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**Bodily Self Recognition and Autonomic Correlates during Social Interaction:
Implications For Restrictive Anorexia**

Coordinatore:

Chiar.mo Prof. Vittorio Gallese

Tutor:

Chiar.mo Prof. Vittorio Gallese

Tesi di dottorato della Dott.ssa Marianna Ambrosecchia

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Chapter 1: General Introduction

1.1 The Bodily Self

Self is a complex, manifold and multileveled concept, since ever one of the most salient issues throughout the history of philosophy and more recently in psychology and cognitive neuroscience.

In the 19th century, William James categorized different senses of the self (James, 1892): physical self, mental self, spiritual self, and the ego. James considered the self, rather than a permanent or “unchanging metaphysical entity” generating experience, as a process that entails the existence of a multiplicity of selves. He focused on the crucial distinction between an ‘I’, subject of experience, the self who is knower, and a ‘Me’, object of experience, the self who is known, or the “empirical aggregate of things objectively known”. Thanks to its nature, the core sense of ‘me’ corresponded to a current sense of existing as a body.

In a recent review, Gallagher, (2000) examined two important notions of self: the ‘minimal self’, and the 'narrative self'. The minimal self refers to a pre-reflective level of selfhood, devoid of temporal extension, it phenomenologically corresponds to the awareness of the self as an immediate, direct subject of present experience caught in a first-person perspective (FPP).

The reflective narrative self, is extended in time, creates a subjective feeling of individual identity and continuity throughout time and works by taking a third-person perspective (TPP). This narrative self, based on episodic memory, is thought to be impaired when the subjective linking with the past is disrupted, such as in the case of amnesia. Gallagher suggested that from a psychological point of view this self is the total sum of its narratives (narratives about the self and about others), and includes within itself all of the equivocations, contradictions, struggles and hidden messages that find expression in personal life.

The minimal self, according to Gallagher, is constituted by two different but interrelated

aspects: the self-ownership, corresponding to the pre-reflective experience that it is my body that is moving (selectively impaired in asomatognosia), and the self-agency, the pre-reflective experience that I am the generator or source of action. Sense of agency and sense of ownership coincide in the normal voluntary action, but not in the involuntary action. Indeed, when is present the awareness of movement (and so body-ownership) coming from afferent sensory-feedback (visual and proprioceptive/kinaesthetic information), there are no initial motor commands (efferences) issued to generate the movement, from which the sense of agency seems to depend.

The sense of ownership, however does not simply rely on afferent signals, as various studies on the Rubber Hand Illusion (RHI) attest. The RHI is an experimental paradigm, which consists in watching a rubber hand being stroked together with one's own unseen hand. If synchronic multisensory stimulation is perceived, the position sense of the real hand shifts towards the location of the dummy hand, which is felt to be part of one's own body. In addition to visual and tactile precepts, the sense of body-ownership, during RHI, seems to require the viewed object to fit in a pre-existing, visual and functional (e.g., proprioceptive, postural) representation of one's body. Indeed, according to Tsakiris, Schuetz-Bosbach, & Gallagher, (2007) body-ownership seems to arise from the interaction between bottom-up processes driven by afferent signals and also top-down processes driven by abstract cognitive body-representations.

Summarizing, the self, far from being considered as a unitary concept, is constituted by multiple layers ranging from a pre-reflective embodied experience to a completely narrative and reflective form.

The most basic concept of self, representing an essential element of the experience of a normal self, is the bodily self. It could originate from a low level, pre-reflective and immediate concept of self, and corresponds to the feeling of inhabiting within the boundaries of one's body

(Gallese & Sinigaglia, 2010).

All the notions adopted by contemporary research to answer the question of how we distinguish ourselves as bodily selves from other human bodies, refer to a crucial role of the motor system. Merleau-Ponty (1962), was the first to formally express this idea, when referring to the spatiality of the body he asserted: “[...] my body appears to me as an attitude directed towards a certain existing or possible task, and indeed its spatiality is not, like that of external objects [...], a spatiality of position, but a spatiality of situation”.

Recently, Gallese suggested that the body is primarily given to us as *source* or *power* for action, that is, as the variety of motor potentialities that define the horizon of how we can interact with the world we live in (Gallese, 2005; Gallese & Sinigaglia, 2010). Such primitive sense of self as bodily self is considered antecedent the distinction between sense of agency and sense of ownership.

One might argue that there are many bodily experiences (e.g. headache, hunger, satiety, etc.) leading to a sense of mineness but not related to action. However, such sense of mineness, which essentially consists of attributing feelings and sensations to one’s body, assumes that one, firstly, recognizes oneself as a bodily self as power for action (Gallese & Ferri, 2013).

The existence of such motor experience-based representation of the bodily self presupposes the ability to perceive and identify human bodies and in particular one's own body. In fact, specialized cognitive and neural mechanisms dedicated to body perception and recognition have been demonstrated in humans by studies using different methods (Functional Magnetic Resonance Imaging, Evoked Potentials, Transcranial Magnetic Stimulation; Astafiev, Stanley, Shulman, & Corbetta, 2004; De Vignemont, 2010; Gallagher, 2000; Hodzic, Muckli, Singer, & Stirn, 2009; Myers & Crowther, 2008; Sugiura et al., 2006).

Regarding body perception, Urgesi, Candidi, Ionta, & Aglioti, (2006) proposed that the human brain contains two dissociable and independent brain networks specialized for processing human bodies. One processes the whole body in a configural manner and involves dorsal system areas, such as ventral premotor cortex (vPMc). This suggests that configural processing of bodies may imply the embodiment of observed postures onto the observer's sensorimotor representations. The second network is specialized for local processing of body part details, such as body parts and body form, and entails Extra-striate Body Area (EBA), which is part of the ventral system.

Body recognition implies a critical distinction between one's own body and the body of others (Devue et al., 2007; Sugiura et al., 2006). Several studies (behavioral, fMRI and TMS studies) have shown not only that the recognition of self-body is independent from the recognition of others' one, but also that these processes could be implicit or explicit. While explicit recognition is likely to be based on cognitive and perceptual mechanisms, implicit recognition recruits sensorimotor information and relies upon motor simulation (Ferri, Frassinetti, Costantini, & Gallese, 2011; Urgesi et al., 2006). Self-related body stimuli are processed faster and more accurately compared to other-related body stimuli ('self-advantage', see Ferri, Frassinetti, Ardizzi, Costantini, & Gallese, 2012; Ferri et al., 2011; Frassinetti et al., 2009; Frassinetti, Maini, Romualdi, Galante, & Avanzi, 2008). This advantage for self-related body processing appeared in a visual task in which an explicit self-body recognition was not required. Participants were submitted to a matching task in which three pictures, representing a body part (hand, foot, arm and leg), were presented vertically aligned at the center of the computer screen. They were asked which of the two stimuli, the upper or the lower one, matched with the central target. Participants' performance was more accurate when one of the stimuli belonged to them compared to when they belonged to someone else.

Ferri et al. (2011), conducted a further behavioral study aimed at better investigating the mechanisms underlying the self-advantage effect, supposing the recruitment of a motor simulation to be the crucial element for this effect to emerge. The study showed that participants, when submitted to a hand laterality judgment task (Implicit task), which required mental rotation, showed better performances when the stimuli consisted of their own dominant hand rather than others' hands (Self- advantage). By contrast, the Self-advantage was absent when self-recognition (Explicit task) was explicitly required.

A subsequent fMRI study, adopting the same paradigm, demonstrated that this implicit and pre-reflective sense of being a bodily self is embedded within the sensory-motor system, and revealed a neural network for a general representation of the bodily self, encompassing motor centers like vPMc, the SMA and pre-SMA, plus the anterior insula, and the occipital cortex bilaterally. This result showed that the actual mental rotation process was more efficient for both one's own hands as compared with others' hands, regardless of the laterality of the stimuli. Moreover, the mental rotation of one's own dominant hand turned out to be primarily confined to the left premotor cortex (Ferri et al., 2012). These data highlighted the pivotal role of the premotor cortex in the behavioral self-advantage for right hand but also allowed to identify another distinct pattern of self-processing neural activity, involved in a more general self/other distinction.

Finally, the possible role of anterior insular cortices in self/other distinction is in line with previous studies suggesting that this area may be a convergence zone where interoceptive and exteroceptive self-related information is integrated (Craig, 2010). Anterior insula, indeed, is engaged when individuals attend to or attempt to control a number of internal bodily states, including pain, temperature, heart rate, and arousal (Cattarin, Thompson, Thomas, & Williams, 2000; Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Peyron, Laurent, & Garcia-Larrea,

2000), playing a crucial role in the perception of one's internal bodily state. Such perception has been defined Interoceptive Sensitivity (IS; see the section below).

1.2 Interoceptive sensitivity

Interoceptive Sensitivity (IS) represents the sensitivity to stimuli originating inside the body. It is another important nuclear component of self-awareness since it has profoundly influenced our understanding of our “self”. Even though, conventionally, IS has been referred to the sensitivity to signals of the visceral organs (Cameron, 2001; Sherrington, 1947), today there is evidence that it epitomizes sensations of all tissues of the body (Arthur D. Craig, 2002) and it is closely associated with motivated action to homeostatically regulate the internal state (A. D. Craig, 2008).

Interoception is distinguishable from exteroception (i.e. the perception of the external environment) and proprioception (reflecting the position of the body in space, see Sherrington, 1948). Recently, Garfinkel & Critchley,(2013; 2015) proposed a distinction between IS and interoceptive awareness, given that in the literature these terms have been typically treated as synonymous. According to this distinction, the term IS that we used here, could be considered in the same way as interoceptive accuracy (i.e. the objective and empirical process of accurately detecting and tracking internal bodily sensations). Interoceptive accuracy, in turns, is not the same of Interoceptive sensibility, conceptualized as the subjective self-evaluated characterological trait (from questionnaire measures) to be interoceptively focused (Garfinkel & Critchley, 2013; Garfinkel et al., 2015). Lastly, these authors, retained the use of the term interoceptive awareness to refer to the metacognitive correspondence between objective interoceptive accuracy and subjective report (e.g. a high level of interoceptive awareness reflects the ability of an individual to know when he/she is making good or bad interoceptive decisions, on the level of interoceptive behavioral accuracy) (Garfinkel & Critchley, 2013; Garfinkel et al., 2015).

Empirical research on interoception has predominantly focused on a particular type of IS,

that is, heartbeat perception. One reason is that there are only few bodily signals from the bodily “interior” that can be readily perceived (e.g. the heartbeat or signals from the guts), whereas the rest of internal activity is mostly “hidden”(Herbert & Pollatos, 2012).

The most used method to assess IS is a validated and reliable heartbeat perception tasks (Jones, 1994; Wildman & Jones, 1982) following the “mental tracking method’ (Schandry, 1981). In this task, participants are instructed to perceive their own heartbeats without taking their pulse. Individual heartbeat perception scores resulted from the deviation of the subjectively felt cardiac signal from the objective, “true” cardiac signal, (i.e. individual heartbeats, see Herbert & Pollatos, 2012). Another bodily system that can be manipulated and measured using standardized methods, and that shows spontaneous activity which can be perceived comparably to cardiac activity under controlled conditions, is the gastrointestinal system. Only two studies that investigated awareness of gastrointestinal sensations in healthy individuals under experimentally controlled conditions, using either invasive (Whitehead & Drescher, 1980) or non-invasive methods (Herbert, Muth, Pollatos, & Herbert, 2012), demonstrated that IS assessed with cardiac sensitivity is related to greater sensitivity for gastric functions, suggesting that there is a general sensitivity for interoceptive processes across the gastric and cardiac modality (Herbert, Muth, et al., 2012).

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The individual degree of IS, as measured with the heartbeat detection, can be

conceptualized as a trait-like characteristic. However, it could be also manipulated by procedures evoking changes in autonomic cardiovascular activity (Schandry, Bestler, & Montoya, 1993) or by training focusing on the cardiac signals (Schandry & Weitkunat, 1990). IS seems to improve, indeed, with meditation (Khalsa et al., 2008).

At the neural level, it was suggested that the somatosensory and somatomotor cortices, insular cortex, cingulate cortex (ACC) and prefrontal cortices may represent the putative “interoceptive neural network” (Herbert & Pollatos, 2012) in which, interoceptive perception of signals coming from different bodily systems converges into general IS, thus contributing to the basic sense of self (Devue & Brédart, 2011a).

Among the cortical structures being part of this network, the insula seems to be a relevant projection site of viscerosensory input from different modalities from the body (i.e. dyspnea, the Valsalva manoeuver, “air hunger”, sensual touch, itch, heartbeat, and distension of the bladder, stomach, or esophagus, see Craig, 2009). This relevant role for the insula (especially the anterior insula; AI) was further corroborated by experimental evidence. These findings, besides confirming the relevance of the interoceptive neural network, showed that good heartbeat perceivers, when compared to poor ones, demonstrate greater insular activation, especially in the right AI (Critchley et al., 2004; Pollatos, Gramann, & Schandry, 2007).

Since AI is also relevant for emotion processing and reactivity (Phan, Wager, Taylor, & Liberzon, 2002), the feeling of self-generated and externally-induced emotions (Anders et al., 2004), the self-regulation of feelings and behavior (Beauregard, Levesque, & Bourgouin, 2001; Bechara, 2004), the bodily self-awareness (Craig, 2009; Craig, 2002; Tsakiris, Schuetz-Bosbach, et al., 2007) and the self/other distinction (Farrer & Frith, 2002) it is not coincidence that heartbeat IS has been shown to significantly interact with different aspects of human cognition and behavior

(Herbert & Pollatos, 2012).

For instance, higher IS is associated to greater emotional experience (Herbert, Pollatos, & Schandry, 2007; Zaki, Davis, & Ochsner, 2012), it is negatively correlated with alexitimia (Herbert, Pollatos, Flor, Enck, & Schandry, 2010) and positively related with a better regulation of emotions (Füstös, Gramann, Herbert, & Pollatos, 2012; Herbert & Pollatos, 2012). Once again, IS is involved in physiological reactivity towards emotional cues (Dunn et al., 2010), and, more generally, seems to contribute to the regulation of social behavior.

Concerning social behavior, a positive relation between individuals' interoceptive accuracy and their social anxiety level was found (Domschke, Stevens, Pfliegerer, & Gerlach, 2010; Terasawa, Fukushima, & Umeda, 2013). Moreover IS has been shown to be greatly related to emotional responding and cardiovascular autonomic reactivity in different situations evoking autonomic changes (Herbert & Pollatos, 2012; Herbert et al., 2010, 2007) such as social interactions (Ferri, Ardizzi, Ambrosecchia, & Gallese, 2013). It was proposed that cardiac awareness can also be the result of a "visceral" learning process. A recent study from Ferri et al., (2013) showed that IS might contribute to interindividual differences concerning social attitudes and interpersonal space representation via recruitment of different adaptive autonomic response strategies. Specifically, these authors found that only good heartbeat perceivers showed higher autonomic response in the social compared to the non-social setting, while poor heartbeat perceivers were less predisposed to social engagement (Ferri et al., 2013).

Taken together these findings highlight the role of IS in the "visceral" embodiment of emotional and cognitive processes.

We can conclude that the study of IS offers the empirical framework to investigate the embodiment of affective and cognitive processes and self-awareness, and its possible role in

mental and somatic self-related disorders.

1.3. Autonomic correlates of social interactions

1.3.1 The Autonomic Nervous System

In the last decade, cardiac vagal tone has emerged as a psychophysiological marker of many aspects of behavioral functioning like emotion regulation and social functioning in both children and adults (Beauchaine, Neuhaus, Zalewski, Crowell, & Potapova, 2011).

The vagus nerve is the most important anatomic structure by which the parasympathetic nervous system exerts its influence, hence the term vagal is used as synonymous with parasympathetic.

The parasympathetic, together with the sympathetic nervous system is part of the autonomic nervous system (ANS), which is implicated in the regulation of the circulation and the body's internal environment (Despopoulos & Silbernagl, 1991). ANS has thus a clear homeostatic function, and it plays a pivotal role for the well-being of the organism (Stern, 2000). ANS controls activities that are not under voluntary control, thus functioning below the level of consciousness, as for example, the regulation of respiration, digestion, body temperature, and metabolism. The heart and the circulation are central target organs or functions.

The anatomic centers of the sympathetic division are in the thoracic and lumbar levels of the spinal cord, and those of the parasympathetic division are in the brain stem and in the sacral part of the spinal cord (Despopoulos & Silbernagl, 1991) (Figure 1).

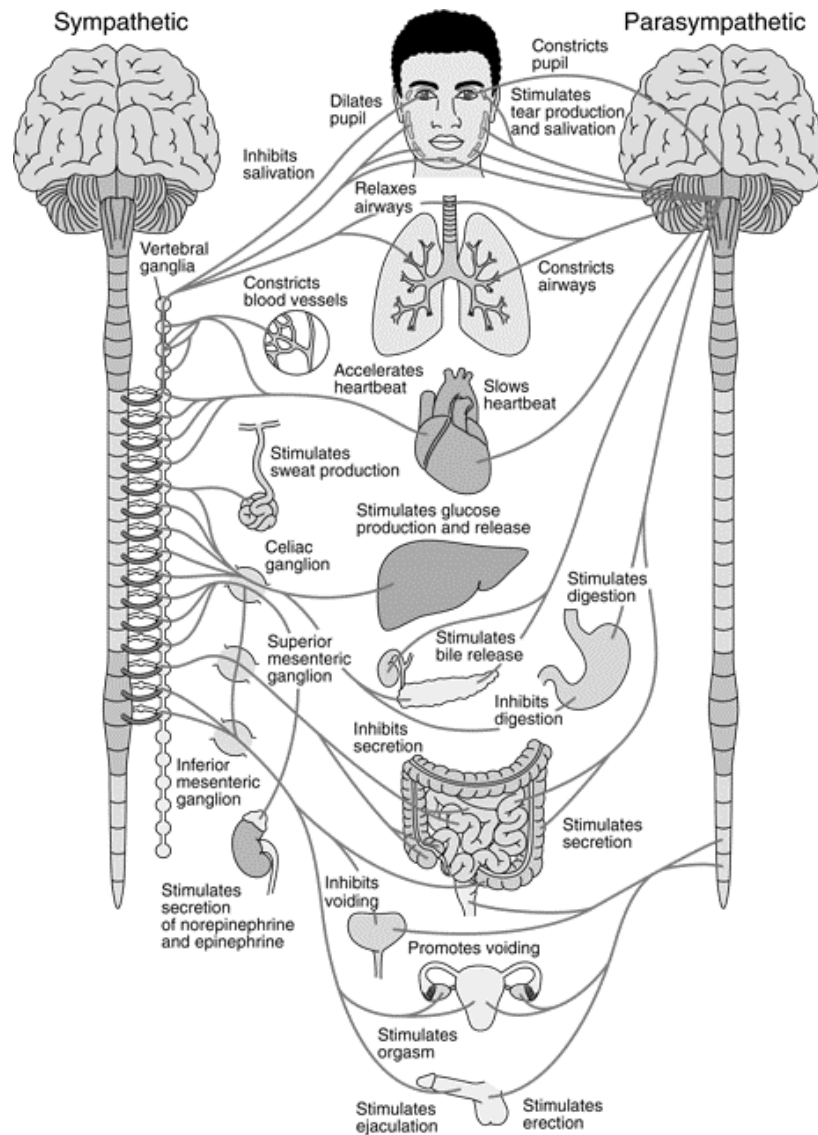


Figure 1: The sympathetic and parasympathetic branches of the autonomic nervous system. Modified from www.merckmanuals.com

The sympathetic nervous system helps mediate vigilance, arousal, activation, and mobilization, preparing bodily resources to cope with increased metabolic needs during challenging situations (Sapolsky, 1998), like during emergencies or threats, in which activity of the sympathetic nervous system comes to a maximum. The sympathetic division is thus closely linked to the fight-or-flight response, also called the acute stress response, which increases respiration, heart rate (HR), and blood pressure (BP).

The parasympathetic nervous system is involved in the conservation of energy and maintenance of organ function during periods of minimal activity (Stern, 2000) as well as in restoration of health following threats or challenges (Porges, Doussard-Roosevelt, Portales, & Greenspan, 1996).

The parasympathetic system is organized mainly for discrete and localized discharge and is rapid and reflexive in nature (Stern, 2000). For example, during stressful situations, the parasympathetic system generally retracts itself quickly to facilitate adaptation to environmental demands (Porges, 1995). This does, however, not exclude a constant flow of parasympathetic activity, which is illustrated by the fact that intrinsic HR would be well over 100 beats per minute without parasympathetic influences, instead of the average of 70 beats per minute normally observed. Thus, the parasympathetic system slows the HR and lowers the blood pressure (BP).

1.3.2. The Polyvagal theory

According to a phylogenetic perspective provided by Porges (1995), the evolution of the ANS provides an organizing principle to interpret the adaptive significance of physiological responses in promoting social behaviors (Porges, 1995, 2001). Following the polyvagal theory, the well-documented phylogenetic shift in neural regulation of the autonomic nervous system passes through three global evolutionary stages associated with different behavioral strategies:

- 1) The first stage is characterized by a primitive unmyelinated visceral vagus that fosters digestion and responds to threat by depressing metabolic activity. It is associated with immobilization behaviors.

- 2) The second stage is characterized by the sympathetic nervous system that is capable of increasing metabolic output and inhibiting the visceral vagus to foster mobilization behaviors necessary for ‘fight or flight’.
- 3) The third stage, is a mammalian characteristics, and is represented by a myelinated vagus that can rapidly regulate cardiac output to foster engagement and disengagement with the environment. The mammalian vagus is neuroanatomically linked to the cranial nerves that regulate social engagement via facial expression and vocalization.

The Polyvagal Theory (Porges, 1995, 1997, 2001; Porges, 1998) emphasizes the integration via evolution of the facial muscles (i.e., facial expression, looking, listening) and the neural regulation of visceral organs (i.e., heart) to regulate behavioral states.

1.3.3. Respiratory Sinus Arrhythmia

Since the myelinated vagus provides efferent control on the heart, Respiratory Sinus Arrhythmia (RSA), as a measure the fluctuations (variance measured as R-R interval expressed in ms) in heart rate (HR) during spontaneous breathing (0.12–0.40 Hz; (Porges, 1995), represents a valid index of the amount of such a control. It is considered an indirect but consistent measure of humans’ ability to adapt their autonomic responses to the environmental social stimuli and to establish a physiological state suitable for social relations (i.e., “self-regulation” and “social disposition” skills, Porges, 2003). From this perspective, the RSA recording RSA , rather than other cardiac parameters like Heart Rate Variability (for a detailed guidelines to the extraction of Heart rate variability and RSA (see Berntson, 1997), Toichi index (Toichi, Sugiura, Murai, & Sengoku, 1997) or Cardiac Coherence (Tiller, McCraty, & Atkinson, 1996) allows the

measurement of specific aspects of the autonomic regulation primarily involved in social behaviors.

A higher level of RSA reflects a higher myelinated vagal control of the heart. A higher vagal control, in turn, suggests a relaxed autonomic state, promoting social communication. In contrast, lower RSA indicates reduced myelinated vagal control that may potentiate defensive behaviors (e.g., fight/flight) and interfere with the ability to regulate behavioral state to spontaneously socially engaged. Coherently, individuals with low RSA and/or poor RSA regulation exhibit difficulties in regulating emotional state, in appropriately attending to social cues and gestures, in expressing contingent and appropriate emotions (Porges & Smilen, 1994), and in the recruitment of appropriate autonomic strategies during social interactions, in function of social distances (Ferri et al., 2013). In addition, it has been demonstrated that RSA can be also considered a marker for positive social functioning in healthy children (Graziano, Habashi, Sheese, & Tobin, 2007) and children with autism (Bal et al., 2010; Patriquin, Scarpa, Friedman, & Porges, 2013). Higher RSA amplitudes at rest (i.e. baseline RSA) were associated with better social behaviors (i.e., more conventional gestures, more instances of joint attention) and receptive language abilities.

Beside its relation with positive social functioning and emotional regulation, further evidence suggests that RSA is also associated with attentive and cognitive behaviors. Specifically, the ability to reduce RSA amplitude in response to attentive demands is positively associated with cognitive function, including better processing speed, working memory, learning, and receptive language skills (Beauchaine et al., 2011; Morgan, Aikins, Steffian, Coric, & Southwick, 2007; Watson, Baranek, Roberts, David, & Perryman, 2010). Higher RSA amplitude in infants leads to more optimal performance on tasks requiring sustained attention (Richards, 1985), and individuals who display both high tonic RSA and greater RSA suppression to attention demanding stimuli are

thought to engage and attend more efficiently with stimuli, therefore producing higher cognitive performance and ability(Thayer & Lane, 2000).

Taken together these findings highlight the role of RSA in providing an accurate index of the impact of the myelinated vagus on the heart. Thanks to this link, we could also investigate several of the behavioral, psychological, and physiological features associated with compromised social behaviors in several psychiatric disorders. As predicted by the social engagement system model (Porges, 1995, 1997, 1998; 2001), indeed, a deficit in this autonomic system might produce various deficits affecting social behavior, communication, lead to poor eye contact, inappropriate facial expressivity and atypical visceral functioning. This is apparently true in autism (Bal et al., 2010; Patriquin et al., 2013; Porges et al., 2013), as well as in several other psychiatric disorders, among which Anorexia Nervosa (e.g.; Petretta et al., 1996; Rommel et al., 2014; Russell, Schmidt, Doherty, Young, & Tchanturia, 2009). Further investigation will be necessary to examine in depth this issue.

1.4. The Anorexic self

1.4.1. Anorexia Nervosa

Anorexia Nervosa (AN) is a serious mental disorder thought to have the highest mortality rate of any psychiatric disorder (approximately 6% of diagnosed anorexic subjects eventually die due to related causes; Herzog et al., 2000).

In a review of the literature, females aged 15 constitute approximately 40% of all identified cases and face the greatest risk of developing AN; the incidence is eight cases per 100,000 per year (Hoek & Van Hoeken, 2003) with a peak onset between 15 and 19 years old (Bulik, Reba, Siega Riz, & Reichborn Kjennerud, 2005). Smink, van Hoeken, & Hoek (2012), showed that the overall incidence rate from the 1980s onwards did not change, while an increase was observed in the number of new cases in the high risk group of 15 to 19 year old girls.

The term Anorexia Nervosa (from 'an' “without” and 'orexis' “appetite”) literally means lack of appetite: It represents an eating disorder characterized by immoderate food restriction and irrational fear of gaining weight, as well as a distorted body self-perception (Hockenbury & Hockenbury, 2010).

The changes that usually alarm, parents, siblings and others are generally the physical changes and changes in mood and behavior displayed by a starving girl. Visible changes include amenorrhea, depression, fits of rage, sleeping problems, concentration problems, social withdrawal and a preoccupation with food, weight and body (Agras, Hammer, McNicholas, & Kraemer, 2004; Wilson, Grilo, & Vitousek, 2007). Despite increasing cachexia¹, individuals with AN continue to obsess about weight gain, remain dissatisfied with the perceived largeness of their bodies, and

¹ The loss of body mass that cannot be reversed nutritionally: Even if the affected patient eats more calories, lean body mass will be lost, indicating that a primary pathology is in place.

engage in a range of behaviors designed to perpetuate weight loss. Patients affected by AN place central importance on their shape and weight as their self-esteem is deeply weaved with their body-esteem (Herzog et al., 2000).

AN has profound medical and psychological consequences that can persist throughout life. It is associated with important secondary symptoms and signs, including hypothermia, bradycardia, hypotension, dry skin, lanugo, reduced immune system function (leukopenia, neutropenia, anemia, and thrombocytopenia), abnormal thyroid values, electrolyte imbalance, intestinal and urinary problems, risk of osteoporosis, reproduction problems, neurological disorders, heart diseases and arrhythmias (Grave, 2011).

1.4.2 *Diagnostic criteria and causes*

Anorexia nervosa is classified among eating disorders in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013).

The diagnostic criteria include:

- 1) Restriction of energy intake relative to requirements leading to a significantly low body weight in the context of age, sex, developmental trajectory, and physical health. Significantly, low weight is defined as a weight that is less than minimally normal, or, for children and adolescents, less than that minimally expected.
- 2) Intense fear of gaining weight or becoming fat or persistent behavior that interferes with weight gain, even though at a significantly low weight.
- 3) Disturbance in the way in which one's body weight or shape is experienced, undue influence of body weight or shape on self-evaluation, or persistent lack of recognition of the seriousness of the current low body weight.

To the diagnosis, it is necessary to specify the current type:

- a) **Restricting type** if during the last three months, the person has not engaged in recurrent episodes of binge eating or purging behavior (i.e., self-induced vomiting or the misuse of laxatives, diuretics, or enemas);
- b) **Binge-Eating/Purging Type** if during the last three months, the person has engaged in recurrent episodes of binge eating or purging behavior (i.e., self-induced vomiting or the misuse of laxatives, diuretics, or enemas) (American Psychiatric Association, DSM-5, 2013).

The International Classification of Diseases (ICD) provides an additional index utilizing Quetelet's index of $<17.5 \text{ kg/m}^2$ which is below the WHO and CDC definitions of underweight ($\text{BMI} < 18.5 \text{ kg/m}^2$).

The causes of AN are unknown, but most clinicians and researchers agree that it is a multifactorial disorder in which no single factor is enough to start or maintain the disorder.

Different variables could contribute to the development of this pathology:

- Genetic factors: relatives of patients have a 10-fold lifetime probability of having an eating disorder than relatives of unaffected controls (Bulik & Tozzi, 2004).
- Biological factors: studies on the brain monoamine function observed that 5HT_{2A} receptors are reduced and 5HT_{1A} receptors are increased in both the acute and recovered state (Frank et al., 2002) and dopamine receptors (DA₂) within the striatum are increased after recovery (Frank et al., 2005).
- Environmental factors: stress during pregnancy (Shoebridge & Gowers, 2000), very preterm birth (Cnattingius, Hultman, Dahl, & Sparén, 1999) and obstetric complications

seem to increase the risk of developing AN (Favaro, Tenconi, & Santonastaso, 2006), due to epigenetic mechanisms or brain damage from hypoxia (Campbell, Mill, Uher, & Schmidt, 2011). Moreover, other environmental potential risk factors have been found: general harmful experiences (e.g. neglect, physical and sexual abuse, dysfunctional parenting) or food and weight-related harmful experiences (e.g., family dieting, childhood and parental obesity, critical comments about eating, shape from family and others, occupational and recreational pressure to be slim). Further, the concept of attachment in relation to eating disorders has been highlighted. (Bowlby (1969), emphasized early experiences of relationships as being important to future relations and pointed to the infant seeking safety and closeness to caregivers when feeling threatened. The last decades of family studies have proposed that high concern parenting in infancy is associated with the subsequent development of AN (Shoebridge & Gowers, 2000). Women with eating disorders, indeed, show an insecure attachment style, with extreme separation anxiety and unresolved loss and trauma (for a review see (O'Shaughnessy & Dallos, 2009). Moreover, Zachrisson & Skårderud (2010) found a greater prevalence of insecure attachment in patients with an eating disorder than in non-clinical samples.

- Others: further risk factors are female gender, adolescence, and some premorbid characteristics (e.g., low self-esteem and perfectionism, thin-ideal internalization, anxiety disorders) (Jacobi, Hayward, de Zwaan, Kraemer, & Agras, 2004).

1.4.3 Comorbidity

Since AN most of the time starts in adolescence (Smink et al., 2012), a time when the personality is under development and unstable, it interrupts and disturbs normal development and

affects self-confidence) (Attie & Brooks-Gunn, 1989; Christie & Viner, 2005). This leads to reduced emotional processing (Roberts, Tchanturia, Stahl, Southgate, & Treasure, 2007; Roberts, Tchanturia, & Treasure, 2010; Tchanturia et al., 2004) (Treasure, Claudino & Zucker, 2010) cognitive abilities, as set shifting (the capability to display cognitive flexibility), which is commonly reduced in adult AN patients with current and past illness (Roberts, Tchanturia, Stahl, Southgate, & Treasure, 2007; Roberts, Tchanturia, & Treasure, 2010; K. Tchanturia et al., 2004; Kate Tchanturia et al., 2004, 2012; Treasure, 2013). Importantly, AN patients have reduced social cognition (Treasure, 2013).

Anckarsäter et al. (2012), in a longitudinal study with 18 years follow-up found in all cases with AN 32% of comorbidity with autism spectrum disorder. Furthermore, AN is frequently accompanied by serious comorbid psychopathology, such as depression with feelings of helplessness and guilt, anxiety disorders, obsessive-compulsive disorder and substance use disorders. The depressive symptoms may not be associated in early adolescence, but, in the middle of the disease or later, when the eating problems are more clearly manifested, they are likely to occur because of underweight and malnutrition (Attie & Brooks-Gunn, 1989). These symptoms often decrease when the weight increases, as shown in a follow up study in which adult AN patients of normal weight reduced their paranoid and obsessive compulsive personality indices to a larger extent than those who were still under weight (Agras et al., 2004; Cooper, 1995; Rø, Martinsen, Hoffart, Sexton, & Rosenvinge, 2005). However, in a 18 years follow-up study of people with teenage onset AN, 39% had psychiatric disorders other than eating disorders, among which anxiety disorders were most common (Wentz, Gillberg, Anckarsäter, Gillberg, & Råstam, 2009).

According to cognitive behavioral theory (Grave, 2011) the over-evaluation of eating, shape, weight and their control is central in the maintenance of all eating disorders. Other clinical

features stem directly (e.g., strict dieting, compensatory vomiting/laxative misuse, low weight and starvation syndrome) or indirectly (e.g., binge eating) from this “core psychopathology”. The theory also proposes that in certain patients some additional maintaining processes can contribute to create a further obstacle to change, like clinical perfectionism, core low self-esteem, mood intolerance, and interpersonal difficulties.

There is no conclusive evidence that any particular treatment for anorexia nervosa work better than others, but early intervention improves the outcome.

Treatment for anorexia nervosa tries to address three main areas:

- 1) Restoring the person to a healthy weight;
- 2) Treating the psychological disorders related to the illness;
- 3) Reducing or eliminating behaviors or thoughts that originally led to the disordered eating (NCCMH, 2004).

These aims can be pursued with various combinations of psychosocial therapy, dietary intervention, and medication. There have been claims that olanzapine is effective in helping to raise the body mass index and reducing obsessional thoughts about food (Brambilla et al., 2007).

1.4.4. The Anorexic self

It is widely known that among others, the most pervasive symptoms characterizing AN concern their body-image overestimation (Cash & Deagle, 1997; Farrell, Lee, & Shafran, 2005; Guardia et al., 2010; Guardia, Cottencin, Thomas, Dodin, & Luyat, 2012; Hodzic et al., 2009; Keizer et al., 2013; Nico et al., 2010) together with the difficulty to discriminate emotional states and visceral sensations related to hunger and satiety (Fassino, Amianto, Gramaglia, Facchini, & Daga, 2004; Garner, Olmstead, & Polivy, 1983; Lilenfeld, Wonderlich, Riso, Crosby, & Mitchell, 2006; Matsumoto et al., 2006) and a wide range of autonomic system disturbances (for a review see Mazurak, Enck, Muth, Teufel, & Zipfel, 2011), which expose patients to high mortality risk due to cardio-vascular complications. Thus, the anorexic body seems to be distorted both exteroceptively (“I’m fat”) and interoceptively (“I’m full”).

1.4.5. AN and Bodily-self overestimation

Regarding the body image overestimation, the empirical investigation of exteroceptive body image disturbance mostly involves body size evaluation. A recurrent finding is that individuals with anorexia operate an overestimation of body image (Farrell et al., 2005), which decreases with the gain of weight and when persisting, enhances patients' risk to relapse. Since patients are “unimpaired in size-estimations of neutral objects” (Cash & Deagle, 1997), the overestimation of the body image cannot be extended to a generalized sensory-perceptual deficit, hence supporting the hypothesis that “body image disturbance in patients with eating disorders is exclusively a problem of processing self-referential information regarding body image” (Benninghoven, Hagenhoff, & Werner, 1997). Body image distortion precedes the onset of AN

(Jacobi, Schmitz, & Agras, 2008) and its persistence may predict a poor outcome of AN (Lay & Schmidt, 1999).

The perceptive component of the body image distortion was considered primarily involved when the tasks were based on the viewing of real own and others' body images (Hodzic et al., 2009).

Two studies investigated the neural correlates of body image distortion in AN using patients' own body image as visual stimulus. Both the studies revealed that AN patients showed no task-dependent increase of activation and a decreased activation in the precuneus (Sachdev, Mondraty, Wen, & Gulliford, 2008) and in the inferior parietal lobule (Sachdev et al., 2008; Vocks et al., 2010) compared with healthy controls. Other studies using patients' own body image (Vocks et al., 2010), line drawings of female body of different weight sizes, (Uher et al., 2005), and tasks of body size estimation (Mohr et al., 2010), showed absence of or lower activation of the precuneus, weaker activation to body shapes in the occipito-temporal cortex (including the EBA) and in the inferior parietal cortex in AN patients than in controls

Moreover, the integrity of the precuneus function seems to be essential for self-reference (Lou, Nowak, & Kjaer, 2005). Association with unilateral parietal lesions was more frequently observed in the left hemisphere in patients with Gerstmann's syndrome, also referred to as autotopagnosia or "body-image agnosia" (i.e. inability to localize and orient parts of the own body, Brawn, 2007). Furthermore, class III evidence of parietal alterations supported both by functional and structural studies, suggests that AN patients may suffer a processing bias of self-body image identification and self-body size estimation, associated with alterations of the IPL and the precuneus.

In a functional study that included a visual perceptual task of other women's body image, results Sachdev et al. (2008), found that AN patients and healthy controls showed increased activation of the superior parietal lobule, the inferior and middle frontal gyri, and the thalamus. These areas were partially overlapping with the findings of the studies of Hodzic et al. (2009). On the other hand, Vocks et al. (2010), pointed out that AN patients, using other women's body image, showed several differences compared to controls. Specifically, AN patients showed stronger amygdala activity than controls. The stronger activity of amygdala found in AN patients when looking at another woman's body has been interpreted as the neural correlate of negative emotional activation, possibly resulting from unfavorable social comparison processes (Vocks et al., 2010). In summary, the findings on the neural correlates of other-body image perception are few and not much consistent.

Beside stemming from a disturbed body image (i.e. explicit perceptual, semantic, aesthetic and emotional representation of the body; De Vignemont (2010), indeed, the body overestimation bias found in AN could alternatively reflect abnormal neural processing of the implicit bodily self, which in turn might disturb the representation of the body in action, i.e. the body schema (Schwoebel & Coslett, 2005). The possibility of body schema disturbances in AN has been previously suggested (Guardia et al., 2010, 2012; Nico et al., 2010). To date, the only study aimed to assess the body schema in action at a more implicit level was made by Keizer et al. (2013), who compared on body-scaled action AN patients and healthy controls. Participants walked through door-like openings varying in width while performing a diversion task. AN patients and healthy control participants differed in the largest opening width for which they started rotating their shoulders to fit through. AN patients started rotating for openings 40% wider than their own shoulders, while HC started rotating for apertures only 25% wider than their shoulders

1.4.6 AN and Interoception

Concerning the sensitivity to stimuli originating inside the body (Interoceptive sensitivity, IS) a recent study by Pollatos et al. (2008), extended the range of the deficits in discriminating hunger and satiety proper of eating disorder to visceral sensation in general, thanks to a study conducted on AN patients. They showed, indeed, lower IS (assessed with the heartbeat perception task; see paragraph 2.2.2 chapter 2 for a detailed description of the task) compared to controls.

1.4.7. AN and Autonomic Reactivity

The relation between IS and autonomic regulation both in resting state and in social contexts of AN have not been yet investigated. Although it has been demonstrated that AN exhibit also a wide range of autonomic system alterations (for a review see Mazurak et al., 2011), the nature as well as the origin and pathogenesis of such alterations are not absolutely clear. In addition, the existing data in literature concerning the nature of autonomic imbalance in AN are contradictory. The majority of papers identified parasympathetic/sympathetic imbalance with parasympathetic dominance and decreased sympathetic modulation; others could not replicate these findings, but instead described sympathetic dominance; finally a group of papers could not identify any autonomic differences in comparison to control samples (Mazurak et al., 2011).

In conclusion, AN patients suffer from a distorted body image, associated to an attenuated IS and a deficit in autonomic regulation, which in turn favor altered feedback from the body. Since these pervasive symptoms largely contribute to the onset and maintenance of Eating Disorders, the purpose of this thesis is to shed new light on the relations among interoception, the bodily self, and self-regulation during social interactions.

Chapter 2: Bodily-Self Recognition: Implications for Anorexia

2.1 Introduction

As already briefly outlined in Chapter 1, the most basic concept of self is the bodily self. It corresponds to the feeling of inhabiting one's body (Gallese & Sinigaglia, 2010). All the notions adopted by contemporary research to answer the question of how we distinguish ourselves as bodily selves from other human bodies, as it has been already hypothesized in the 1962 by Merleau-Ponty and recently by Gallese,(2005), refer to a crucial role of the motor system. Gallese & Sinigaglia (2010), suggested that the body is primarily given to us as “source” or “power” for action, that is, as the variety of motor potentialities that define the horizon of how we can interact with the world we live in. The existence of such motor experience-based representation of the bodily self presupposes the ability to perceive and identify human bodies and in particular one's own body. It was recently shown that processes of Self-body recognition could be both implicit and explicit. While explicit recognition is likely to be based on cognitive and perceptual mechanisms, implicit recognition recruits sensorimotor information and relies upon motor simulation (Ferri et al., 2011; Urgesi et al., 2006).

A Study of Ferri et al., (2011) showed that participants, when submitted to a hand laterality judgment task (Implicit task), which required mental rotation, showed better performances when the stimuli consisted of their own dominant hand rather than others' hand (Self- advantage). By contrast, the Self-advantage was absent when self-recognition (Explicit task) was explicitly required. A subsequent fMRI study, adopting the same paradigm, demonstrated that this implicit and pre-reflective sense of being a bodily self is embedded within the sensory-motor system, and revealed a neural network for a general representation of the bodily self, encompassing the SMA and pre-SMA, the anterior insula, and the occipital cortex bilaterally. Moreover, the representation of one's own dominant hand turned out to be primarily confined to the left premotor cortex (Ferri

et al., 2012). Beside a motor experience of one's body, any experience of the body provide us with a variety of information related to its physiological state, concerning exteroceptive, proprioceptive and interoceptive feedback. Part of this sensory-motor system, specifically the anterior insula, is also engaged when individuals attend to or attempt to control a number of internal bodily states, including pain, temperature, heart rate, and arousal (Critchley et al., 2004; Peyron et al., 2000), playing a crucial role in the perception of one's internal bodily state. Such perception has been defined Interoceptive Sensitivity (IS).

IS represent another important nuclear component of self-awareness and it is crucial for the bodily self since it has a primary role for Body-homeostasis. IS "could affect cognition or behavior with or without awareness" (Cameron, 2001), is also related to greater sensitivity to emotional responses and autonomic reactivity in different situations evoking autonomic changes (Herbert & Pollatos, 2012; Herbert et al., 2010, 2007) as during social interactions (Ferri et al., 2013).

At the neural level, it was recently shown that the putative neural bases of interoceptive integration (i.e. Anterior Cingulate Cortex, and Anterior Insula) could participate in maintaining the basic sense of self (Devue & Brédart, 2011b). Empirical research on interoception has predominantly focused on a particular type of IS, that is heartbeat perception. One reason is that there are only few bodily signals from the bodily "interior" that can be readily perceived (e.g. the heartbeat or signals from the guts), whereas the rest of internal activity is mostly "hidden" (Herbert & Pollatos, 2012).

It is widely known that Anorexia nervosa (AN) is characterized by a deficit regarding interoception. AN patients, indeed, seem to be impaired not only in recognizing certain visceral sensations related to hunger and satiety (e.g. Fassino et al., 2004), but also exhibit a generally reduced capacity to accurately perceive cardiac bodily signals, assessed with heartbeat perception

task, (Pollatos et al., 2008). A major clinical symptom of Anorexia Nervosa (AN) is the body size overestimation, and it is generally accepted that it reflects a distortion of body representation. Besides deriving from a disturbed body image (i.e. explicit perceptual, semantic, aesthetic and emotional representation of the body; De Vignemont, 2010) indeed, the body overestimation bias found in AN could alternatively reflect abnormal neural processing of the implicit, embodied self, which disturbs the representation of the body in action, i.e. the body schema (Schwoebel & Coslett, 2005). The possibility of body schema disturbances in AN has been previously suggested (Guardia et al., 2010, 2012; Nico et al., 2010). For example, a motor imagery study, in which participants imagined walking through a projected aperture, showed that AN patients indicated they would rotate their shoulders for relatively larger apertures than healthy controls (Guardia et al., 2010). This was interpreted as indicative of a body schema disturbance (Guardia et al., 2010). It should be noted that participants did not actually perform the action of walking in this study, and it cannot be determined whether AN patients made a conscious decision about having to rotate their shoulders or not. To date, the only study aimed to assessing the body schema in action at a more implicit level was made by Keizer et al. (2013), who compared on body-scaled action AN patients and healthy controls. Participants walked through door-like openings varying in width while performing a diversion task. AN patients and healthy control participants differed in the largest opening width for which they started rotating their shoulders to fit through. AN patients started rotating for openings 40% wider than their own shoulders, while HC started rotating for apertures only 25% wider than their shoulders.

Based on these previous findings, the present study aimed at investigating whether and to which level the perceived size of hands stimuli could modulate both explicit and implicit Self-recognition, and whether the overestimation of anorexic's own body size extended to the motor

representation of the bodily self, influencing the implicit self-advantage. Furthermore, since IS seems to be related to the bodily self, here we also aimed to assessing the possible relationship between IS and the ability to implicitly recognize one's own body parts.

As in Ferri et al., (Ferri et al., 2012, 2011), in a first experiment (Implicit task) both healthy participants and restrictive anorexia (AN) patients² were submitted to a laterality judgment task with either self or others' hands as body stimuli. Stimuli could be presented in their original size, or with the hand slightly fatter, fatter, slightly thinner or thinner.

In a second experiment (Explicit task), we employed the same stimuli as in the Implicit task, but asked participants to explicitly recognize their own hand. We adopted this task because it is well known that in order to perform the implicit task, participants simulate a mental motor rotation of their own body parts to match that of the observed stimulus (Ionta, Fourkas, Fiorio, & Aglioti, 2007; Parsons, 1994). Mental motor rotation of body parts shares the same temporal and kinematic properties with actual body rotation in space (Decety, Jeannerod, Germain, & Pastene, 1991; Jeannerod & Pacherie, 2004; Parsons, 1994; Porro et al., 1996).

Since previous studies (Ferri et al., 2012, 2011) showed an implicit self-advantage in healthy controls, we hypothesized that the laterality judgment in Experiment 1 for healthy controls should be easier when the displayed stimulus is one's own hand in the original size. If in AN patients the body overestimation relies upon the motor representation of the bodily self, we might expect an absence of the self-advantage or a greater self-advantage for stimuli depicting one's hand fatter than its original size.

² According to DSM V, the restrictive subtype of AN is characterized by the absence, during the last three months, of recurrent episodes of binge eating or purging behavior as self-induced vomiting or the misuse of laxatives, diuretics, or enemas.

To evaluate the IS, a well-assessed heartbeat perception task (Schandry, 1981) was administered. Besides the expectancy to confirm the results of Pollatos et al. (2008), for AN, we hypothesized that if IS is strictly related to bodily self-recognition, it should modulate the self-advantage in AN and HC.

2.2 Method

2.2.1. Participants

Twenty right-handed women with a diagnosis of Anorexia Nervosa (AN) restrictive subtype according to the DSM V criteria (American Psychiatric Association, 1994) and 22 healthy right-handed women were included in the study. All patients (mean age: 23.8 SE= 2; mean BMI: 15.8 Kg/m² ES= 0.2) followed a controlled diet for the ten days prior to the experiment in order to avoid the confounding effects of malnutrition on the performance.

Twenty healthy control participants (HC group) were matched with AN patients for age (mean age: 21.2 ES=6) and sex (all were women). At the time of the study, the mean Body Mass Index (BMI) of the control group was 21 Kg/m² ES= 0.2. Exclusion criteria for both groups included actual or past cognitive disorders (mental retardation), psychiatric disorders (psychosis), severe medical illnesses (head trauma, neurological and cardio-respiratory diseases, and diabetes), substance dependence, intake of medications altering the cardio-respiratory activity. A further exclusion criterion for the control group was a personal history of eating disorders. Given the frequent comorbidity in AN with major depression or personality disorders, these were not comprised between exclusion criteria for AN patients. All participants gave their written informed consent for participation in the study.

Height and weight were assessed and both the groups, in a previous and separate session from the experiment, filled in several questionnaires (see table 1) including the Beck's Depression Inventory (BDI), the State Trait Anxiety Inventory (STAI), the Eating Disorder Inventory (EDI-3), the Eating Disorder Examination Questionnaire (EDE Q), the Body Uneasiness Test (BUT), the Body Shape Questionnaire (BSQ), the Symptom Checklist-90 (SCL-90).

Table 1- Comparison between the two groups with respect to socio-demographic and questionnaire data (p.05 =*, pb.01 =**, pb.001 = ***)

	AN mean (SE)	HC mean (SE)	F(df=1,40)	p
Age	23.8 (2)	21.2 (6)	2.07	n.s.
BMI	15.8 (0.2)	21 (0.2)	94.1	***
Weight	42 (0.8)	57 (1.6)	59.4	***
Height	1.6 (0.02)	1.6 (0.01)	0.23	n.s.
DES	22.1 (3.7)	9 (2.0)	9.25	*
EDI 3	116 (7.6)	36.1 (6.2)	68.9	**
EDE- Q	52,9 (0.2)	2 (0.2)	37.7	***
SCL-90	107.2 (14.3)	52.9 (11.1)	8.9	***
STAI- State	41 (1)	43(0.8)	2.38	**
STAI- Trait	47.7 (0.2)	43.6 (0.2)	13.08	n.s.
BDI	28 (2.5)	7 (1.3)	47.51	***
BUT (GSI)	3.3 (1.4)	0.9 (1.5)	2.51	***
BUT (D)	2 (0.2)	0.4 (0.1)	38.7	n.s.
BSQ	123 (7.8)	69.1 (6.3)	30.7	***

2.2.2. Stimuli and Procedure

The experimental stimuli consisted of grey-scale pictures of the dorsal view of right and left hands. The hands of each participant were photographed with a digital camera in a session prior to the experiments (at least 1 week before the experimental session). This session took place in a controlled environment with constant artificial light and a fixed distance between the camera lens and the hands (40 cm), which were always photographed in the same position. Subsequently, photographs were modified with Adobe Photoshop software: they were cut from the original picture and modified in their horizontal dimension in order to provide a “Weight Gain” (+2%, +4%, +6% in width) or a “Weight Loss” (-2%, -4%, -6% in width) effect (see fig.2). Then, the obtained

images were pasted on a white background, and reoriented into the different rotated positions. Other people's hands were selected from this database as the best match for size, skin color and age, in comparison with each participant's hands. The sizes of the hands were compared in the pictures, in order to minimize the differences between matched hands both in length and in width. Images of hands were presented one at a time at the center of the computer screen in five different clockwise orientations from the upright (0° , 45° , 90° , 135° , and 180°). The upright orientation was defined as fingers pointing upwards (see fig 2).

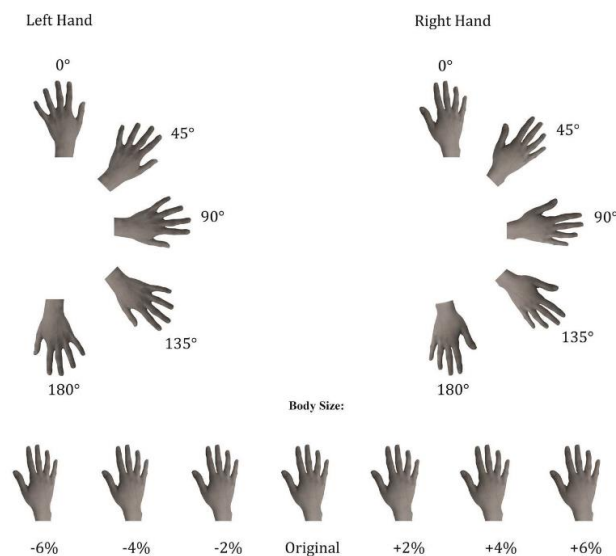


Figure 2. Stimuli- Experimental stimuli used in both Implicit and Explicit Experiment, they depict the dorsal view of right and left hands in seven different size and five different clockwise orientations. Image of participant's hands or of three other people's hands were presented one at time in "self" trials and "other" trial, respectively.

Participants sat in front of a PC screen, at a distance of about 30 cm. Stimuli presentation was controlled by E-Prime (Psychology Software Tools Inc.,). Each trial started with a central

fixation cross (500 ms duration), followed by stimulus presentation. The trial was timed-out as soon as participants responded (up to 4000 ms).

In the Implicit task participants were required to judge the laterality (left or right) of observed digital images of hands by pressing as accurately as possible and within the allowed time interval, a left or a right response key, with their left and right index fingers, respectively (see fig. 3).

In the Explicit task (see fig. 3) participants were required to explicitly judge whether the displayed hand corresponded or not to their own hand by pressing as accurately as possible and within the allowed time interval, a left or a right previously assigned response key, with their left and right index fingers, respectively. The response keys were counterbalanced between subjects. At the end of the experimental session, participants were submitted to the heartbeat perception task (Schandry, 1981) (see fig.3). Reaction times (RTs, times elapsed between the stimuli presentation and spacebar pressure) and accuracy rates (percentage of correct answers) were recorded in Implicit and Explicit tasks.

Each Experiment consisted of 420 trials. Stimuli depicted the participant's own left or right hand in half of the trials (210 'self' trials). In the other half of the trials, stimuli depicted the right or left hand of other three people (210 'other' trials). Each hand-stimulus was presented in seven weight conditions ("Weight Gain": +2%, +4%, +6%; "Original size": 0%; "Weight Loss": -2%, -4%, -6%; for a total of 7 weight conditions). Each weight condition was randomly presented 15 times. Tasks were always preceded by a task-specific practice block. The Implicit task was always conducted before the Explicit task.

Tasks were always preceded by a task-specific practice block. The Implicit task was always conducted before the Explicit task.

Heartbeat perception was measured using the Mental Tracking Method (Schandry, 1981) that has been widely used to assess IS, has good test–retest reliability (up to .81; Mussgay, Klinkenberg, & Rüdell, 1999; Pollatos et al., 2007) and highly correlates with other heartbeat detection tasks (Knoll & Hodapp, 1992). Participants were instructed to start silently counting their own heartbeat on an audio-visual start cue until they received an audio-visual stop cue. After one brief training session (15 s), the actual experiment started. This consisted of four different time intervals of 140 s, 45 s, 35 s and 25 s, presented in random order across participants. Participants were asked to tell a second experimenter the number of heartbeats counted at the end of each interval. Throughout, participants were not permitted to take their pulse, and no feedback on the length of the counting phases or the quality of their performance was given. Heartbeat perception score was first calculated as the mean score of four heartbeat perception intervals according to the following transformation (Pollatos et al., 2008; Schandry, 1981):

$$\frac{1}{4} \sum \left(1 - \frac{(|\text{recorded beats} - \text{counted beats}|)}{\text{recorded beats}} \right)$$

According to this transformation, heartbeat perception score can vary between 0 and 1, with higher scores indicating small differences between recorded and counted heartbeats (i.e., higher interoceptive sensitivity).

All the tasks were performed in a single experimental session (see Fig 3.).

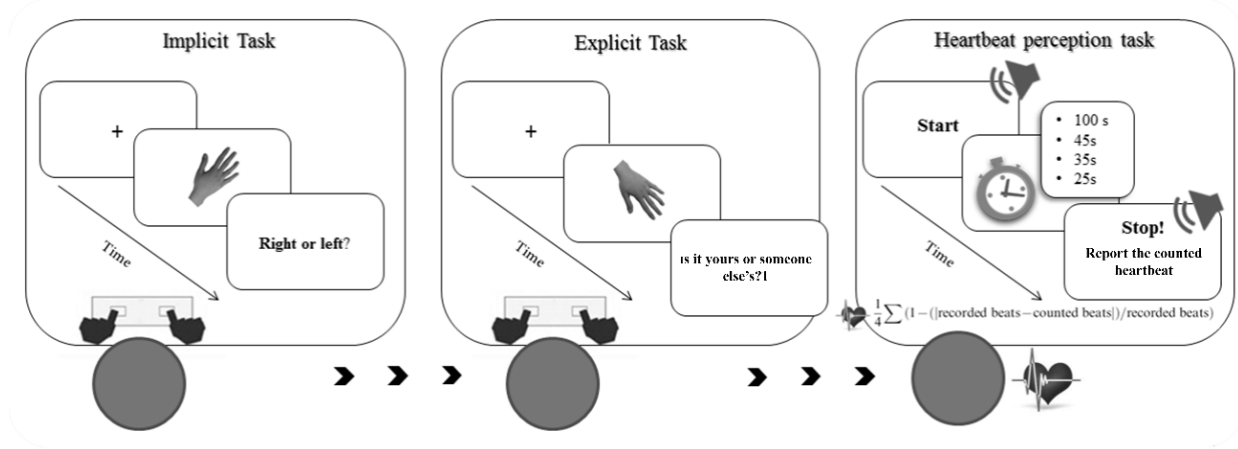


Figure 3 - Description of the experimental paradigm and order of events.

2.3 Results

Two AN patients and one healthy control were excluded from the analysis as they failed to respond correctly to two-third of trials of Experiment 2.

For each experiment, trials in which participants failed to respond correctly were excluded from the analysis of response times (RTs). The mean RTs were calculated for each condition and responses more than 2 standard deviations from the individual mean were treated as outliers.

Since the conditions -6% and -4% weight loss, did not mutually differ, as well as the conditions +4% and +6% weight gain, they were collapsed into two new conditions. Thus, the factor Weight comprised five level of body size: slightly thinner (-2%), thinner (-4% and -6%), original size, slightly fatter (+2%), fatter (+4% and +6%).

For both Implicit and Explicit tasks, correct RTs mean and accuracy (correct responses log₁₀ transformed) entered in four repeated measures ANOVAs (2 for An group and 2 for HC group) with Owner (one's own and other people's stimuli), Laterality (left and right), and Size

(slightly thinner, thinner, original size, slightly fatter, fatter) as within-subject factors. The Newman-Keuls test was used for all post-hoc comparisons.

Previous studies on AN patients demonstrated a disrupted self/other discrimination in emotional responses as disgust (for a review see Moncrieff-Boyd, Byrne, & Nunn, 2014). Thus, we also compared, only for the Explicit task, the two types of errors between AN patients and HC group by independent samples t-test. Errors were classified as self-misattributions, when other people's hands were erroneously attributed to oneself, and self-omissions, when one's own hand was erroneously recognized as others' hand.

2.3.1 Implicit task

Results of HC group. The ANOVA on accuracy showed that the interaction between Owner and Laterality was significant [$F(1, 20) = 5.8; p < 0.05$], confirming only for the right hand a better performance with self-related stimuli than other-related stimuli, independently from the perceived sizes (93% accuracy $SE=0.01$ vs. 90% $SE= 0.01$; Newman-Keuls test close to significance: $p = 0.07$).

The same analysis conducted on RTs revealed the main effect of Laterality [$F(1, 20) = 20.29; p < 0.001$] since RTs to right stimuli were faster than RTs to left stimuli (1015 ms, $SE=50$ vs. 1128 ms $SE=54$). The main effect of Weight was also significant [$F(1, 20) = 4.09; p < 0.01$]. This effect was accounted for by slower RTs in the slightly fatter condition than the original, thinner and slightly thinner conditions (1126 ms $SE= 61$ vs. 1042 ms $SE= 45$, 1058 ms $SE= 54$ and 1047 ms $SE= 49$ all $ps < 0.05$). The Owner by Weight interaction was significant [$F(1, 20) = 3.9; p < 0.01$], because of the faster performance with slightly fatter self-related stimuli than slightly fatter other-related stimuli (1083 ms $SE= 59$ vs 1169 ms $SE= 66$). Furthermore, the interaction among

Owner, Laterality and Weight was significant [$F(1, 20) = 2.9$; $p < 0.05$], showing a Self-advantage for right Self-related stimuli in the Slightly Fatter condition (987 ms; ES=57 vs. 1166 ms; ES=78; $p < 0.01$) evidencing that the perceived size of the hand stimuli modulated the implicit self-advantage (see Fig 4).

Results of AN patients. In contrast with data of HC group, when the ANOVA was conducted on accuracy, the interaction between Owner and Laterality was not significant [$F(1, 18) = 0.003$; $p > 0.4$]. The same analysis conducted on RTs revealed only the main effect of Weight [$F(1, 18) = 2.51$; $p < 0.05$] being RTs slower in the slightly fatter condition than the fatter condition (1298 ms SE=101 vs. 1249 ms SE=90). Relevant for our study and contrary to HC group, neither the interaction between Owner by Weight [$F(1, 18) = 1.27$; $p > 0.2$] nor the interaction among Owner, Laterality and Weight [$F(1, 19) = 0.50$; $p > 0.7$] resulted significant. Hence, irrespective of the perceived size of the hand, AN patients did not show any self-advantage (see fig. 4).

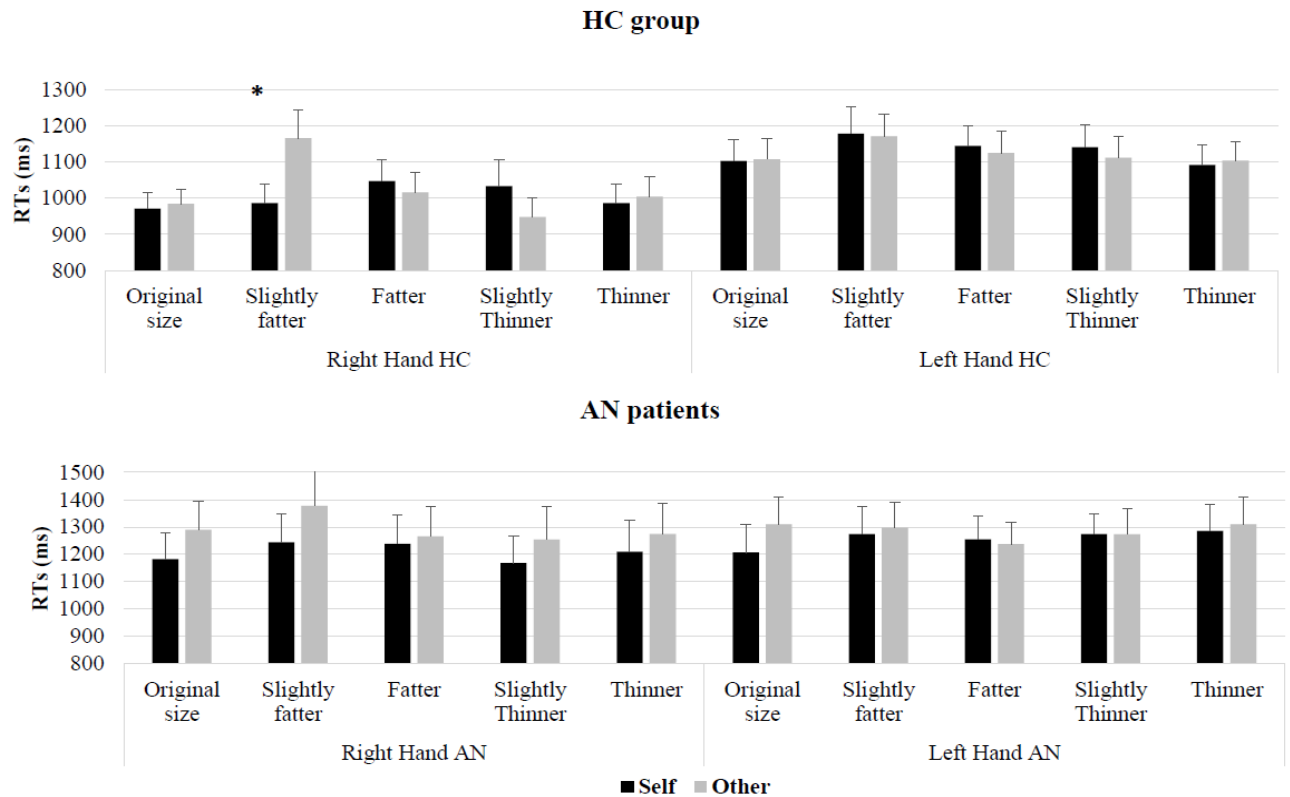


Fig 4- Mean RTs at Self and Others' hands stimuli sizes in the Implicit task for the HC group (upper panel) and AN patients (bottom panel). Error bars depict the standard error of the mean.

2.3.2. Explicit task

Results of HC group. The ANOVA on accuracy did not show any significant effect. The ANOVA conducted on RTs showed the main effect of Owner [$F(1, 20) = 4.51; p < 0.05$] with faster performance

for others' than self-stimuli (977 ms SE=61 vs. 1019 ms SE= 69). The main effect of Weight was also significant [$F(1,20) = 3.1; p < 0,05$] with slower performance in the slightly fatter than all other conditions (slightly fatter: mean= 1035, SE= 72; original size: mean =970 ms SE=

62; fatter: mean= 991 ms, SE= 61; slightly thinner: mean= 995 ms, SE= 61; thinner: mean= 988, SE= 60; all ps <0.05)(see Fig.5).

Results of AN group. While the ANOVA conducted on accuracy did not show any significant effect, the same analysis conducted on RTs showed the main effect of Owner [F (1, 18) = 7.6; p < 0.001]. As for HC group, indeed, AN patients were faster for others' than for self-stimuli (1445 ms, SE 73 vs. 1168 ms SE= 62).

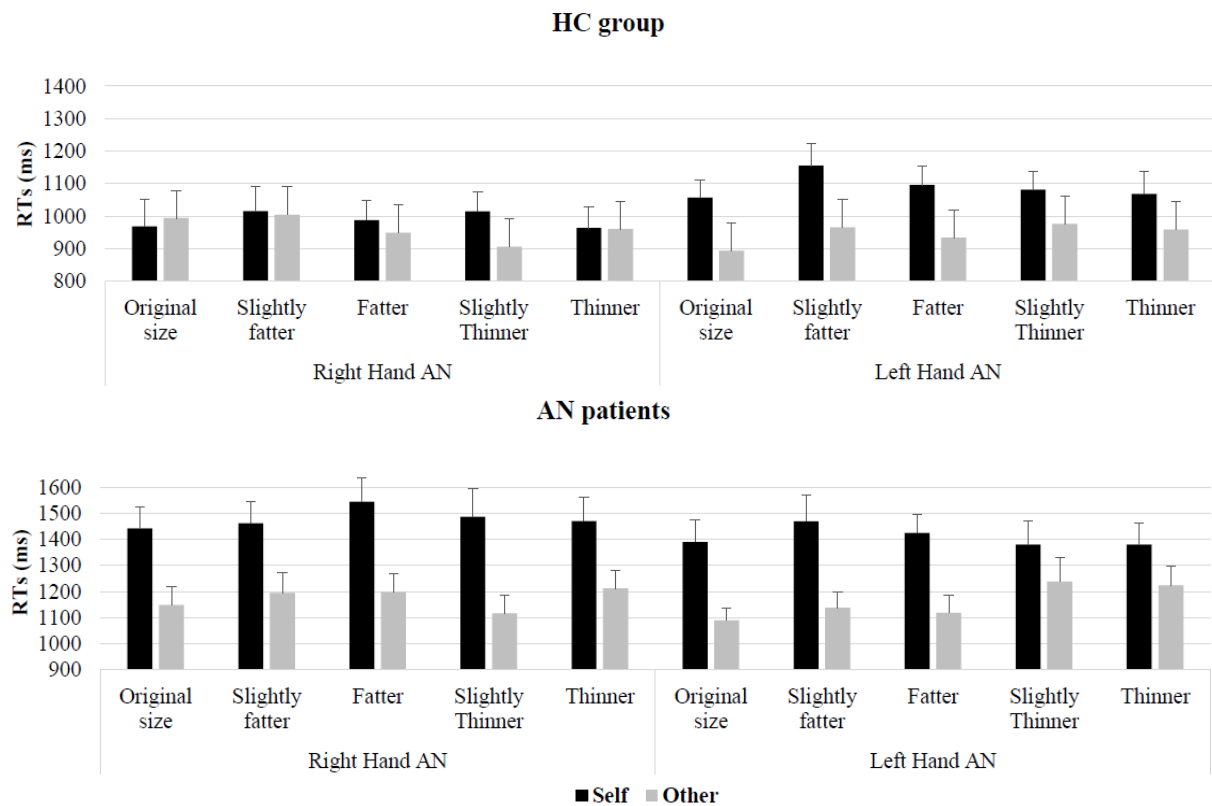


Figure 5 - Mean RTs at Self' and Others' hands stimuli sizes in the Explicit task for the HC group (upper panel) and AN patients (bottom panel). Error bars depict the standard error of the mean.

Errors.

Independent sample t-test on self-misattribution errors (log10 transformed) showed a significant difference ($t_{37} = -2.4$; $p < 0.05$) between AN patients (12.4%) and HC (6%). Conversely, the same test on percentages of self-omission errors showed that they did not differ ($t_{37} = -1.5$; $p > 0.1$) between the two groups (AN patients = 9.7% vs. HC group = 5.1%).

2.3.3 Interoceptive Sensitivity

Interoceptive sensitivity score was calculated as the mean score of four heartbeat perception intervals (140 sec- 45 sec – 35 sec – 25 sec) according to the following transformation: $1/4 \sum (1 - (\text{recorded beats} - \text{counted beats}) / \text{recorded beats})$.

An independent sample t-test was conducted comparing IS of AN patients and HC group. Confirming the results of Pollatos et al., (2008), AN patients showed a lower heartbeat perception score compared to HC ($t_{37} = -2.47$, $p < 0.05$); AN= 0.45 SE= 0.01, HC= 0.56 SE=0.01; see fig. 6).

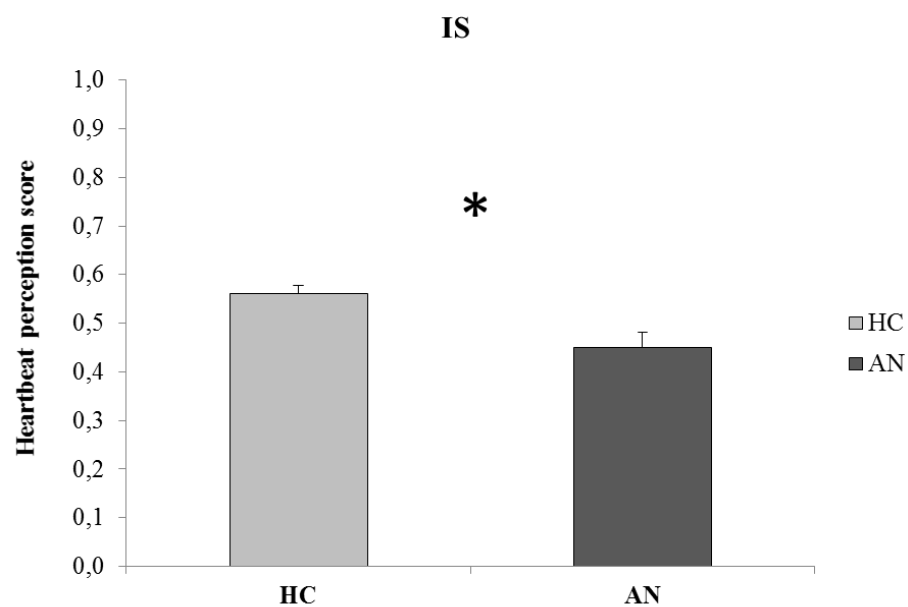


Figure 6- Heartbeat perception score of HC and Error bars depict the standard error of the mean; * = $p > 0.05$

To assess the relationship between motor simulation and IS, we conducted, for each group of participants, two hierarchical regression analysis with the mean heartbeat perception score as predictor and the overall performance (RTs mean) in the implicit and the explicit task as criterion. Since it is known that Body Mass Index (BMI) could affect the ability to detect heartbeat sensations (Jones et al., 1994; Montgomery et al., 1984), and similarly both anxiety and depression, we included also STAI state score, STAI trait score, and BDI score as predictors of the hierarchical regression.

IS and Implicit RTs. For HC group the hierarchical regression analysis demonstrated that the criterion RTs to the implicit task was explained by the heartbeat perception score ($t = -2.25$, $\beta = -0.4$, $p < 0.05$) with a total of 21% explained variance for the regression model ($F_{1, 20} = 5.1$, $p < 0.05$, $R = 0.46$, $R^2 = 0.21$). Not all other predictors were included in the regression model. For AN patients, the same regression did not show any relation between IS and the performance in the Implicit task (see fig. 7).

IS and Explicit RTs. For both HC group and AN patients, when hierarchical regression analysis with the mean heartbeat perception score, BMI, STAI trait and state score and BDI as predictors and RTs to the explicit task as criterion was performed, no predictors were included in the regression model (see fig. 7).

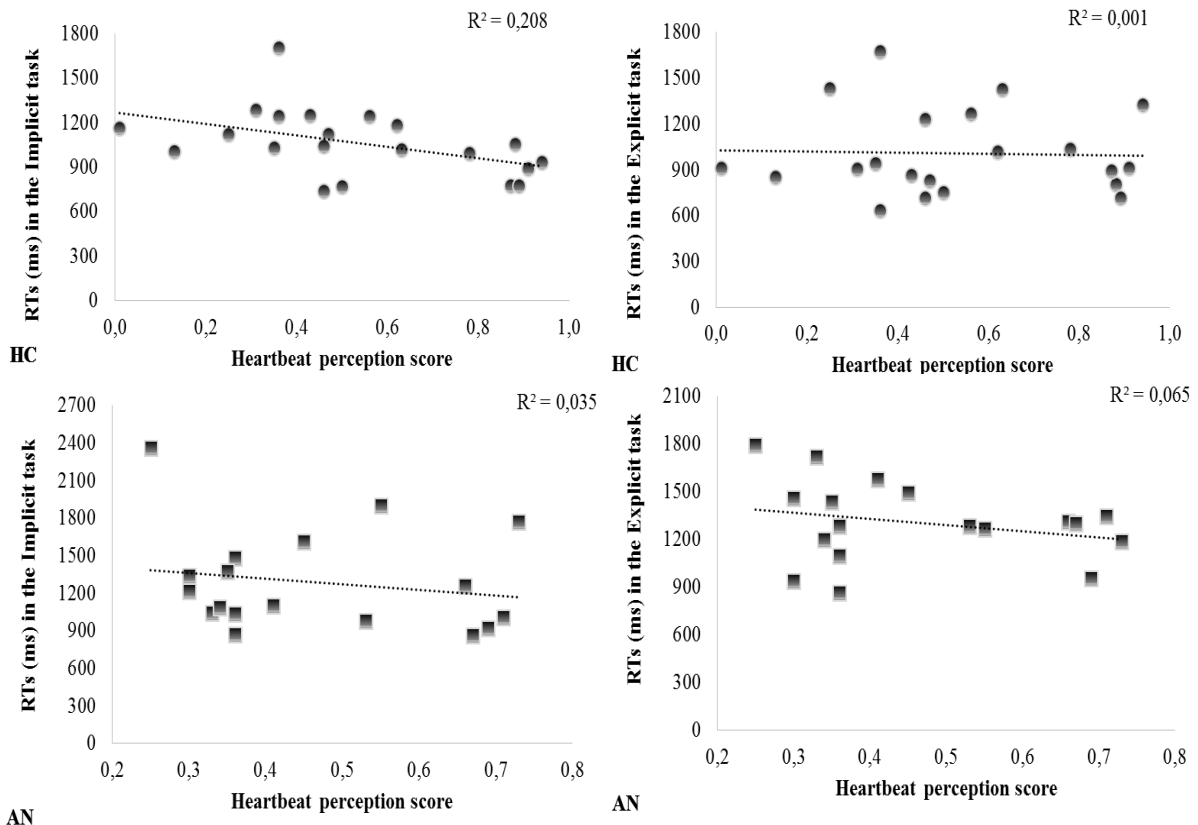


Figure 7- Linear regression plot showing the relation between IS and the overall RTs both in Implicit and Explicit tasks for each group of participants (AN e HC groups).

IS and Errors. Two separate linear regression analysis with heartbeat perception score as predictor and self-misattribution ($R^2= 0.05$; $F_{1, 38}=1.8$; $p> 0.1$) or self-omission ($R^2= 0.11$; $F_{1, 38}=4.8$; $p< 0.05$) as criteria were carried out. While IS seems not to predict the number of self-misattribution ($\beta =0.2$, $t=1.3$; $p<0.1$), it seem to predict the number of self-omission ($\beta =-0.3$, $t=-2.2$; $p< 0.05$). Specifically, the higher IS, the lower is the number of self-omission (see fig.8).

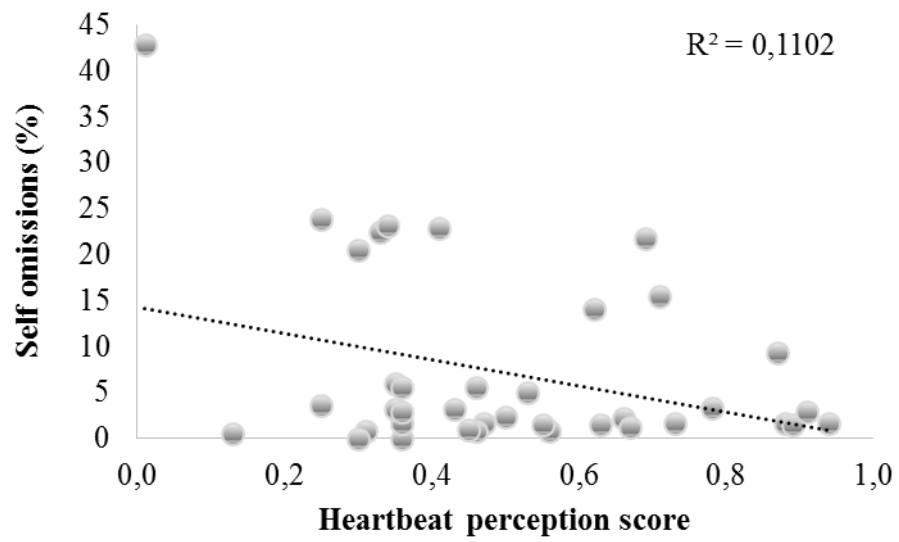


Figure 8- Linear regression plot showing the negative relation between IS and the number of self-omissions both in HC and in AN group.

2.4 General discussion

The current study investigated in HC whether and to which level the perceived size of hands stimuli could modulate both explicit and implicit Self-recognition and whether the overestimation of AN patients' own body size could extend to the motor representation of the bodily self, influencing the implicit self-advantage. Furthermore, it explored the relationship between IS and the implicit self-advantage.

To these aims, we submitted a group of AN patients and a group of HC to a hand laterality judgment task (Implicit task) requiring a mental motor rotation of their own body parts (Decety et al., 1991; Jeannerod & Pacherie, 2004; Parsons, 1994; Porro et al., 1996), and an Explicit task where the recognition of self body part was required and which relies upon different cognitive and/or perceptually-based mechanisms. We used the same procedure and stimuli employed by Ferri et al., (2011), yet editing the hand pictures in order to obtain a "Weight gain" and a "Weight loss" effect. To assess IS we used the well-assessed Heartbeat perception task (e.g. Shandry, 1981).

The present study confirms in HC the dissociation between implicit and explicit Bodily-Self recognition found in Ferri et al., (2011, 2012), resulting in a self-advantage only when a motor simulation is required, and in its lack when an explicit discrimination between self and others' hands was made, leading to a sort of "other advantage". In the implicit task, HC were not only more accurate and faster in response to self-stimuli than to others' stimuli, but also showed a clearer self advantage in RTs only for the right hand slightly fatter stimuli (2-4% fatter). Even if we should have expected a greater self-advantage for self-stimuli having the original size, we might hypothesize the reasons underlying these unforeseen results. First, this finding is in line with Longo & Haggard (2010) who, studying human sense of body part's position, which refer to a stored body model of the body's metric properties, such as body part size and shape, developed a technique to

isolate and measure this body model. Participants judged the location in external space of 10 landmarks on the hand. By analyzing the internal configuration of the locations of these points, they produced implicit maps of the mental representation of hand size and shape of the hand. These authors discovered not only that this part of the body model was distorted, featuring shortened fingers and broadened hands, but intriguingly, these distortions appeared to retain several characteristics of primary somatosensory representations, such as the Penfield homunculus. In contrast to these distortions, however, Longo & Haggard (2010), assessed also explicit judgments of body shape with a template-matching task, and they were approximately veridical, confirming that, besides being distinct from the postural schema, the body model is also distinct from the conscious body image.

Secondly, also an affective involvement could be speculated to have influenced the bodily self-processing, considering that our HC group included a sample of participants composed only by young female students. This hypothesis is coherent with Devue et al. (2007), who explored the cerebral activity while participants performed a task in which they had to implicitly recognize their body self. They found that the observation of an altered version of one's own body elicited activity in prefrontal and limbic areas only in female participants; while for men it rather elicited activity in the right occipital cortex. For these authors, this suggests that women would perceive distorted images of themselves by complex cognitive-emotional processing whereas for men a more visuo-spatial processing would be involved. This gender difference definitely requires further investigations in self-body perception. Our results seems to be coherent with Longo, and Devues's conclusions by showing a self-advantage effect for HC group with hand stimuli at the slightly fatter condition, supporting the view that the perceived size of one's body parts affects motor simulation, which in turn modulates implicit Bodily Self recognition.

Another important result of the present study is that while AN patients, similarly to HC, showed an other-advantage in the Explicit task, they did not show the self-advantage in the implicit task, no matter what the perceived size of their body parts was. This result, in line with the finding of Keizer et al. (2013), confirms that the disturbed experience of body size in AN is more pervasive than previously assumed and might rely upon an impaired implicit and motor-based representation of the body.

The last point to be discussed concerns IS and its possible relationship with the motor-based experience of the bodily self. Although we did not find a direct relationship between IS and the implicit self-advantage, we found that IS predicts the ability to execute a hand mental rotation (Implicit task: higher IS, faster RTs) but not the ability to perform a task in which more cognitive and/or perceptually-based mechanisms are likely involved. More importantly this relationship was lacking in AN patients, whose IS, as in Pollatos et al., (2008) was also significantly lower than HC. This reduction in IS is suggestive of a generalized reduction in AN patients of the ability to perceive bodily signals, and has associated consequences, like the potential for body feedback misinterpretation. Low IS has also been associated with a greater capacity for distortion of external experiences of body representation and ownership (Tsakiris, Tajadura-Jiménez, & Costantini, 2011).

The results of our study support this claim. Indeed, we found that IS is negatively related to self-omissions. In other words, the higher the value of IS, the lower the number of self-omissions, in which participants tend to attribute their body parts to other people. Moreover, in the explicit task a relevant difference between AN and HC was a higher percentage of self-misattribution errors in the former than in the latter group. This means that when required to explicitly discriminate whether the body parts presented on the screen were their own or not, AN patients beside failing

in recognizing their own body parts from those of others as HC, also tended to misattribute other people's body parts to themselves. In the same vein Ainley & Tsakiris, (2013), found that lower IS predict a higher self-objectification (Fredrickson & Roberts, 1997; the tendency to experience one's body principally as an object, in a third-person perspective, by diverting attention to the 'seen' body, probably at the expense of attending to the inner body).

Taken together these results not only highlight a relationship between IS and the bodily self, suggesting that low IS might account for the weaker self-advantage in AN patients, but also corroborate the interpretations on the possible crucial role of anterior insula in bodily self-awareness (Craig, 2009; Craig, 2002; Tsakiris, Hesse, Boy, Haggard, & Fink, 2007). The anterior insula is not only a map of the body, but also a center of visceromotor integration (Caruana, 2011; Gallese, Keysers, & Rizzolatti, 2004; Jezzini, Caruana, Stoianov, Gallese, & Rizzolatti, 2012) as it deals with both interoceptive (Critchley et al., 2004) and sensorimotor information (Karnath & Baier, 2010). Nunn et al. Nunn, Frampton, Fuglset, Törzsök-Sonnevend, & Lask (2011) posit a dysfunction in the insular cortex as a central risk factor for the development and maintenance of the AN disorder. The insular hypothesis of AN (Nunn et al., 2011) proposes that dysfunction in the insula and its cortical and subcortical circuits, paired with socio-cultural pressures to diet and pubertal changes, may trigger the development of AN, and be responsible for the majority of behaviors and conditions associated with the disorder, such as self-disgust associated with reduced interoceptive sensitivity and body awareness.

In conclusion, our data together with previous findings showed that the perceived size of body parts could modulate the implicit self-advantage and also that the ambiguous or distorted body representations of AN is due not only to psycho-affective and perceptive factors but rather to impaired neural processing of body dimensions that might find its source in a sensory-motor

network regarding the bodily self as power for action. These findings shed new light onto the relationship between the two core aspects of self-regulation as interoception and the implicit motor experience of the body.

All in all, although further investigations will be necessary, IS may offer the empirical framework to investigate self-awareness, opening new therapeutic approach for bodily self-disorders.

Chapter 3: Interoceptive Sensitivity and Autonomic Correlates During Social Interactions. Implications for Anorexia

3.1 Introduction

As mentioned in Chapter 2, Anorexia nervosa (AN) is an eating disorder (ED) characterized by voluntary restriction of food and loss of weight of at least 85% of desired weight, that often leads to severe malnutrition and an exceedingly high mortality risk compared with most other psychiatric illnesses (Casiero & Frishman, 2006; Sullivan, 1995). In the last decades, the frequency of this illness and of other EDs greatly increased (Fassino et al., 2004; Friederich et al., 2006; Keski-Rahkonen et al., 2007), representing a great challenge for physicians of various specialties and significantly impacting health care, mostly in the female population (Mitchell & Bulik, 2006).

It is widely known that, among other cognitive, social, and emotional deficits, a core symptom of Anorexia is the difficulty to discriminate emotional states and visceral sensations related to hunger and satiety (Fassino et al., 2004; Garner et al., 1983; Lilenfeld et al., 2006; Matsumoto et al., 2006).

A recent study by Pollatos et al. (2008), besides confirming this finding, extended the range of this deficit to visceral sensation in general. These authors assessed the Interoceptive Sensitivity (i.e. the sensitivity to stimuli originating inside the body; IS) with the heartbeat perception task (Schandry, 1981).

The heartbeat perception task is associated with a more finely tuned self-regulation of behavior according to one's bodily needs (Herbert et al., 2007) and correlates with the ability to detect changes in other autonomically innervated organs, such as the activity of the stomach (Herbert, Muth, et al., 2012; Whitehead & Drescher, 1980). This highlights its role as an indicator of a generalized sensitivity for visceral processes in situations evoking interoceptive signals (Herbert & Pollatos, 2012), even during food deprivation and while feeling hungry (Herbert,

Herbert, et al., 2012). The processing and perception of internal body signals seem to be crucial factors for EDs, and it has been suggested they might constitute preceding factors for eating behavior and body weight (Ainley & Tsakiris, 2013; Herbert & Pollatos, 2014; Klabunde, Acheson, Boutelle, Matthews, & Kaye, 2013; Pollatos et al., 2008). IS, indeed, is negatively correlated with self-objectification (Ainley & Tsakiris, 2013) and seems to contribute to the implicit processes related to bodily representation, which seems to be impaired in AN (Ambrosecchia et al., in preparation).

IS has been shown to interact with different aspects of human cognition and behavior, (for a review see Herbert e Pollatos, 2012). For instance, higher IS is associated to greater emotional experience (Herbert et al., 2007; Zaki et al., 2012) and a better regulation of emotions (Füstös et al., 2012; Herbert, Herbert, et al., 2012). It is involved in physiological reactivity towards emotional cues (Dunn et al., 2010), and, more generally, seems to contribute to the regulation of social behavior. There is, indeed a positive relation between individuals' interoceptive accuracy and their social anxiety level (Domschke et al., 2010; Terasawa et al., 2013).

Respiratory sinus arrhythmia (RSA) is one of the periodic components of heart rate variability, which tend to aggregate within several frequency bands (Berntson, 1997). It has been conceptualized as directly resulting from the interaction between the cardiovascular and respiratory systems (Grossman & Taylor, 2007). There is evidence suggesting that RSA response can be modulated by emotional processing (Porges & Smilen, 1994) and that is positively correlated with social disposition (Porges et al., 2013). RSA can be also considered as a marker for positive social functioning in healthy children (Graziano et al., 2007) and children with autism (Bal et al., 2010; Patriquin et al., 2013).

The relationship between IS and RSA in the context of real social interactions was the target of a recent study by Ferri et al. (2013), carried out on healthy individuals. This study showed that IS contributes to inter-individual differences concerning social attitudes and interpersonal space representation, via recruitment of different adaptive autonomic response strategies. Ferri et al., (2013) investigated whether IS to one's heartbeat predicted participants' autonomic response during social interactions occurring at different social distances. This was accomplished by measuring respiratory sinus arrhythmia (RSA) during either a Social or a Non-social task. In the Social task participants viewed the experimenter performing with his hand a caress-like movement at different distances from participants' hand. In the Non-social task a metal stick was moved at the same distances from participants' hand.

They found that only good heartbeat perceivers showed higher autonomic response in the social compared to the non-social setting, specifically, when the experimenter's hand was moving at the boundary of participants' peri-personal space (20 cm from the participants' hand). On the contrary, lower heartbeat perceivers were less predisposed to social engagement as they responded to the presence of the experimenter's hand as if it were very near to their own body (Ferri et al., 2013).

Although it has been demonstrated that AN exhibit a wide range of autonomic system disturbances which expose patients to high mortality risk due to cardio-vascular complications (for a review see Mazurak et al., 2011), the nature as well as the origin and pathogenesis of such changes are not absolutely clear. Moreover, to the best of our knowledge, the possible relation between IS and autonomic regulation both in resting state and in social contexts of AN have not been yet investigated.

To this aim we submitted both a group of healthy participants (HC) and a group of AN patients (restrictive type³) to a Physiological proxemics task (in which the ECG was recorded for the extraction of RSA), a modified version of a personal space regulation task used by Kennedy, Gläscher, Tyszka, & Adolphs (2009), in which participants were instructed to view, one by one, two female experimenters (the one obese, the one underweight) slowly approaching them from 470 cm across the room to a tip-to-tip distance (about 30 cm), or vice versa, slowly distancing from participants.

Since higher baseline RSA suggests the activation of the “vagal brake” to promote social disposition, emotion expression and self-regulation skills (Porges, 2009), and, on the contrary, lower baseline RSA interferes with the ability to regulate behavior to socially engage with others, we recorded 2 minutes of ECG in a resting state before (baseline) and after (recovery) the Physiological proxemics task.

Participants were also submitted to a Behavioral proxemics task in which we adopted the same procedure and trials of the Physiological proxemics task, but we did not record ECG, and asked participants to explicitly stop the experimenter as soon as she reached a distance at which they felt most comfortable.

In both these tasks, besides the Body Mass Index (BMI) of experimenters, the presence or the absence of their gaze toward the participant was also manipulated.

³ According to DSM V, the restrictive subtype of AN is characterized by the absence, during the last three months, of recurrent episodes of binge eating or purging behavior as self-induced vomiting or the misuse of laxatives, diuretics, or enemas.

To evaluate the IS, a well-assessed heartbeat perception task following the Mental tracking Method by Shandry, (1981) was administered.

Regarding IS, as in Ferri et al., (2013) we expected IS to predict RSA responses. Following Pollatos et al., 2008, we also hypothesized that AN patients should show lower IS than controls, lower baseline RSA and lower autonomic reactivity in the Social proxemics task when compared to HC.

Finally, we assessed whether the BMI and the presence or the absence of eye contact, which is an important cue for social interaction, could modulate RSA responses both in HC and AN. We finally expected the Behavioral proxemics task to help us to better interpret the physiological results.

3.2 Method

4.2.1. Participants

Twenty-two right-handed women with a diagnosis of Anorexia Nervosa, restrictive subtype according to the DSM V criteria (American Psychiatric Association, 1994) and 22 healthy right-handed women were included in the study. All patients (AN; mean age: 24.1 SE= 1.6; mean BMI: 16 Kg/m² ES= 1.1) followed a controlled diet for the ten days prior to the experiment in order to avoid the confounding effects of malnutrition on the performance.

Twenty healthy control participants (HC group) having a normal Body Mass Index (BMI comprised between 18.5 and 24.5) were matched with AN patients for age (mean age: 22 ES=8.6) and gender (all were women). At the time of the study, the mean BMI of the control group was 21 Kg/m² ES= 1.9. Exclusion criteria for both groups included actual or past cognitive disorders

(mental retardation), psychiatric disorders (psychosis), severe medical illnesses (head trauma, neurological and cardio-respiratory diseases, and diabetes), substance dependence, intake of medications altering the cardio-respiratory activity. As it is known that regular exercise influences autonomic tone, especially the vagal component (de Geus, Willemsen, Klaver, & van Doornen, 1995; Jurca, Church, Morss, Jordan, & Earnest, 2004), which in turn improves IS as assessed by heartbeat perception (Bestler, Schandry, Weitkunat, & Alt, 1990; Herbert et al., 2010), only individuals not regularly involved in athletic or endurance sports were recruited.

A further exclusion criterion for the control group was a personal history of eating disorders. Given the frequent comorbidity in AN with major depression or personality disorders, these were not comprised between exclusion criteria for AN patients. All participants gave their written informed consent for participation in the study.

Height and weight were assessed, and participants of both groups in a previous and separate session from the experiment filled in several questionnaires (see table 2) including the Eating Disorder Inventory (EDI-3), the Eating Disorder Examination Questionnaire (EDE Q), the Body Uneasiness Test (BUT), the Body Shape Questionnaire (BSQ), the Symptom Checklist-90 (SCL-90).

Since there is evidence suggesting that depression symptoms and RSA interact (Yaroslavsky, Rottenberg, & Kovacs, 2013, 2014), participants were required to fill in the Italian version of the Beck's Depression Inventory (BDI). The BDI is a widely used 21-item multiple-choice self-report inventory that measures the presence and severity of affective, cognitive, motivational, psychomotor, and vegetative symptoms of depression.

Similarly, because it has been shown that anxiety interacts with RSA (Gorka et al., 2013; Mathewson et al., 2013) and evidence suggests a positive association between cardiac awareness and anxiety (der Does, Willem, Antony, Ehlers, & Barsky, 2000; Pollatos et al., 2007; Pollatos, Traut-Mattausch, & Schandry, 2009) participants filled in the Italian version of the State-Trait Anxiety Inventory (STAI, Pedrabissi & Santinello, 1989). The STAI (Spielberger, 1983) is a 40 item scale, which assesses both state (this latter was administered during the experimental session) and trait anxiety. It represents well validated and reliable self-report measures of dispositional and state anxiety.

Table 2- Comparison between the two groups with respect to socio-demographic and questionnaire data (p.05 =*, pb.01 =**, pb.001 = ***)

	AN mean (SE)	HC mean (SE)	F(df=1,43)	p
Age	24.1 (1.9)	22 (0.6)	2.3	n.s.
BMI	16 (0.2)	21 (0.4)	94.1	***
Weight	43 (0.8)	57 (1.6)	59.1	***
Height	1.6 (0.01)	1.6 (0.01)	0.23	n.s.
DES	20.2 (3.7)	8.4 (1.6)	11.25	*
EDI 3	116 (3.6)	36.1 (6.2)	68.9	**
EDE- Q	52,9 (0.2)	2 (0.2)	37.7	***
SCL-90	107.2 (14.3)	52.9 (11.1)	8.9	***
STAI- State	41 (1)	42(0.8)	0.4	n.s.
STAI- Trait	47.4 (0.1)	43.4 (0.1)	13.08	n.s.
BDI	28.6 (2.6)	7 (1.2)	47.5	***
BUT (GSI)	3.3 (1.4)	0.9 (1.5)	2.5	***
BUT (D)	2 (0.2)	0.4 (0.1)	38.7	n.s.
BSQ	123 (7.8)	69.1 (6.3)	30.7	***

3.2.2. Procedure

Participants were required to abstain from alcohol, caffeine and tobacco for 2 hours prior to each session (Bar et al., 2010). After arrival at the laboratory for the first session, participants were asked to fill in the BDI and the State-Trait STAI (Pedrabissi et al., 1989). At the beginning and at the end of the experimental session, and after the Physiological proxemics task, a 2-minute resting baseline ECG recording was done, in which participants were instructed to quietly stand up with their shoulders leaning against the wall, and to look a blue circle in front of them.

Then, they were asked to perform, in the following order, the Physiological proxemics task, the Heartbeat Perception Task and the Behavioral proxemics task (Kennedy, 2009; see below and Figure 9 for a description of the tasks). All tasks were performed in a single experimental session during which participants were led into a quiet and softly illuminated room and were fitted with Ag-AgCl adhesive disposable electrodes for electrocardiogram (ECG). All recordings were performed in the same room, with participants instructed to relax and to remain as still as possible during recording to minimize motion artefacts. All measurements were done in a comfortable position for the participants.

A) Physiological proxemics task. Participants stood up at an end of a 470 cm strip previously placed on the floor, in a comfortable and relaxed position, leaning against the wall. Then, they were connected to the PowerLab for the ECG recording. The experiment consisted in two blocks in which a female experimenter slowly approached or distanced herself from the participant along the strip, (from 470 cm to approximately 30 cm, or vice versa, frontally). In the first block, the experimenter had an underweight BMI (Thin condition: 17.5 Kg/m²) and in the second block, the experimenter had an obese BMI (Fat condition: 34 Kg/m²). Both the experimenters were dressed in the same way, with a black tracksuit (see fig. 9). The order of the two blocks was counterbalanced across participants.

Participants were instructed to pay attention and always follow with their gaze the experimenter. They were reassured that the experimenter would have never touched them.

Each experimental block consisted of 16 trials, 4 for each condition presented in a random order. Following audio cues, each experimenter could move along the strip 1) starting from 470 cm to 30 cm from the participant and looking in the participant's eyes (Far-Eye condition); 2) starting from 470 cm to 30 cm from the participant glancing down (Far-No Eye

condition; 3) starting from 30 cm to 470 cm from the participant and looking in the participant's eyes (Near-Eye condition); 4) starting from 30 cm to 470 cm from the participant and glancing down (Near-No Eye condition). Each trial lasted 30 sec with an inter-trial of 15 sec.

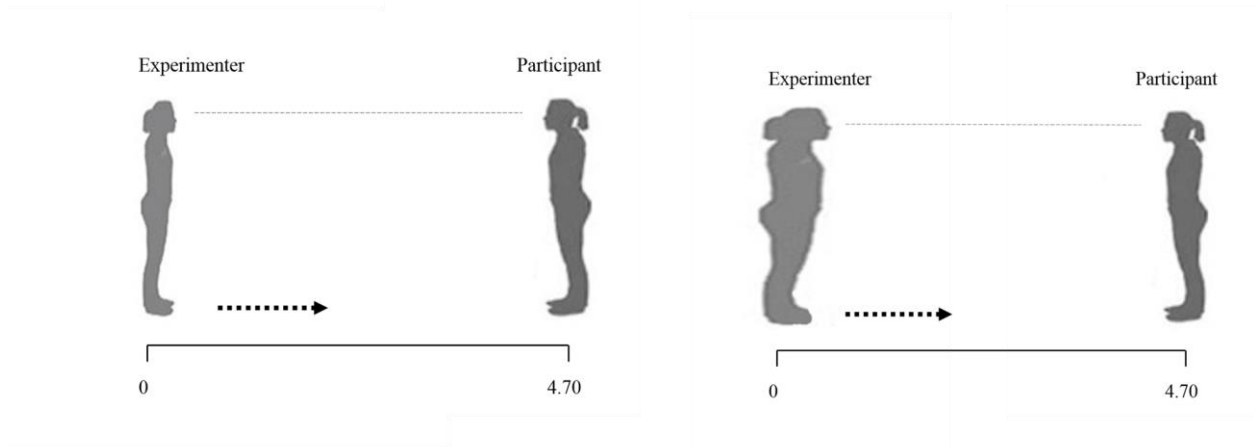


Figure 9 - Physiological and Behavioral Proxemics task.

B) Heartbeat perception task. Heartbeat perception was measured using the Mental Tracking Method (Shandry 1981) that has been widely used to assess IS, has good test–retest reliability (up to .81; Mussgay et al., 1999; Pollatos et al., 2007) and highly correlates with other heartbeat detection tasks (Knoll & Hodapp, 1992). Participants were instructed to start silently counting their own heartbeat on an audio-visual start cue until they received an audio-visual stop cue. After one brief training session (15 s), the actual experiment started. This consisted of four different time intervals of 140 s, 45 s, 35 s and 25 s, presented in random order across participants. Participants were asked to tell a second experimenter the number of heartbeats counted at the end of each interval. Throughout, participants were not permitted to take their pulse, and no feedback on the length of the counting phases or the quality of their performance was given. Heartbeat perception score was first calculated as the mean score of four heartbeat

perception intervals according to the following transformation (Shandry, 1981; Pollatos et al., 2008):

$$\frac{1}{4} \sum \left(1 - \frac{(|recorded\ beats - counted\ beats|)}{recorded\ beats} \right)$$

According to this transformation, heartbeat perception score can vary between 0 and 1, with higher scores indicating small differences between recorded and counted heartbeats (i.e., higher interoceptive sensitivity).

C) Behavioral proxemics task. In this third phase, the Physiological proxemics task was repeated but in this case participants stopped the experimenter at the distance at which they felt most comfortable. Shoulder-to-shoulder distance was recorded using a digital laser measurer. In this phase the ECG was not recorded (see fig.9).

4.2.3 Electrocardiogram (ECG) and Respiratory Sinus Arrhythmia (RSA) response

Three Ag/AgCl pre-gelled electrodes (ADInstruments, UK) with a contact area of 10 mm diameter were placed on the wrists of the participants in an Einthoven's triangle configuration to monitor ECG (Powerlab and OctalBioAmp 8/30, ADInstruments, UK). The ECG was sampled at 1 KHz and online filtered by the Mains Filter with negligible distorting effect on ECG waveforms. The peak of the R-wave of the ECG was detected from each sequential heartbeat and the R-R interval was timed to the nearest ms. The R-R intervals were edited. Editing consisted of a software artefacts detection (artefacts threshold 300 ms) followed by a visual inspection of the ECG recorded signal. Artefacts were then edited by integer division or summation.

The amplitude of Respiratory Sinus Arrhythmia (RSA) was quantified with CMetX (available from <http://apsychoserver.psych.arizona.edu>). This approach is a time-domain method but, like spectral techniques, allows derivation of components of heart rate variability within specified frequency bands (Berntson et al., 1997). The amplitude of RSA was assessed as the variance of heart rate activity across the band of frequencies associated with spontaneous respiration. RSA estimates were calculated using the following procedures (Allen et al., 2007) a) linear interpolation at 10 Hz sampling rate; b) application of a 241-point FIR filter with a 0.12–0.40 Hz band pass; c) extraction of the band passed variance; d) transformation of the variance in its natural logarithm. According to guidelines (Berntson et al., 1997), these procedures were applied to epochs of 30 sec, corresponding to the duration of each experimental trial. Then, RSA values corresponding to Thin/ Fat Far-eye, Far- no eye, Near- eye, Near No-eye conditions in each task were separately computed as the average of four 30 sec - epochs. Consistently, RSA values corresponding to baseline and recovery were computed as the average of the four 30 sec – epochs. Similarly, baseline RSA values were computed as the mean of four 30 sec – consecutive epochs. RSA response to Far-eye, Far- no eye, Near- eye, Near No-eye condition were then separately obtained for the two Thin/Fat blocks as changes from resting baseline RSA values to reactivity during each condition. Heart rate data were used for assessing the heartbeat perception score.

3.2.4 Data analysis

One participant of AN and 2 participants of HC group were excluded because of missing data.

An independent sample t-test was conducted to compare IS of AN patients and HC group. To investigate whether and to what extent heartbeat perception sensitivity predicts RSA response at baseline, we conducted a hierarchical regression (forward stepping) with RSA as criterion and

IS as predictor for both AN and HC. In order to analyze if the association between heartbeat perception score and RSA response was mediated by BMI, Anxiety, Depression, BMI, STAI score and BDI score were included as predictors. To assess the presence of significant differences between AN and HC in social disposition, we conducted two independent simple T-tests comparing RSA responses at baseline and recovery between the two groups.

It is well known that in situations demanding sustained attention, or with challenging stimuli, RSA is suppressed (Porges, 1995). To disentangle this possible confounding effect on our results, we contrasted Baseline and Recovery of each group carrying out an ANOVA with Condition (baseline vs. recovery) as within factor and Group (AN vs. HC) as between factor. If an attentional effect were present, Recovery should be significantly lower than Baseline.

Finally, to assess changes in autonomic reactivity and the behavioral responses both in AN and HC, data of the Physiological proxemics task and the Behavioral proxemics task entered in two repeated measures ANOVA with BMI (Fat vs. Thin), Distance (far vs. near) and Gaze (gaze vs. no gaze) as within factors and Group (AN vs. HC) as between factor. The Fisher test was used for all post-hoc comparisons.

3.3 Results

IS and RSA responses to baseline and recovery. The independent sample t-test confirmed the results of Pollatos et al., (2008). AN patients, indeed, showed a lower heartbeat perception score compared to HC ($t_{39} = 2.09$, $p < 0.05$; AN: mean = 0.45 SE = 0.05, HC: mean = 0.57 SE = 0.05; see fig. 10).

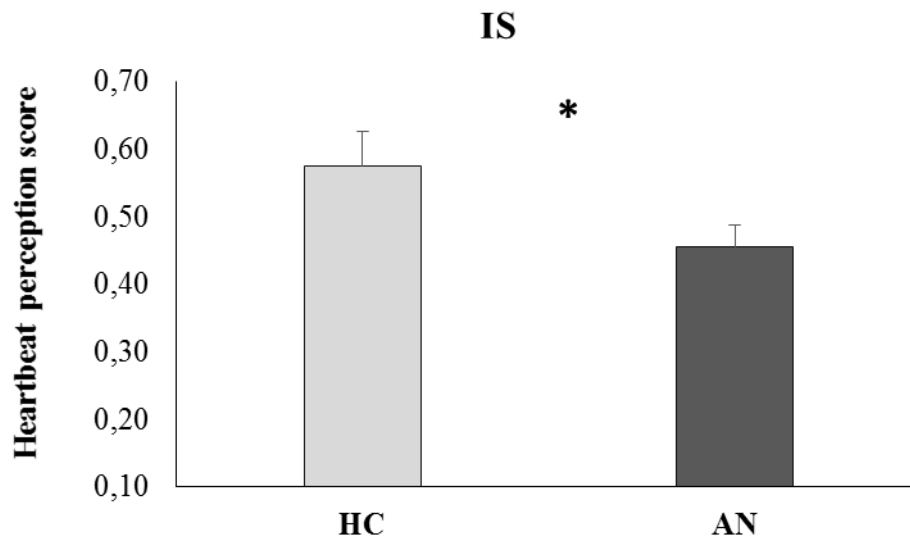


Figure 10- Heartbeat perception score of HC and AN. Error bars depict the standard error of the mean; * = $p < 0.05$

Hierarchical regression analyses (forward stepping) in HC demonstrated that the criterion RSA response at baseline condition was explained only by the heartbeat perception score ($t = 2.22$, $b = 1.62$, $p < 0.05$) explaining the 21% of the variance for the regression model ($F_{1, 18} = 5$, $p < 0.05$, $R = 0.46$, $R^2 = 0.21$). All other predictors (BMI, BDI score and STAI score) did not significantly predict RSA responses so that they were not included in the regression model. When the same regression analysis were conducted on RSA responses at baseline for AN group, neither IS nor all other predictors (BMI, BDI score and STAI score) significantly predicted RSA responses; they were thereby not included in the regression model (see fig 11).

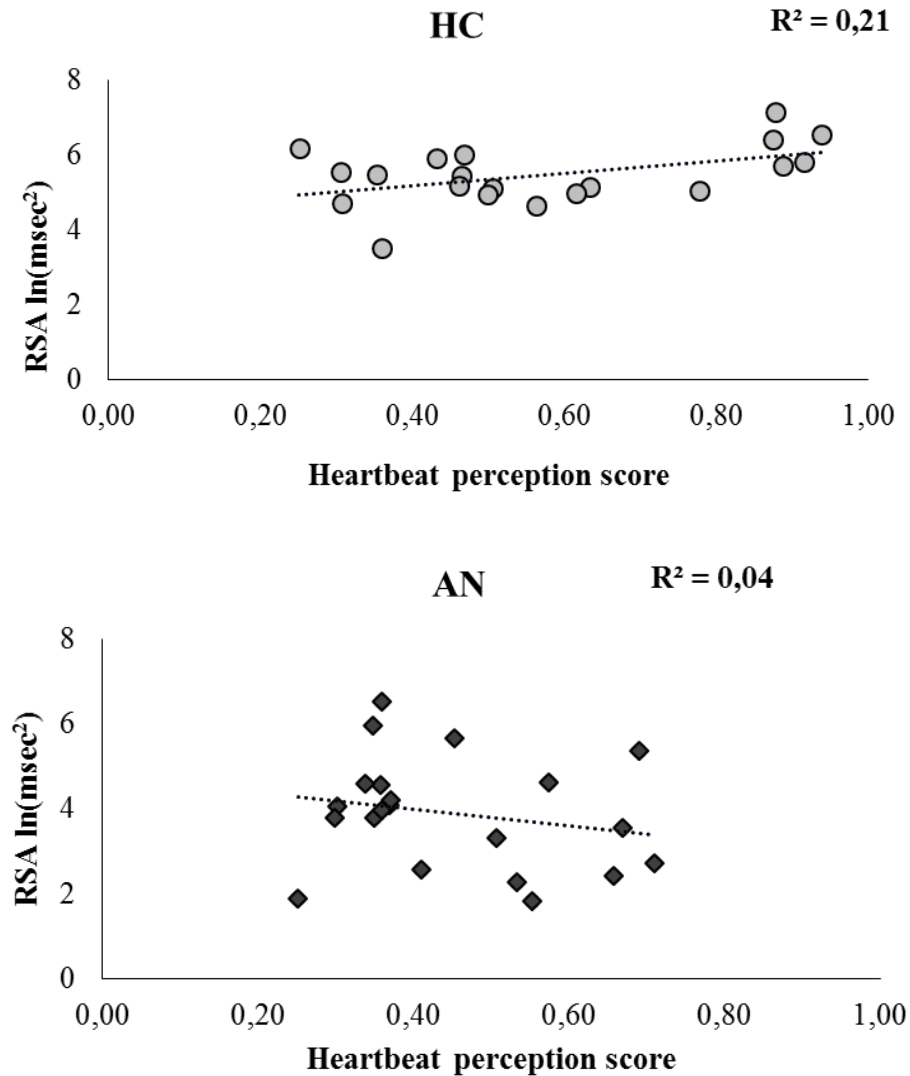


Figure 11- Linear regression plot showing the relation between IS and the RSA responses at baseline for each group of participants (AN e HC groups).

As previously hypothesized, the independent sample T-test conducted on RSA responses at baseline showed lower RSA responses for AN patients than HC group [AN: mean =3.9 ln(ms)²SE= 0.3; HC: mean =5.5 ln(ms)²SE= 0.2; $t_{39}=4.6$; $p<0.001$]. AN patients showed also lower recovery than HC [AN: mean =3.7 ln(ms)²SE= 0.3; HC: mean =5.4 ln(ms)²SE= 0.1; $t_{39}=4.6$; $p<0.001$] (see fig.12).

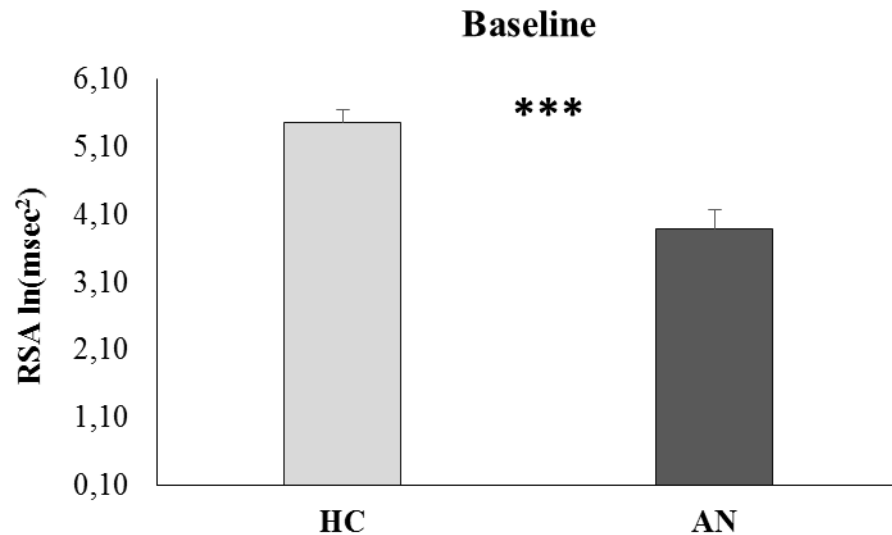


Figure 12- RSA responses at baseline of HC and AN. Error bars depict the standard error of the mean; *** = $p > 0.001$.

The ANOVA contrasting Baseline and Recovery of each group revealed only the main effect of group ($F_{1, 39} = 25.7$; $p < 0.001$) confirming lower RSA responses for AN than HC both in the baseline and in recovery conditions. The interaction between Group and Condition were not significant ($F_{1, 39} = 0.2$; $p > 0.6$) showing that RSA responses in baseline and recovery condition did not differ within each group.

Physiological proxemics task. The ANOVA revealed that the interaction among Group, BMI, Distance and Gaze was significant ($F_{1, 39} = 4.5$; $p < 0.05$), because of the greater RSA responses for the Thin-Far-Eye condition than all other conditions [mean = $-0.11 \ln(m)^2$; SE = 0.1; all p s < 0.05] showing an actual modulation across the experimental conditions only for HC (see fig.13).

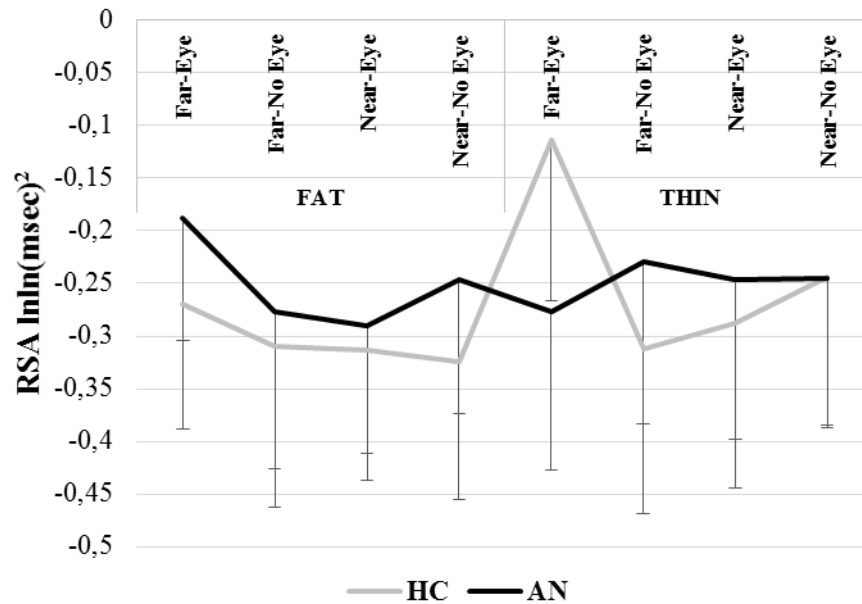


Figure 13- RSA responses during the Physiological proxemics task of HC and AN. Error bars depict the standard error of the mean.

Behavioral proxemics task. The main factors BMI ($F_{1,39} = 16.5$; $p < 0.001$), and Distance ($F_{1,39} = 12.44$ $p < 0.001$) were significant, showing that both groups felt comfortable with the thin experimenter, stopping her 16 cm closer than the fat one (Fat: mean = 137 cm SE=0.1 vs. Thin: mean= 122 cm, SE= 0.1; see fig. 4.4.5). Furthermore participants stopped 17 cm closer both the experimenters when they distanced from them (Far: mean= 121 cm SE=0.1vs. Near: mean=138 cm, SE= 0.1) (see fig. 14).

The interaction between BMI and Distance was significant ($F_{1,39} = 23.5$; $p < 0.001$) since participants felt more comfortable with both the thin and fat experimenter in the FAR condition than in the NEAR condition [(Fat-Far: mean= 123 cm, SE=0.1; Fat-Near: mean= 150 cm SE= 0.1; $p < 0.01$); (Thin-Far: mean= 120 cm, SE=0.1; Thin-Near: mean= 125 cm SE= 0.1; $p < 0.01$)].

Finally also the interaction between Distance and Gaze was significant ($F_{1, 39} = 7.24$; $p < 0.01$), showing that participants felt more comfortable with the fat experimenter approaching them glancing down (Far-eye: mean= 127 cm, SE= 0.1; Far-No-eye: mean=116 cm; $p < 0.01$). For the thin experimenter there was no difference between the Near-Eye and the Near-No Eye conditions (Near-eye: mean= 138 cm, SE= 0.1; Near –No-eye: mean=137 cm; $p < 0.8$).

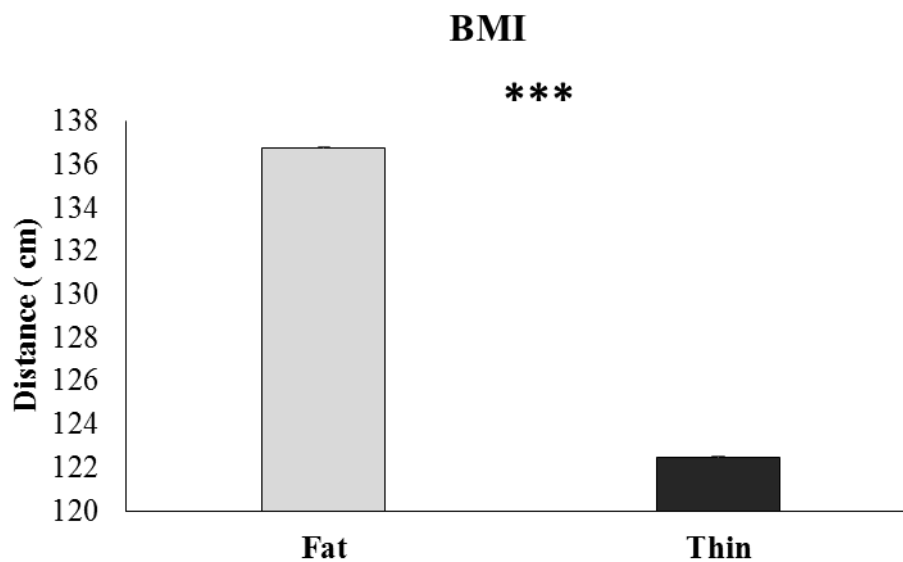


Figure 14- Responses during the Behavioral proxemics task of both HC and AN in function of the BMI condition. Error bars depict the standard error of the mean. *** = $p > 0.001$.

3.4 General Discussion

The capacity to adapt to social settings does not merely reflect high sensitivity in assessing information from the external environment, but also from the inner body. We aimed to investigate the relationship between IS and autonomic functioning, in a population of patients – Anorexic patients – whose ability to perceive their bodily signal is impaired (Pollatos et al., 2008). Furthermore, we investigated the autonomic reactivity of AN during social interactions.

To this purpose we submitted both HC and AN patients to a well assessed heartbeat perception task (Shandry, 1981). Then, we recorded their RSA responses during both resting state and social interaction (Physiological proxemics task), and, to better interpret our results, we submitted participants to an “overt” behavioral version of the Physiological proxemics task.

Our results not only confirm those of Pollatos et al., (2008) showing that AN patients suffer of a reduced capacity to accurately perceive their bodily signals, but they also demonstrate that this capacity may be strictly related to social disposition (as measured by RSA responses at baseline). Heartbeat perception score, indeed, predicted, at baseline, higher RSA responses in HC, but not in AN patients, whose RSA magnitude resulted also significantly lower. The observed relationship between IS and RSA responses for HC remains significant even after controlling for possible confounding variables as BMI, anxiety and depression. Since higher baseline RSA is an index of self-regulation and social disposition, and higher baseline RSA is considered a marker of positive social functioning in autism (Bal et al., 2010; Patriquin et al., 2013), our results revealed a lower social disposition in AN patients than HC.

This interpretation is corroborated by RSA responses in social context as the Physiological proxemics task in which AN patient showed a flattened autonomic reactivity across experimental

conditions. AN patients seem not to be engaged in social interactions; they did not respond differently to the presence of two different experimenters, and to the manipulation of significant social cues as social distances and the eye contact (for a review see Kleinke, 1986) with the experimenter.

On the contrary, HC showed a better autonomic reactivity in response to social stimuli, with higher autonomic reactivity in the condition in which the underweight experimenter approached them keeping the eye contact, which has a crucial role for the relevance and intention of social stimuli (Carlston, 2013).

It is possible, however, that the higher RSA could also reflect effortful emotion regulation in presence of a moderately stressful stimulus, caused by social anxiety or by unpleasantness. We can exclude this interpretation of our results for the following reasons: First, regression analysis revealed that participants' anxiety did not significantly contribute to the association between IS and RSA response; Second, the Behavioral proxemics task showed that both AN and HC felt more comfortable when interacted with the thin experimenter than with the fat one.

Our findings are coherent with Ferri et al., (2013). They found that on the one hand people with lower IS are harder to engage in social interactions, while on the other, good heartbeat perceivers showed higher social disposition (Ferri et al., 2013).

The last point to be addressed is the overt judgment of comfort in defining social distances, in which both AN and HC (the latter showed also a coherent autonomic response), felt less comfortable with the obese experimenter, stopping her at closer distances only when she was glancing down. These results could reflect the internalization of cultural beliefs related to obese individuals, who are perceived to be less attractive than their thinner counterparts (Harris 1990;

Puhl and Heuer 2009; Sobal 2005). A recent study indeed showed that medical students' level of visual contact with their patient differed depending on the patient's weight (Persky et al., 2010). This might be true even more so within AN patients and a sample of very young females, for whom thinness is an ideal to achieve.

Taken together, our results confirm the relationship between IS and autonomic correlates of social interaction. They also suggest that the attenuated capacity to perceive themselves might account for the affected autonomic regulation of AN patients and their autonomic reactivity in social context.

Furthermore, since IS could also affect cognition or behavior (Cameron 2002), bodily self-recognition (Ambrosecchia et al., in preparation) and emotional responses (Herbert et al., 2012; Herbert et al., 2010b; Herbert et al., 2007b), several other deficits of AN may be related to anorexics' attenuated sensitivity to their bodily changes, like alexithymia and body size overestimation. (Ambrosecchia et al., in preparation).

A possible limitation of this study is the limited sample of patients, however we believe that our study contributed to shed new light on the role of IS in the autonomic regulation in AN disorder.

4 General discussion and conclusions

Previous studies on healthy controls (HC) demonstrated the existence of a pre-reflective motor experience of the bodily self, resulting in an implicit advantage for self compared to others' body parts (Ferri et al., 2011). The first aim of my thesis (see chapter two) was to assess in HC and AN patients whether and to which level the perceived size of hands stimuli could modulate both explicit and implicit Self-recognition. The second aim of my thesis was to investigate whether the overestimation of AN patients' body size could extend to the motor representation of the bodily self, influencing the implicit self-advantage.

To these aims, following the procedure of Ferri et al., (2011), we submitted a group of AN patients and a group of HC to a hand laterality judgment task (Implicit task) of their own or others' hands stimuli. This task required a mental motor rotation of their own body parts (Decety et al., 1991; Jeannerod & Pacherie, 2004; Parsons, 1994; Porro et al., 1996). The same participants were then submitted to an Explicit task which relies upon different cognitive and/or perceptually-based mechanisms and where the recognition of self-body part was explicitly required. We edited the hand pictures in order to obtain a "Weight gain" and a "Weight loss" effect.

Our results confirmed in HC the dissociation between implicit and explicit Bodily-Self recognition found in Ferri et al., (2011, 2012), resulting in a self-advantage only when a motor simulation is required, and in its lack when an explicit discrimination between self and others' hands is being made, leading to a sort of "other advantage". Despite our expectations, in HC in the implicit task we found a clear self-advantage only for the right hand slightly fatter stimuli (2-4% fatter), but not for the original size stimuli. We interpreted these results in line with those of Longo et al., (2010) who found a distorted implicit map of the mental representation of hand size and shape, retaining several characteristics of primary somatosensory representations, such as the

Penfield homunculus. We also speculated an affective involvement influencing the bodily self-processing (Devue et al., 2007). In any case a self-advantage for hand stimuli at the slightly fatter condition supports our view that in HC the perceived size of one's body parts affects motor simulation, which in turn modulates implicit Bodily Self recognition.

Regarding AN patients, our results demonstrated that the disturbed experience of body size in AN is more pervasive than previously assumed and might rely – at least partly – upon an impaired implicit and motor-based representation of the body.

The third aim of my thesis was to explore the possible relationship between IS – another important component of self-awareness –and the motor-based experience of the bodily self in HC and AN patients. To assess IS we used the well-assessed Heartbeat perception task (e.g. Shandry 1981). Although we did not find in either group a direct relationship between IS and the implicit self-advantage, in HC we found that IS predicts the ability to execute a hand mental rotation (Implicit task: higher IS, faster RTs). Such relationship was lacking in AN patients.

We found, as in Pollatos et al., (2008) a significantly lower IS in AN than in HC, suggestive of a generalized reduction in AN patients of the ability to perceive bodily signals We speculate that it could have associated consequences, like the potential for body feedback misinterpretation. Accordingly, we found that the higher the value of IS, the lower the number of self-omissions, in which participants tend to attribute their body parts to other people. Moreover, AN patients beside failing in recognizing their own body parts from those of others as HC did, also tended to misattribute other people's body parts to themselves, resulting in a higher percentage of self-misattribution than HC. In the same vein Ainley and Tsakiris, (2013) found that lower IS predict a higher self-objectification (Friedrickson et al., 1997; the tendency to experience one's body principally as an object, in a third-person perspective, by diverting attention to the 'seen' body,

probably at the expense of attending to the inner body). In other words, we demonstrated that low IS might account for the weaker self-advantage in AN patients. Hence, the distorted body representation of AN is not only due to psycho-affective and perceptive factors, but also to impaired processing of body dimensions, likely because of alterations in the sensory-motor network mapping the bodily self as power for action.

The fourth aim of thesis (see the second study of chapter 3) was to investigate the relationship between IS and autonomic functioning, in a population of patients – Anorexic patients – whose ability to perceive their bodily signal is impaired (Pollatos et al., 2008).

To this purpose we submitted both HC and AN patients to a well assessed heartbeat perception task (Shandry, 1981). Then, we recorded their RSA responses during both resting state and social interaction (Physiological proxemics task), and, we submitted participants to an “overt” behavioral version of the Physiological proxemics task.

Our results not only confirmed those of Pollatos et al., (2008) showing that AN patients suffer of a reduced capacity to accurately perceive their bodily signals, but they also demonstrate that this capacity may be strictly related to social disposition (as measured by RSA responses at baseline). Heartbeat perception score, indeed, predicted, at baseline, higher RSA responses in HC, but not in AN patients, who showed significantly lower RSA.

We also found, in the social proxemics task, a flattened autonomic regulation in AN compared to HC. In other words, coherently with Ferri et al., (2013), people with lower IS (in our case, AN patients) are harder to engage in social interactions, while on the other hand, good heartbeat perceivers showed higher social disposition (Ferri et al., 2013).

In conclusion, our results demonstrate the relationship between IS and autonomic correlates of social interaction. They also suggest that the attenuated capacity of anorexic patients to perceive themselves might account for their affected autonomic regulation and autonomic reactivity in social context.

Our findings highlight also the internalization of cultural beliefs related to obese individuals, who are perceived both for AN and HC to be less “attractive” than their thinner counterparts (Harris 1990; Puhl and Heuer 2009; Sobal 2005) in the overt judgment of social distances.

In the light of our results, AN disorder might have deeper roots encompassing the relationship between two core aspects of self-regulation: interoception and the implicit motor experience of the body. AN patients’ blunted interoceptive sensitivity might have a pivotal role in the lack of the implicit, pre-reflective sense of self as power for action (Gallese & Sinigallia 2010), which leads to a less efficient self/other distinction. The lack of contact with the inner body might also account for the affected autonomic regulation of AN patients and their autonomic reactivity in social contexts. Therefore, we can conclude that AN, far from being just a body image disorder, could be considered as a pervasive self disorder.

Since, as previously demonstrated, AN patients did not show any self-advantage in the implicit task, it would be interesting to carry out an fMRI study using the same paradigm used in Ferri et al., (2012) to evaluate the possible alterations of the sensory-motor neural network of the bodily self (encompassing the SMA and pre-SMA, the anterior insula, and the occipital cortex bilaterally, premotor cortex controlling the dominant hand) and to assess whether these alterations could affect to a greater extent the anterior insula, which is part of the putative “interoceptive neural network” (Herbert et al., 2012).

Since AN patients suffer from self-objectification (Friedrickson et al., 1997; the tendency to experience one's body principally as an object, in a third-person perspective, by diverting attention to the 'seen' body, probably at the expense of attending to the inner body), and IS negatively correlated to it (Myers et al., 2008), future experiments should assess the neural and autonomic correlates of self-other distinction. To this purpose, we might investigate, for example, the possible differences between AN patients (experiencing self-objectification) and HC individuals in neural activation and autonomic reactivity during social interactions between participants and their own body or someone's else body approaching them, by means of immersive virtual reality.

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