-size-relevant feedback

In the Emotional mode, we found that Post-feedback Error Rates were significantly different between the AN vs HC group. That is, the AN group misestimated their emotional body size at a greater degree in comparison to the HCs, and the effect remained significant following Holm corrections on the *p* value and when correcting for age and perceptual bias. This effect was smaller and not statistically significant between the AN-WR and HCs groups (Table 11). However, planned contrasts showed significantly greater misestimation in the AN group in comparison to the AN-WR group (Holm corrections applied; Table 12).

Table 9

Main results for Hypothesis 2

	Main Analyses			
Effect: Post-feedback Envisioned Error Rate	**β(*SE*)**	***t***	***p***	***95% CI***
Intercept (HC)	0.059(*0.04*)			
Age	-0.002(*0.001*)	*-1.440*	*0.154*	
Balloon Error Rate	0.029(0.02)	*1.749*	*0.084*	
AN	0.065(*0.02*)	*3.029*	***0.003***	
AN-WR	0.02(*0.02*)	*0.867*	*0.389*	
Adj R^2: 0.11; df(76)				-.145 - .186

Table 10

Planned Contrasts for Hypothesis 2: Post-feedback Envisioned Error Rates

	Planned Contrasts between Group					
Comparison	**β(*SE*)**	***t***	***p***	**df**	**Adj R^2**	**95% CI**
AN – HC	0.061(*0.02*)	*2.846*	***.018***	*58*	.107	-.156 - .226
AN-WR - AN	-0.046(*0.03*)	-1.800	*.157*	*46*	.046	-.142 - .165
AN-WR - HC	0.015(*0.02*)	*0.692*	*.492*	*52*	-.001	-0.156 - .226

Table 11

Main results for Hypothesis 3

	Main Analyses			
Effect: Post-feedback Emotional Error Rate	**β(*SE*)**	***t***	***p***	***95% CI***
Intercept (HC)	0.160(*0.11*)	*1.467*		
Age	-0.007(0.004)	*-1.700*	*.093*	
Balloon Error Rate	0.060(0.05)	*1.243*	*.218*	
AN	0.437(*0.06*)	*7.104*	***<.001***	
AN-WR	0.090(*0.07*)	*1.376*	*.173*	

Adj R^2: 0.41; df(75)	-.457 - .712

Table 12

Planned Contrasts for Hypothesis 3: Post-feedback Emotional Error Rates

	Planned Contrasts between Group					
Comparison	**β(*SE*)**	***t***	***p***	**df**	**Adj R^2**	**95% CI**
AN – HC	-0.012(*0.04*)	*-0.269*	***<.001***	*57*	*.244*	*-.598 – .638*
AN-WR - AN	-0.351(*0.08*)	-4.160	***<.001***	*46*	*.258*	*-.598 - .638*
AN-WR - HC	0.080(*0.05*)	*1.784*	*0.080*	*51*	*.040*	*-.327 - .559*

The rate at which women with AN, AN-WR and healthy women updated their beliefs about their envisioned body size was not significantly different

Our analysis showed that the slope (Figure 8; Table 13) of the Pre-feedback Envisioned body size estimates of the two clinical groups did not significantly differ to the slope of the HCs. Based on the structural equivalence between the linear regression and belief update equations (see above), this finding indicates that the interaction between group and pre-feedback estimates (interpreted as the Envisioned Updating Rate between the AN, AN-WR and HC) was not significantly different between our three groups.

Women with AN, but not AN-WR women updated their beliefs about their emotional body size at a lower rate than healthy women

Our analysis of emotional body size belief updating showed a significant interaction between group and the Pre-feedback Emotional body size estimates (Figure 9; Table 13). Specifically, the slope of the AN group was steeper than that of the HC group, which indicates that the Emotional Updating Rate was significantly lower in the AN group compared to the HCs. On the other hand, the slope of the AN-WR group was not significantly different to that of the HCs, showing no statistically significant difference between the Emotional Updating Rate of these two groups.

Table 13

Main results for Hypotheses 4 and 5

	Main Analyses			
Envisioned Updating Rate	**β(*SE*)**	***t***	***p***	***95% CI***

Intercept (BU)	0.802(*1.50*)			
Pre-feedback Envisioned Estimate	-0.663(*0.06*)	*-10.780*	***<.001***	
Feedback: Self-BMI	0.66(*0.11*)	*6.127*	***<.001***	
AN: Pre-feedback Envisioned Estimate	-0.018(*0.03*)	*-0.579*	*.564*	
AN-WR: Pre-feedback Envisioned Estimate	-0.014(*0.02*)	*-0.716*	*.476*	
Adj R^2: 0.74; df(76)				-3.925 – 3.492
Effect: Emotional Updating Rate				
Intercept (BU)	-3.744(*2.12*)			
Pre-feedback Emotional Estimate	-0.231(*0.07*)	-3.209	***.002***	
Feedback: Clinician-Feedback-BMI	0.433(0.14)	3.196	***.002***	
AN: Pre-feedback Emotional Estimate	0.112(0.04)	2.787	***.007***	
AN-WR: Pre-feedback Emotional Estimate	-0.02(0.03)	-0.767	*.446*	
Adj R^2: 0.18; df(74)				-6.989 – 4.875

Figure 6

Pre-feedback Error Rates Between Groups in the Envisioned (ENV) and Emotional (EMO) Modes

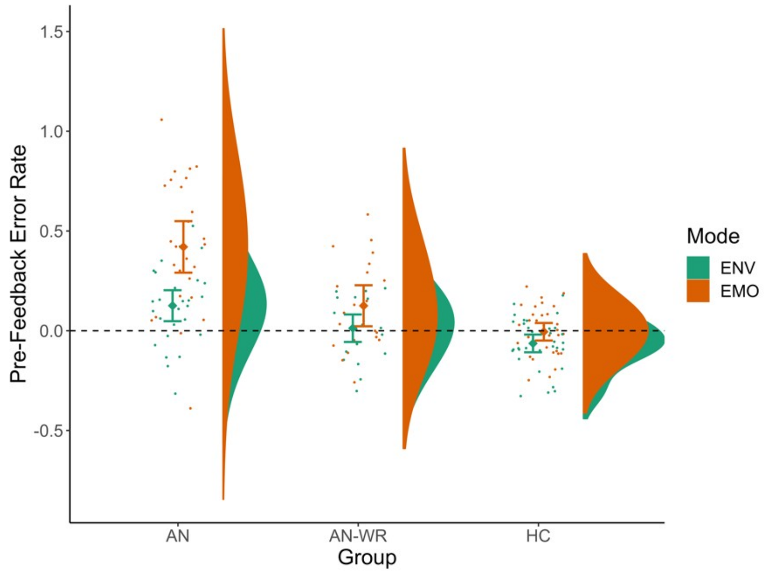


Figure 8

Updating Rate Between the Groups Following Self-BMI Feedback

Figure 7

Post-feedback Error Rate Between Groups in the Envisioned (ENV) and Emotional (EMO) Modes

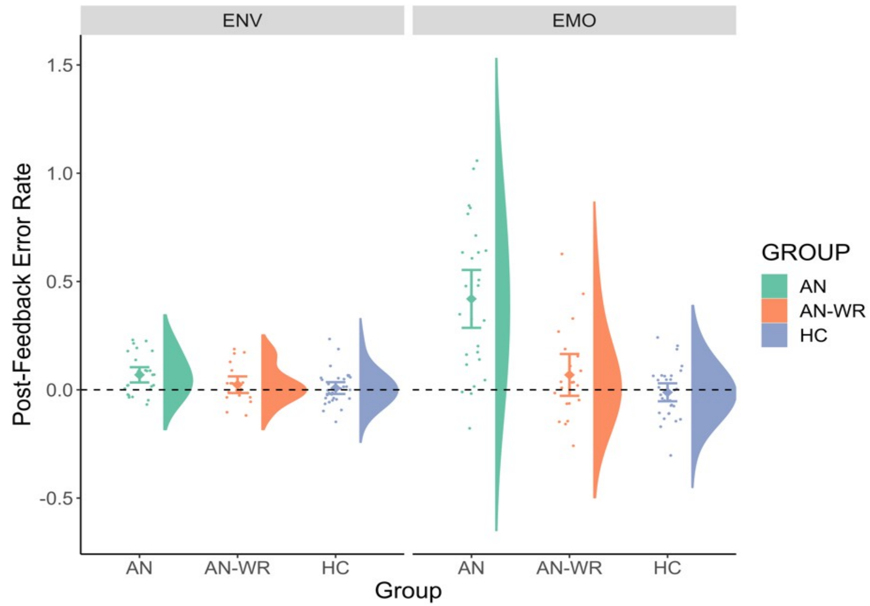
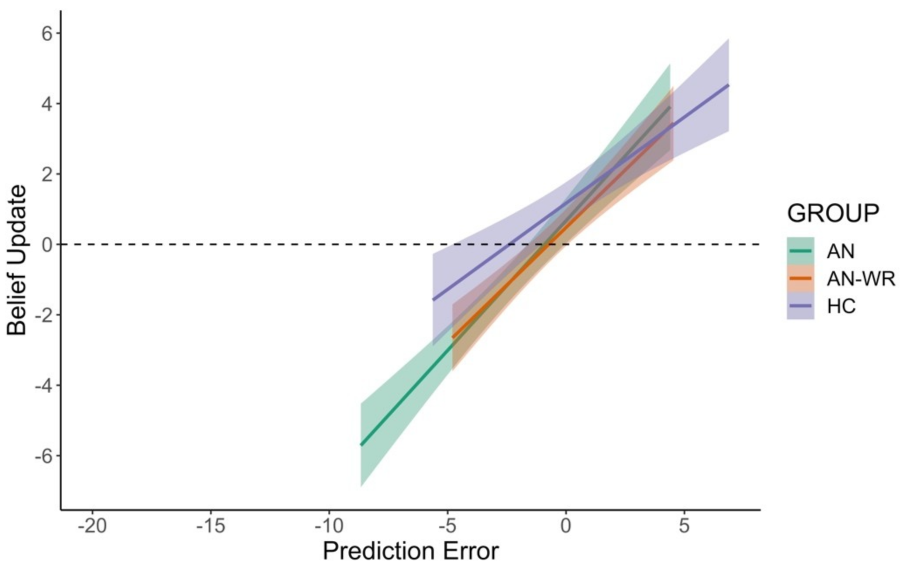
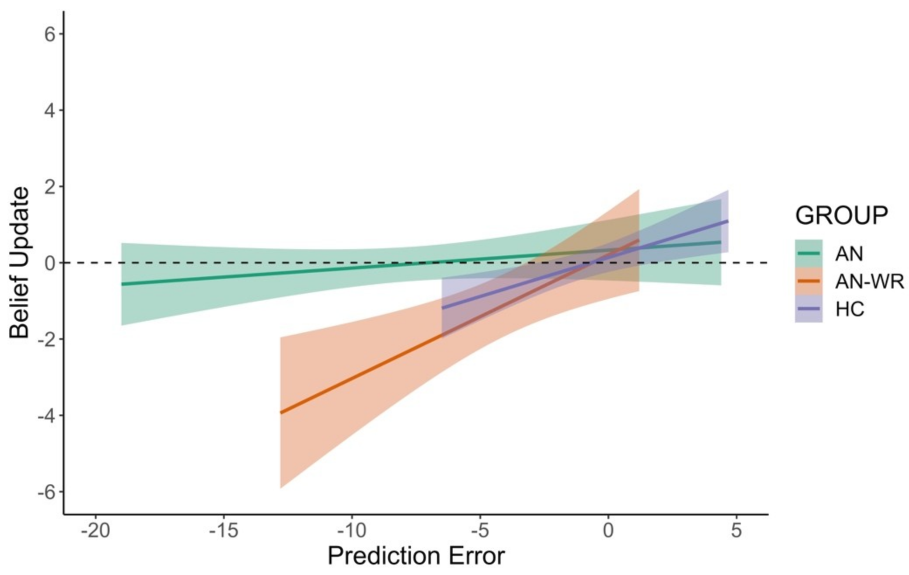


Figure 9

Updating Rate Between the Groups Following Clinician-feedback-BMI


Belief Update
Prediction Error
GROUP
AN
AN-WR
HC


Belief Update
Prediction Error
GROUP
AN
AN-WR
HC

Discussion

In this study we investigated the updating of beliefs in women with, and weight-restored from AN. In *Experiment 1* we looked at the prospective and retrospective interoceptive self-efficacy beliefs individuals hold before and after completing a heartbeat counting (HCT) task (Schandry, 1981), and after receiving different types of information about their heartrate (i.e., embodied signals during HCT performance, and explicit, verbal feedback from the experimenter). In *Experiment 2* we examined perceptual belief updating in the domain of body image, examining how participants' envisioned ('*How does it look?*') and emotional ('*How does it feel?*') body size estimates may vary prior to and after receiving visual feedback regarding their body size. Overall, our results showed that the AN group held more pessimistic self-efficacy beliefs in comparison to the HCs, both before and after the HCT (*Experiment 1*). Similarly, in *Experiment 2* we saw that the AN group tended to overestimate their body size more than the HCs, in both the envisioned and emotional modes, before and after getting feedback. As expected, before feedback, the AN-WR group also misestimated their emotional body size more than HCs and gave higher emotional body sizes compared to their actual BMI. However, contrary to our predictions there were no significant differences in comparison to the HCs' estimations in the other measures (i.e., envisioned body size estimate before or after feedback, or emotional body size estimate post-feedback). We discuss the implications of our results below, separately for each experiment, given that design differences did not allow direct statistical comparisons between the two experiments. Only qualitative common considerations are discussed below.

Experiment 1: Interoception and Metacognition

In line with our first hypothesis, women with AN, but not AN-WR women, provided lower prospective performance estimates (i.e., pessimistic prospective self-efficacy beliefs about cardiac awareness) in the HCT in comparison to HCs. Specifically, the AN group gave more pessimistic, predictive estimates about their future performance on a HCT that asked them to focus on and report felt heartbeats during certain, different time intervals. These results may relate to previous findings in eating disorders suggesting differences between patients and control groups in the prediction and anticipation of various interoceptive signals (Crucianelli et al., 2021; Khalsa et al., 2015; see Introduction), although these studies tested only prospective beliefs at the perceptual level (e.g., the equivalent of "*How many heartbeats do you think you would perceive*") and not at the metacognitive level tested here (i.e., "*How well do you think you will do in this task*"). Interestingly, in clinical studies, prospective self-efficacy at treatment onset has been found to be predictive of eating disorder treatment dropout (Keshen et al., 2017). To our knowledge, however, no studies have examined interoceptive self-efficacy prospectively and our results warrant further investigation of the role of such beliefs in treatment response.

In our sample, only those with acute AN and not the AN-WR group presented more pessimistic beliefs than HCs. This result may be explained by our relatively small sample, or factors relating to recovery (e.g., some weight-restored patients may have improved their self-efficacy more generally), or illness duration. Indeed, acute AN patients typically have a longer illness duration than those in the AN-WR group (e.g., Kinnaird et al., 2020; Konstantakopoulos et al., 2020; Miles et al., 2020). We observed this pattern also in our sample. However, it is unlikely that the pessimistic prospective self-efficacy beliefs of the AN group were explained by illness duration given that our within-group analyses with illness duration as an IV did not yield significant effects (see Supplementary Material). Finally, this result may suggest a state, rather than trait effect. In fact, prolonged starvation can lead to severe modifications of brain and peripheral-organ function which in turn impact aspects of cognitive abilities (e.g., Abbate-Daga et al., 2011; Kaye, 2009; Miles et al., 2020). Thus, the lack of a significant difference between the AN-WR and HC group suggests that the significantly more pessimistic prospective self-efficacy estimates of the AN group as opposed to those of the HC group may have been a secondary effect of starvation, and not a pre-existing trait which persisted after weight-restoration. Future studies should explore these different possibilities further.

As predicted, HCT performance did not differ between the three groups. These findings are consistent with previous studies reporting no differences in IAcc between clinical and HC groups (e.g., Kinnaird et al., 2020; Lutz et al., 2019; Richard et al., 2019; see Introduction), although contrary findings also exist (e.g., Pollatos et al., 2008). These differences between the studies may be at least partly explained by sampling differences (e.g., comorbidities, inpatient or outpatient treatment, illness stage; Fischer et al., 2016; Pollatos et al., 2008; Richard et al., 2019). In our AN group we included individuals who met restrictive AN criteria (DSM-5; APA, 2013) and were at different treatment stages, receiving either inpatient or outpatient care, and had various comorbidities unlike Pollatos and colleagues (2008) who recruited outpatients with either a restrictive or binge-purge AN diagnosis and with fewer comorbidities. Notwithstanding, heterogeneity in treatment stage and type, BMI, and clinical profiles did not affect our analysis outcomes (see Supplementary Material), suggesting that in our cohort these factors were unlikely to have influenced participant HCT performance. All of our groups performed above chance – something observed in most studies with similar methodologies (e.g., Kinnaird et al., 2021; Lutz et al., 2019; Pollatos et al., 2008; Pollatos et al., 2016). It is worth noting that studies in the general population have sometimes demonstrated poorer performance in HCs (even below chance, e.g., Desmedt et al., 2020), and this variability could be attributed to the instructions, duration of the counting trials, mixed gender samples, or other factors which we could not account for in the current report. Despite our groups' scores being close to what has been observed in other studies, the validity and reliability of the HCT task itself has been criticised and thus our study's methods regarding cardiac, perceptual accuracy are less conclusive. Instead, our emphasis is placed on the prospective self-efficacy beliefs patients generate before the HCT, and their retrospective beliefs after the HCT, and then after explicit, verbal feedback.

Indeed, we assessed participants' retrospective self-efficacy beliefs regarding cardiac interoceptive abilities. We predicted that the retrospective self-efficacy estimates of the AN group would be lower than those of the HC group despite the fact that the two groups did not significantly differ in their performance *per se*; *Hypothesis 3*) and we further hypothesised that pessimistic retrospective beliefs would be better explained by their similarity to prior prospective self-efficacy beliefs than performance levels (*Hypothesis 4*). In line with our hypotheses, our results showed that (i) the AN but not the AN-WR group were significantly more pessimistic than the HCs in their retrospective self-efficacy estimates, and (ii) as the discrepancy between performance and prior prospective self-efficacy beliefs (Prediction Error) of the AN group (but not of the AN-WR group) increased, the AN group's retrospective self-efficacy estimates were reduced. These results suggest that even as performance on the task was better than these patients expected, their retrospective beliefs about performance were not updated and instead continued to reflect the initial, pessimistic prior. Although these results are based on a task with few trials and known limitations, they are consistent with previous findings on impaired retrospective metacognition about interoception in AN, based on paradigms using confidence ratings on interoceptive performance from multiple trials (e.g., Kinnaird et al., 2020; Smith et al., 2020). Interestingly, by sampling also explicit beliefs prior to the task, we are able to observe these metacognitive difficulties at the level of prospective, self-efficacy beliefs and not only retrospectively. Future studies could explore whether greater reliance on pessimistic, prior beliefs is present in the AN-WR individuals when employing a larger AN-WR sample, or whether the pessimism observed in the current study is explained by other factors relating to the acute stage of illness as outlined above.

Interestingly and as predicted, all groups provided lower estimates following false-negative feedback, and higher estimates following false-positive feedback, a manipulation not previously applied in experimental studies using the HCT. This finding demonstrates that the ability to use feedback to update beliefs about task performance in AN may not be compromised across all levels and self-efficacy beliefs may be modified by social feedback, even if false as in this case. The pessimistic beliefs about one's abilities observed in those with AN are also present in depression, wherein individuals have difficulty adapting their beliefs to novel situations (Stange et al., 2017) despite being able to use arbitrary positive feedback to update task-specific expectations (Kube et al., 2021). Yet, the study's sample experienced difficulty generalising such expectations to other, future tasks (global prospective metacognition; Kube et al., 2021). Given clinical time constraints not all of our participants were assessed on depression (using the DASS-21 questionnaire; Lovibond & Lovibond, 2005) and we thus only directly examined the effects of depression on prospective self-efficacy beliefs and interoceptive accuracy. The results were non-significant (see Supplementary Material) and although less conclusive given our small sample size, we suggest that the pessimistic beliefs observed throughout our study were not directly influenced by depressive traits or states (the AN group scored higher than the AN-WR and HC groups on the DASS-21) but may instead be attributed to a bias in metacognitive beliefs or other factors as described above. Future studies will need to test this speculative interpretation. Interestingly, although the AN group showed more pessimistic, retrospective beliefs in comparison to HCs, despite similar performance in the HCT, following explicit, albeit false, performance feedback, they were able to adjust their estimates towards the direction of the feedback received. Thus, in line with Kube's et al. (2021) findings, we showed that in certain circumstances people with AN are able to use external, (dis)confirming information about their performance and update an isolated estimate. It is also likely that participants from all groups, especially those in the AN group were able to use false-feedback to update their beliefs because of low confidence in their own interoceptive abilities. Future studies should further investigate the role of explicit, external feedback in individual with both high and low interoceptive self-efficacy beliefs.

Despite the insights this experiment provided on the evaluation of abilities regarding perception of interoceptive signals and related metacognitive beliefs across groups, there were several limitations which will be addressed in our follow-up study. The HCT (Schandry; 1981) has received several criticisms for being a poor measure of interoceptive accuracy as approximately 40% of typically developing adults are not consciously aware of their heartbeat (Khalsa et al., 2009), making the task less sensitive when examining interoception in individuals with lower ranges of ability (Murphy et al., 2018b). Additionally, heartbeats may be perceived via vibrations against the chest wall (Khalsa et al., 2009) and depend on factors such as body-fat percentage (Rouse et al., 1988), and resting heart-rate variability (HRV; Knapp-Kline & Kline, 2005). Some questioning the validity and reliability of the HCT (Brener & Ring, 2016; Desmedt et al., 2018) also suggested that participants may report their felt heartbeats based on an approximation of the time they think has passed, general knowledge about average heartbeats in the general population and a calculation of the number of heartbeats they should have felt based on time awareness and heartbeat knowledge (e.g., Ainley et al., 2014; Murphy, Geary et al., 2018; Shah et al., 2016). Though, Murphy et al. (2018b) suggested that the criticisms may be less valid when controlling for these aforementioned measures - measures which we will control for in our follow-up study. Finally, interoception has been associated with symptoms of difficulties in emotional awareness and emotion identification and description (often referred to as alexithymia), given findings on poor interoception in individuals with higher alexithymia scores (Herbert et al., 2011; Murphy et al., 2017). However, this was not the case in our sample as seen in the analyses available in the *Supplementary Material,* suggesting that in our sample the differences in alexithymia scores did not explain the significant differences in prospective self-efficacy beliefs or interoceptive accuracy.

Experiment 2: Body Image and Body Size Estimation

In line with our first hypothesis for *Experiment 2,* we found significant between-group differences in *emotional* body size estimation at baseline, i.e., before feedback, with both clinical groups misestimating their felt body size significantly more than HCs (i.e., feeling larger than the image that corresponds to their BMI). Further analyses on group-differences in emotional body size estimates before receiving feedback, showed that the AN group also significantly misestimated their emotional body size in comparison to the AN-WR group. A similar significance between group difference in body size overestimation was also found for ‘the *envisioned* body’, with the AN group ‘seeing’ their body image as larger than that that corresponds to their BMI to a significantly greater degree than the HCs group; however, contrary to our prediction, this difference was not significant in the AN-WR group versus the HCs. Importantly, the emotional estimates of the AN patients were also significantly higher than their envisioned estimates, supporting the notion that the different aspects of body image can dissociate, and emotional aspects may be of particular relevance in AN (e.g., Cash & Deagle, 1997; Friederich et al., 2010; Gaudio et al., 2016; Gaudio & Quattrocchi, 2012;

Hagman et al., 2015; Henninghausen et al., 1999; Uher et al., 2005). This result is also consistent with findings showing that different aspects of body image are elicited and tested by different instructions (i.e., 'provide a cognitive estimate' and/or 'provide a felt estimate'; Moccia et al., 2021; Piryankova et al., 2014). Additionally, our results support the notion that emotional attitudes towards one's body size and shape in AN may not always be in line with neither the actual BMI of patients, nor their own cognitive estimates about their body size (e.g., Gaudio & Quattrochi, 2012; Guardia et al., 2012; Meyer et al., 2009; Schneider et al., 2009). This pattern also suggests that misestimations of the perceptual body image component (i.e., envisioned mode) are present during the acute state only, while misestimations of the emotional or attitudinal body image component (i.e., emotional mode) may be present pre-morbidly and endure beyond weight-restoration, pointing to trait rather than state differences. Further longitudinal studies could explore this indication further.

Our results also confirmed our hypotheses that individuals with AN would still overestimate both their envisioned and emotional body size, in comparison to HCs, even after receiving feedback about their body size. We found significant differences in the emotional body size estimates of the AN group vs HCs after receiving feedback, with the AN group "feeling" their body as larger than their body size in reality. Yet, this was not the case for the AN-WR group vs HCs. We also found that the AN, but not the AN-WR group, updated their beliefs to a smaller degree than the HCs following feedback in the emotional mode. In other terms, the rate at which prior beliefs changed following feedback significantly differed between groups, with the AN group showing a lower updating rate than the HCs. However, this was not the case for the emotional updating rate of the AN-WR vs HC groups, or for both our clinical groups vs HCs in the envisioned mode.

There are several alternative interpretations for this lack of updating, including general cognitive inflexibility, or more body-specific abnormalities in weighting of prior beliefs in relation to new information about the body (here, clinician-feedback-BMI; Kube & Rosenkrantz, 2021; Swann & Hill, 1982). In terms of Bayesian learning theory, such possibilities point to less precision about new information relative to the precision of one's prior beliefs (Friston, 2003; Mathys et al., 2011; Smith et al., 2020). We did not have the trials or measures needed to assess this hypothesis directly here, but future studies could manipulate and, or model precision about one's body image again with various types of new information. Although perceptions of body size have been shown to be affected by exposure to thinner or larger bodies (Glauert et al., 2009), or to general norms and ideals about the female body (Cazzato et al., 2016; Glauert et al., 2009), no study had explicitly investigated how different kinds of direct, external feedback regarding one's own body size could influence one's body size estimations.

Another interpretation of our results could be based on attitudes towards (social) feedback *per se*, rather than specific body image feedback. Even in a healthy sample, participants updated beliefs about themselves less following social feedback when the information was undesirable and updated their beliefs more when presented with desirable information (Korn et al., 2012). This finding is supported by work showing that inferences about future events are positively biased when anticipating a positive event, whilst the likelihood of negative events is significantly underestimated (Sharot, 2011). Applied to the current study, this might result in feedback regarding emotional body size that is of a different valence than AN patients' own feelings about their body size (i.e., feedback contradicting prior beliefs in valence, not just size) having less of an effect on their estimates than feedback that is more like their own, prior beliefs in valence or, 'desirability'. It is noteworthy that desirable vs. non-desirable feedback in AN is complex given the ego-syntonic nature of AN: if a patient with AN overestimates their body size at baseline, body size feedback will be that they are smaller than they perceive or feel their body to be in reality. The feedback itself may be positive based on societal ideals, but for some patients who lack insight into the severity of their condition and the consequences starvation may have on their appearance, the feedback may be regarded as negative. Although we did not manipulate the valence of feedback, i.e., feedback was the participants' BMI (*Envisioned* mode) or the clinician's estimation of the participant's BMI (*Emotional* mode), the valence of feedback not in line with participants' own beliefs about their body size may have been interpreted differently than feedback aligned with pre-feedback estimates and related body-size beliefs. Though we could not directly assess whether the feedback participants received was desirable, our findings in the balloon conditions – in which all groups performed similarly and estimated the balloon's size at similar levels – suggest that feedback about one's body may be processed differently than feedback about another object. This, however, warrants further investigation.

Interestingly, while only the AN group overestimated their post-feedback envisioned body size in comparison to HCs, the groups did not differ in their Envisioned updating rates. This could suggest that when given undesirable and disconfirming information about their actual BMI (i.e., information that is not aligned with their own beliefs) the AN group did not consider it to a significant extent – whereas HCs did not misestimate their body size significantly and as such did not need to adjust their estimates to a great extent following feedback. Collectively, these findings suggest that those with AN hold firmly onto their body size related beliefs, especially emotional body size beliefs, and are less likely to be influenced by external feedback about their body image than HCs (or AN-WR vs HC groups; Cash & Deagle, 1997; Cooper & Turner, 2000; Glashouwer et al., 2019). However, future studies need to assess in greater detail the factors that contribute to this finding, including how individuals with AN weigh new information in relation to their prior beliefs, as well as whether this lack of emotional belief updating about the body is specific to body image, and what could be the role of interoception in such estimates (see *Experiment 1*). Finally, future studies should examine whether social feedback by clinicians or experimenters is treated differently than other sources of more objectified feedback, e.g., computer-generated feedback.

A further alternative interpretation of our findings could be based on general higher-order, cognitive difficulties. A limitation in clinical studies, including ours, was that AN patients are often heavily medicated, and psychoactive medications may have an effect on cognition (Tapper et al., 2019). It should be noted that general, visuospatial, or belief updating difficulties were not observed in our control, 'neutral-object' condition where patients and controls had to estimate the size of a balloon in a similar 2D measuring scale as for their own body and update their estimates based on feedback. Furthermore, findings in the field of body image in AN point towards a bias limited specifically to one's own body, rather than a general impairment in body-size estimation of other bodies (Guardia et al., 2012). Using a balloon as a control measure, we could not examine the potentially interesting issue of self- vs other-body biases. Thus, in our follow-up study we will modify the design and ask participants to estimate the size of their own body avatar and that of another body. This modification will allow for the investigation of differences within 'Self' body representation and the use of the 'Other' body estimates, in line with previous literature (Guardia et al., 2012), to explore whether such biases are limited to one's own body, and not generalised across all bodies, or domains in general.

Experiment 2 represents a first attempt to study body size belief updating following personalised feedback, in two different components. However, there were several limitations. We could not quantitatively compare between the two types of updating rate given the different methods of giving feedback and the type of feedback in each mode. Hence, we cannot draw conclusions beyond qualitative comparisons between the updating of estimates in the envisioned and emotional components. Additionally, clinician feedback may not be reliable and may be biased based on the different perspectives about the patient's state

(Babinski, 1914; Conde-Sala et al., 2014). This is a phenomenon observed in other disorders (e.g., anosognosia; Babinski, 1914; and Alzheimer's; Conde-Sala et al., 2014) where we see a reduced accuracy in clinicians' estimates of patient ability (Jenkinson et al., 2011; Orfei et al., 2010). Even though this was not the case in our study – clinician feedback was close to participants' actual BMI (in all three groups) – it is not possible to exclude the effects clinician feedback may have on individual beliefs about body size in the prior experience of some of these patients. In turn, it was not possible to determine whether the lower rate of emotional (subjective) belief updating was due to reduced consideration of the (clinician's) feedback, or other belief updating deficits in one's emotional body image. Future studies should instead standardise the feedback across different conditions, to further disentangle how beliefs about different components of body image (e.g., here envisioned vs emotional) are updated when receiving the same evidence (e.g., feedback based on participant's actual BMI), both within-group and between-groups. Consistent feedback between modes would also encourage better exploration of belief updating within-group, i.e., a better understanding of how feedback influences envisioned and/or emotional beliefs in each group, as well as between-group differences post-feedback per mode.

Conclusion

To conclude, in this first exploratory study, we investigated simple instances of explicit belief updating in two domains in AN: cardiac awareness and body image. In *Experiment 1* we found that AN patients hold pessimistic interoceptive, metacognitive self-efficacy beliefs even after a relatively successful, heartbeat counting performance, and mainly rely on such pessimistic, prospective self-efficacy beliefs, even when rating performance retrospectively. In *Experiment 2* we found that AN patients misestimate their body size more than HCs, especially in the emotional (felt) stance and these misestimation rates are maintained following feedback (*Experiment 2*). *Envisioned* body updating rates did not differ between groups; however, the AN group updated *emotional* body size estimates at a lower rate than the HCs. Therefore, AN patients appear to also have 'pessimistic' feelings about their body size (they feel it to be larger than it is) that they struggle to update following clinician feedback. Although our findings suggest that these findings may be linked to the acute illness stage of AN and hence may be secondary to starvation and malnutrition rather than enduring traits, our results offer preliminary insights regarding belief updating difficulties in AN that warrant further study, particularly in the interoceptive and emotional domains and in relation to insight deficits that are also relevant only in the acute state of illness. Our findings also highlight the importance of studying belief updating processes across different domains in AN to better understand how deficits in one or more domains may have manifested during the anorectic state or have been traits that lead to the development of symptoms and/or endured post-weight restoration and subsequently influenced engagement in and outcomes of treatment interventions. Future studies should further disentangle the roles of belief updating across and within different domains of relevance to AN.

Authors Contributions

LC, BD, PMJ and AF conceived and designed the experiment. AS, LC, BD, DG and VN performed data collection. OG, BD and DG supported the clinical recruitment of individuals with and weight-restored from Anorexia Nervosa. AS analysed the data under the supervision of AK, PMJ and AF. AS, LC, AB, BD, PMJ and AF wrote the manuscript. All the authors approved the manuscript before submission.

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Disclosures

The authors declare no financial interests or potential conflicts of interest.

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Supplementary Material: Experiment 1

Table S1

Supplementary analyses to control for BMI and age between the three groups

	Control Analyses		
Effect: BMI ~ Group	**β(*SE*)**	***t***	***p***
Intercept (HCs)	21.17(*0.31*)		
AN	-5.37 (*0.47*)	*-11.455*	***<.001***
AN-WR	-1.29(*0.47*)	*-2.709*	***0.008***
Adj R^2: 0.58; df(78)			
Effect: Age ~ Group			
Intercept (HCs)	25.14(*0.88*)		
AN	1.37(*1.31*)	1.041	*0.299*
AN-WR	0.24(*1.34*)	0.179	*0.858*
Adj R^2: -0.02; df(79)			

Table S2

Descriptive statistics for Experiment 1, M(SD)

	Group		
	AN	**AN-WR**	**HC**
Prospective Performance Estimates	39.80(*24.62*)	49.32(*20.62*)	53.43(*17.85*)
IAcc (Total)	63.08(*17.30*)	65.27(*21.13*)	60.10(*24.00*)
IAcc_25s	63.55(*19.70*)	65.22(*22.70*)	61.87(*25.99*)
IAcc_45s	65.48(*21.09*)	66.23(*21.87*)	60.74(24.99)
IAcc_65s	59.91(*21.03*)	64.25(*21.86*)	57.67(24.98)
HRV (5min)	229(*42.98*)	237.94(*57.23*)	331.98(*91.20*)
Retrospective Performance Estimates	32.40(*24.12*)	49.68(*21.08*)	52.23(*22.93*)
Post-positive Feedback Retrospective	62.86(*24.62*)	67.50(*16.58*)	68.16(*15.56*)
Post-negative Feedback Retrospective	25.37(*25.66*)	34.00(*20.88*)	43.43(*23.46*)
EDEQ	19.41(*8.91*)	12.64(*10.20*)	5.94(*5.24*)

DASS-21	66.44(*25.40*)	44.61(*29.87*)	23.86(*18.33*)
TAS	61.53(*16.17*)	48.24(*16.08*)	39.66(*9.88*)
BAQ	72.08(*18.00*)	74.21(*17.86*)	81.50(*14.82*)
Illness Severity Error	2.89(*2.1*)	n/a	n/a
Health Consequences Error	1.24(*2.35*)	n/a	n/a
Future Hopes	6.07(*2.62*)	n/a	n/a
Future Fears	2.62(*8.04*)	n/a	n/a

Table S3

Heart-rate (HR) between groups and control analyses for Hypothesis 1 and Hypothesis 2 with age and HR as covariates

Effect: HR ~ Group	**β(*SE*)**	***t***	***p***
Intercept (HCs)	331.98(*10.27*)		
AN	-102.98(*15.50*)	*-6.642*	***<.001***
AN-WR	-94.04(*15.90*)	*-5.916*	***<.001***
Adj R^2: 0.32; df(112)			
Effect: Prospective Performance ~ Group + Age + HR			
Intercept (HCs)	58.23(*12.60*)		
AN	-16.89(*5.54*)	*-3.048*	***0.003***
AN-WR	-5.95(*5.49*)	*-1.085*	*0.280*
Age	0.15(*0.29*)	*0.501*	*0.618*
Baseline	-0.02(*0.03*)	*-0.825*	*0.411*
Adj R^2: 0.06; df(108)			
Effect: Performance ~ Group + Age + HR			
Intercept (HCs)	69.41*(*12.39)		
AN	-2.17(*5.45*)	*-0.398*	*0.692*
AN-WR	5.01(*5.42*)	*0.924*	*0.357*
Age	0.29(*0.29*)	*1.011*	*0.314*
Baseline	-0.05(*0.03*)	*-1.864*	*0.065*
Adj R^2: 0.04; df(110)			

Table S4

Control analyses for Hypothesis 2

	Control Analyses		
Effect: IAcc_25s ~ Group	**β(*SE*)**	***t***	***p***
Intercept (HCs)	55.42(*7.65*)		
AN	1.36(*4.69*)	*0.290*	*0.722*
AN-WR	3.38(*4.84*)	*0.698*	*0.486*
Age	0.256(*0.27*)	*0.938*	*0.350*
Adj R^2: -0.012; df(135)			

	Control Analyses		
Effect: IAcc_45 ~ Group	**β(*SE*)**	***t***	***p***
Intercept (HCs)	55.62(*7.62*)		
AN	4.48(*4.66*)	*0.962*	*0.338*
AN-WR	5.54(*4.83*)	*1.146*	*0.254*
Age	0.203(*0.27*)	*0.748*	*0.456*
Adj R^2: -0.006; df(134)			

	Control Analyses		
Effect: IAcc_65s ~ Group	**β(*SE*)**	***t***	***p***
Intercept (HCs)	49.01(*7.54*)		
AN	1.83(*4.61*)	*0.398*	*0.692*
AN-WR	6.61(*4.77*)	*1.385*	*0.168*
Age	0.34(*0.27*)	*1.277*	*0.204*
Adj R^2: 0.004; df(136)			

Table S5

Analyses on prospective performance estimates and actual performance with respect to illness (AN group only). For illness severity and health consequences we computed an error score by subtracting patients' scores from the clinician's respective score. Error scores could range from -10 to +10, with a score of -10 indicating negative bias (i.e., patients see their condition and the effects as more severe than the clinician), a score of 0 indicating no bias between patient and clinician perspective, and a score of +10 indicating positive bias (i.e., patients see their condition *and the effects as less severe than the clinician). In the* *future perspectives we only used the patient scores. For the 'Health Consequences' dimension we obtained the average of the two scores.*

Insight Analyses

Effect: Prospective Performance ~ Severity Error	**β(*SE*)**	***t***	***p***
Intercept (AN)	52.52 (*7.99*)		
Severity Error	-3.37(*2.25*)	*0.398*	*0.692*
Adj R^2: 0.046; df(25)	0.07(*4.63*)	*1.385*	*0.168*
Effect: IAcc ~ Severity Error			
Intercept (AN)	63.17(*6.21*)		
Severity Error	0.60(*1.75*)	*0.345*	*0.733*
Adj R^2: -0.035; df(25)			
Effect: Prospective Performance ~ Health Effects Error			
Intercept (AN)	42.46(*5.51*)		
Health Effects Error	0.258(*2.11*)	*0.123*	*0.903*
Adj R^2: -0.039 df(25)			
Effect: IAcc ~ Health Effects Error			
Intercept (AN)	68.41(*3.83*)		
Health Effects Error	-2.81(*1.46*)	*-1.922*	*0.066*
Adj R^2: 0.093; df(25)			
Effect: Prospective Performance ~ Future Hopes			
Intercept (AN)	47.92(*12.41*)		
Future Hopes	-0.85(*1.88*)	*1.88*	*0.657*
Adj R^2: -0.031; df(25)			
Effect: IAcc ~ Future Hopes			
Intercept (AN)	57.25(*9.13*)		
Future Hopes	1.26(*1.39*)	*0.911*	*0.371*
Adj R^2: -0.007; df(25)			
Effect: Prospective Performance ~ Future Fears			
Intercept (AN)	57.57(*16.89*)		
Future Fears	-1.84(*2.02*)	*-0.912*	*0.370*

Adj R^2: -0.006; df(25)			
Effect: IAcc ~ Future Fears			
Intercept (AN)	81.99(*12.29*)		
Future Fears	-2.12(*1.47*)	*-1.447*	*0.16*
Adj R^2: 0.04; df(25)			

Table S6

Analyses on prospective performance and actual performance with illness duration and illness severity as predictors (AN and AN-WR groups, separately)

	Control Analyses		
Effect: Prospective Performance ~ Illness Duration (AN only)	**β(*SE*)**	***t***	***p***
Intercept (AN)	36.58(*4.60*)		
Illness Duration	0.23(*0.37*)	*0.629*	*0.532*
Adj R^2: -0.01; df(47)			
Effect: IAcc ~ Illness Duration (AN only)			
Intercept (AN)	61.77(*3.51*)		
Illness Duration	0.12(*0.28*)	*0.448*	*0.656*
Adj R^2: -0.02; df(47)			
Effect: Prospective Performance ~ Illness Severity (AN only)			
Intercept (AN)	26.56(*7.75*)		
Illness Severity	0.25(*0.13*)	*1.945*	*0.058*
Adj R^2: 0.06; df(46)			
Effect: IAcc ~ Illness Severity (AN only)			
Intercept (AN)	62.94(*5.92*)		
Illness Severity	0.01(*0.10*)	*0.141*	*0.888*
Adj R^2: -0.02; df(46)			
Effect: Prospective Performance ~ Illness Duration (AN-WR only)			
Intercept (AN-WR)	41.64(*5.24*)		
Illness Duration	1.38(*0.88*)	*1.565*	*0.126*
Adj R^2: 0.04; df(37)			
Effect: IAcc ~ Illness Duration (AN-WR only)			

Intercept (AN-WR)	65.57(*5.24*)		
Illness Duration	0.31(*0.88*)	*0.356*	*0.724*
Adj R^2: -0.02; df(36)			
Effect: Prospective Performance ~ Illness Severity (AN-WR only)			
Intercept (AN-WR)	44.89(*7.81*)		
Illness Severity	0.05(*0.11*)	*0.458*	*0.65*
Adj R^2: -0.02; df(36)			
Effect: IAcc ~ Illness Severity (AN-WR only)			
Intercept (AN-WR)	70.27(*8.08*)		
Illness Severity	-0.03(*0.11*)	*-0.303*	*0.763*
Adj R^2: -0.03; df(35)			

Table S7

Main analyses with questionnaire traits as predictors, between groups

	Control Analyses		
Effect: Prospective Performance ~ EDE-Q * Group	**β(*SE*)**	***t***	***p***
Intercept (HC)	55.05(*7.03*)		
AN	-11.72(*11.89*)	*-0.986*	*0.328*
AN-WR	0.49(*10.21*)	*0.048*	*0.962*
EDE-Q	1.46(*1.12*)	*1.310*	*0.195*
AN x EDE-Q	-1.49(*1.20*)	*-1.238*	*0.221*
AN-WR x EDE-Q	-1.20(*1.21*)	*-1.65*	*0.105*
Adj R^2: 0.12; df(62)			
Effect: IAcc ~ EDE-Q * Group			
Intercept (HC)	49.23(*7.68*)		
AN	12.49(*13.01*)	*0.960*	*0.341*
AN-WR	19.65(*11.17*)	*1.759*	*0.084*
EDE-Q	1.12(*1.22*)	*0.915*	*0.364*
AN x EDE-Q	-0.95(*1.32*)	*-0.723*	*0.472*
AN-WR x EDE-Q	-1.62(*1.33*)	*-0.875*	*0.385*
Adj R^2: 0.003; df(62)			

Effect: Prospective Performance ~ DASS-21 * Group			
Intercept (HC)	60.45(*7.75*)		
AN	-16.15(*13.85*)	*-1.166*	*0.248*
AN-WR	-9.87(*11.74*)	*-0.841*	*0.404*
DASS	0.08(*0.30*)	*0.270*	*0.788*
AN x **DASS-21**	-0.10(*0.34*)	*-0.305*	*0.761*
AN-WR x **DASS-21**	-0.11(*0.34*)	*-0.338*	*0.736*
Adj R^2: 0.07; df(62)			
Effect: IAcc ~ DASS * Group			
Intercept (HC)	59.49(*8.23*)		
AN	19.16(*14.70*)	*1.303*	*0.197*
AN-WR	8.68(*12.45*)	*0.697*	*0.489*
DASS-21	-0.23(*0.32*)	*-0.728*	*0.469*
AN x **DASS-21**	0.024(*0.36*)	*0.067*	*0.947*
AN-WR x **DASS-21**	0.23(*0.36*)	*0.654*	*0.515*
Adj R^2: 0.02; df(62)			
Effect: Prospective Performance ~ BAQ * Group			
Intercept (HC)	17.92(*24.24*)		
AN	3.56(*30.55*)	*0.117*	*0.908*
AN-WR	42.26(*31.51*)	*1.341*	*0.185*
BAQ	0.34(*0.29*)	*1.177*	*0.244*
AN x BAQ	-0.14(*0.39*)	*-0.359*	*0.721*
AN-WR x BAQ	-0.51(*0.39*)	*-1.283*	*0.204*
Adj R^2: 0.02; df(63)			
Effect: IAcc ~ BAQ * Group			
Intercept (HC)	56.52(*22.63*)		
AN	2.07(*28.74*)	*0.072*	*0.943*
AN-WR	3.42(*29.98*)	*0.114*	*0.910*
BAQ	0.11(*0.27*)	*0.412*	*0.682*
AN x BAQ	-0.07(*0.37*)	*-0.179*	*0.858*
AN-WR x BAQ	-0.05(*0.37*)	*-0.144*	*0.886*
Adj R^2: -0.07; df(63)			

Effect: Prospective Performance ~ TAS * Group			
Intercept (HC)	73.73(*14.71*)		
AN	-9.86(*18.74*)	*-0.526*	*0.600*
AN-WR	-11.74(*17.74*)	*-0.662*	*0.509*
TAS	-0.53(*0.38*)	*-1.407*	*0.162*
AN x TAS	0.14(*0.42*)	*0.328*	*0.743*
AN-WR x TAS	0.25(*0.42*)	*0.588*	*0.558*
Adj R^2: 0.09; df(132)			
Effect: IAcc ~ TAS * Group			
Intercept (HC	81.23(*14.38*)		
AN	-8.01(*18.46*)	*-0.434*	*0.665*
AN-WR	-3.51(*17.48*)	*-0.201*	*0.841*
TAS	-0.55(*0.37*)	*-1.503*	*0.135*
AN x TAS	0.38(*0.41*)	*0.939*	*0.349*
AN-WR x TAS	0.30(*0.41*)	*0.733*	*0.465*
Adj R^2: 0.01; df(132)			

Supplementary Material: Experiment 2

The Error Rate for body estimates was calculated using the following formula:

$$PreFeedbackErrorRate = \frac{(Pre\,feedback\,body\,¿ - BMI)}{BMI} \quad (10)$$

The balloon error rate was calculated using the following formula:

$$PreFeedbackBalloonErrorRate = ¿¿ \quad (11)$$

The Post-feedback error rates for both *Hypotheses 2* and *3* were calculated using the following formula:

$$PostFeedbackErrorRate = \frac{(Post\,feedback\,body\,¿ - BMI)}{BMI} \quad (12)$$

Table S8

Supplementary analyses to control for BMI and age between the three groups

	Main Analyses		
Effect: BMI between Groups	**β(*SE*)**	***t***	***p***
Intercept (HCs)	20.78(*0.33*)		
AN	-4.96 (*0.48*)	*-10.191*	***<.001***
AN-WR	-0.06(*0.52*)	*-1.842*	*0.069*
Adj R^2: 0.58; df(78)			
Effect: Age between Groups			
Intercept (HCs)	25.88(*1.16*)		
AN	-0.85(*1.75*)	-0.483	*0.63*
AN-WR	0.17(*1.88*)	0.088	*0.93*
Adj R^2: -0.02; df(79)			

Table S9

Descriptive Statistics for Experiment 2, M(*SD*)

	Group		
	AN	**AN-WR**	**HC**
Pre-Feedback Envisioned Estimate	17.94 (*4.23*)	20.09 (*3.55*)	19.63 (*3.62*)
Pre-Feedback Envisioned Error Rate	0.13(*0.20*)	0.01(*0.15*)	-06(*0.13*)
Feedback Mode: BMI	15.82 (*1.64*)	19.82 (*1.74*)	20.78 (*2.12*)
Post-Feedback Envisioned Estimate	16.93 (*2.41*)	20.27 (*2.31*)	21.11 (*3.03*)
Post-Feedback Envisioned Error Rate	0.07(*0.09*)	0.02(*0.08*)	0.007(*0.08*)
Percentage of Envisioned (Body) Belief Updating	-2.74 (*15.56*)	2.58 (*12.39*)	9.20 (*14.55*)
Pre-Feedback Emotional Estimate	22.50 (*5.61*)	22.18 (*4.27*)	20.73 (*3.15*)
Pre-Feedback Emotional Error Rate	0.42(*0.33*)	0.13(*0.23*)	-0.005(*0.12*)
Feedback Mode: Clinician-feedback-BMI	14.91 (*1.59*)	18.43 (*1.57*)	19.71 (*2.16*)
Post-Feedback Emotional Estimate	22.47 (*5.66*)	20.97 (*3.65*)	20.69 (*3.55*)
Post-Feedback Emotional Error Rate	0.42(*0.34*)	0.06(*0.16*)	-0.1(*0.12*)
Percentage of Emotional (Body) Belief Updating	0.50 (*10.07*)	-3.92 (*12.53*)	0.00 (*0.08*)
Pre-Feedback Balloon Error Rate	-0.2(*0.51*)	-0.16(*0.51*)	-0.01(*0.59*)