A behavioural investigation into body misperception in eating disorders

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Abstract

Over the last few decades, clinical and experimental psychologists have paid increasing attention to the study of body misperception in Eating Disorders (EDs). EDs are a family of psychopathologies characterized by disordered eating accompanied by alterations in body image and perception. EDs have been linked to severe impairments in psychosocial functioning, and show the highest mortality rate of any other psychiatric disorder. However, existing treatments are limited in their effectiveness, with low recovery and high relapse rates. A better understanding of body misperception in EDs may be therefore pivotal for the development of more targeted treatment programs.

Recent research has suggested body misperception in EDs to be better conceptualized as a general impairment in the multisensory perception of the body, as indicated by abnormalities in the processing and integration of multisensory information. This thesis attempts to contribute to the current state of knowledge on perceptual processes and multisensory integration in the context of EDs. (i) Specifically, the first aim of this thesis was to investigate whether participants presenting with high levels of ED symptoms would show alterations in visuo-tactile multisensory integration. Visuo-tactile multisensory integration was assessed using the Somatic Signal Detection Task (SSDT; Lloyd et al., 2008), which involves detecting very subtle tactile vibrations in the presence or absence of a concomitant light. (ii) The second aim of this thesis was to assess whether exposure to the vision of the body during the SSDT would influence participants' performance, and whether this effect would be different in high versus low ED symptomatic participants. (iii) A third aim was to investigate the effects of an off-line manipulation alternative to exposure to the vision of the body during the SSDT. Specifically, whether a caress-like tactile manipulation intervention (i.e., affective touch) could alter subsequent SSDT performance as compared to a neutral condition. (iv) Lastly, the contribution of physiological arousal in explaining participants' heterogeneity of responses in SSDT performance was investigated.

In Experiment 1, 27 women reporting low ED symptoms, versus 26 women reporting high ED symptoms, undertook a face-version of the SSDT, which involved detecting tactile stimuli on the cheek in the presence or absence of a concomitant light. The SSDT was completed while looking at a photograph of one's own face (vision of the body), another female face (control condition), and a scrambled face (control condition). Heart rate and skin conductance levels (SCLs) were recorded continuously during the SSDT as indices of physiological arousal. High ED participants were found to be differentially affected by

exposure to the vision of the body. For the high ED group, physiological arousal (SCLs), and tactile sensitivity were increased when exposed to the vision of their own face. Conversely, for the low ED group, physiological arousal (SCLs) and sensitivity were higher in the other two control conditions. In those with high ED symptoms, exposure to the vision of the body may exacerbate a predisposition to focusing on external bodily information, such as tactile stimuli.

In Experiment 2, 31 women reporting low ED symptoms, versus 34 women reporting high ED symptoms, undertook a version of the SSDT which involved detecting tactile stimuli on the fingertip in the presence or absence of a concomitant light. Participants completed the SSDT while their hand was visible (vision of the body), and while their hand was hidden from the sight (no vision). In agreement with results of Experiment 1, vision of the body was found to have a different effect on SSDT performance according to participants' levels of ED symptoms. High ED participants were better able to correctly detect the touch during the SSDT when their hand was visible. Conversely, for low ED participants, vision of the body was linked to a greater effect of the light in inducing false reports of touch. Results of Experiment 2 were in line with the previous suggestion that in those with high ED symptoms, vision of the body may exacerbate a predisposition to focusing on external information.

The aim of Experiment 3 was to investigate the effects on SSDT performance of an alternative off-line manipulation that can possibly alter multisensory processes; that is affective touch. Affective touch refers to a slow caress-like touch that has been linked to perceived pleasantness and to the activation of a specialised system of nerves (the CT system; Loken et al., 2009; McGlone et al., 2014). Affective touch has been also shown to play an important role in the building of the bodily self: the multisensory integrated global awareness of one's own body (Ciaunica & Fotopoulou, 2017; Crucianelli et al., 2013). In this experiment, it was tested whether receiving affective touch could enhance tactile accuracy in the subsequent multisensory task of the SSDT. Participants repeated the SSDT twice, before and after receiving either affective touch (CT optimal; n = 32), or non-affective touch (non-CT optimal; n = 34). Levels of arousal (skin conductance levels, SCLs) and mood changes after the touch manipulation were also measured. Affective touch led to an increase in tactile accuracy, as indicated by less false reports of touch and a trend towards a higher tactile sensitivity during the subsequent SSDT. Conversely, non-affective touch was found to induce a partial decrease in the correct detection of touch possibly due to a desensitization of skin mechanoreceptors. Both affective and non-affective touch induced a more positive mood and higher SCLs in participants. The increase in SCLs was greater after affective touch. It was concluded that receiving affective touch enhances the sense of a bodily self therefore increasing perceptual accuracy and awareness. Higher SCLs are suggested to be a possible mediator linking affective touch to a greater tactile accuracy. Clinical implications in the context of EDs are discussed.

In Experiment 4, a correlational study was performed clustering together some of the data of Experiment 1 and 3 to systematically investigate the relationship between SSDT performance, and participants' ED and ED-related symptoms and physiological arousal (skin conductance levels, SCLs). Results showed a trend for SCLs to be partially associated with a more accurate perception of the touch during the SSDT. Moreover, it was found that the presence of the light during the SSDT induced an increase in participants' reports of touch from light-absent to light-present trials, which was stronger for those participants reporting higher ED symptoms. This is in line with the prior observation that ED patients tend to place a greater focus on visual information over other sensory information.

Taken together, the main results of this thesis suggest that multisensory information is indeed processed and integrated differently by women presenting with different levels of ED symptoms. It is hypothesised that, in a multisensory context, ED symptoms are associated with a greater tendency to focus on external perceptual information to the detriment of internal bodily signals. Moreover, this tendency may get exacerbated by exposure to the vision of the body. Results of this thesis have also opened the way for further research into a possible use of affective touch to address alterations in multisensory integration in EDs.

Declaration

I declare that this thesis represents my own work, and it has not previously been submitted or an award.

The study presented in Chapter 3 has been published in:
Sacchetti, S., Mirams, L., McGlone, F., & Cazzato, V. (2020). Self-focused attention enhances tactile sensitivity in women at risk from eating disorders. *Scientific reports*, *10*(1), 1-15.

The study presented in Chapter 4 has been published in:

Sacchetti, S., Cazzato, V., McGlone, F., & Mirams, L. (2021). In your eyes: Vision of the body alters touch perception in women with Eating Disorder symptoms. *Psychological Research*.

Aspects of the studies presented in Chapters and 4 have been published in:
Sacchetti, S. & Cazzato, V. (2020).Why looking in the mirror is so hard for people with eating disorders. *The Conversation*. Retrieved in: https://theconversation.com/why-looking-in-the-mirror-is-so-hard-for-people-with-eating-disorders144758?fbclid=IwAR29qnJq y3QBQxonFJ538dNTyIp1lIMAsAnxEUep9xrNjsxoVdE2x1DML9M

The study presented in Chapters 5 is under review for publication in:

Sacchetti, S., McGlone, F., Cazzato, V., & Mirams L. (under review). The impact of affective touch on multisensory integration and tactile perceptual accuracy during the somatic signal detection task. *Plos One*.

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Aspects of the studies presented in Chapters 3, 4, 5 and 6 have been presented at the following conferences and workshops:

- Sacchetti, S., Cazzato, V. McGlone, F, & Mirams, L. (2018). Feeling the body, losing the body: altered interoception and touch perception in relation to Eating Disorder risk. Poster presented at the doctoral academy research conference, Liverpool John Moores University, Liverpool, 9 May 2018.

- Sacchetti, S., Cazzato, V. McGlone, F, & Mirams, L. (2018). Feeling the body, losing the body: altered interoception and touch perception in relation to eating disorder risk. Poster presented at the faculty of science research seminar day, Liverpool John Moores University, Liverpool, 18 June 2018.
- Sacchetti, S., Cazzato, V. McGlone, F, & Mirams, L. (2018). Inside and outside: Erroneous reports of touch sensation and interoceptive accuracy is linked to body image concerns. Poster presented at the Body Representation Network (BRNet) workshop Multi-faceted body: Updates into body representation and embodiment research workshop, Heriot-Watt University, Edinburgh, 29 June.
- Sacchetti, S., Mirams, L., McGlone, F, & Cazzato, V. (2019). Eyes on me: The effect of self-focused attention on touch perception and its association with interoceptive accuracy and eating disorder symptoms. Poster presented at the International conference of psychological science (ICPS), Paris, 7-9 March 2019.
- Sacchetti, S., Mirams, L., McGlone, F, & Cazzato, V. (2019). The effect of self-focused attention on touch perception and its association with eating disorder risk. Poster presented at the doctoral academy research conference, Liverpool John Moores University, Liverpool, 9 May 2019.
- Sacchetti, S., Mirams, L., McGlone, F, & Cazzato, V. (2019). The effect of self-focused attention on touch perception and its association with eating disorder risk. Oral presentation at the faculty of science research seminar day, Liverpool John Moores University, Liverpool, 11 June 2019.
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- Sacchetti, S., Mirams, L., McGlone, F, & Cazzato, V. (2019). The effects of CT optimal touch on multisensory integration, arousal and mood, using the Somatic Signal

Detection. Poster presented at the International association for the study of affective touch (IASAT), Sweden, 11-13 September 2019.

- Sacchetti, S., Mirams, L., McGlone, F, & Cazzato, V. (2021). Eyes on me: The effect of self-focused attention on touch perception and its association with eating disorder symptoms. Poster presented at the Eating Disorders International Conference (EDIC), 20-21 January 2021.

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Chapter 1

General introduction

The aim of the work presented here was to investigate somatic perception and misperception in Eating Disorders (EDs) using a signal detection methodology. Previous research on body misperception in EDs has shown EDs to be characterized by alterations in the body image, encompassing negative thoughts and feelings towards the body, and overestimation of body size. However, it has been recently suggested that body misperception in EDs may be more profound than previously recognised, involving also primary perceptual processes and multisensory integration. The current thesis aims to build upon this suggestion by investigating the integration of tactile and bodily and non-bodily related visual information. In this chapter, a definition of EDs is presented (Section 1.1). In Section 1.2, the criteria defining EDs are problematized, and limitations of available treatments are discussed. In Section 1.3, 1.4 and 1.5 different domains of body misperception in EDs are described (i.e., from alterations in the visual aspects of body image to abnormalities in multisensory integration). Section 1.6 outlines the role of vision of the body in perceptual processes, and in relation to EDs. Lastly, in Section 1.7, the aims and methodology of the research presented in this thesis are outlined.

1.1 Definition of Eating Disorders

1.1.1 International diagnostic criteria

Eating Disorders (EDs) are a family of psychopathologies that are overall characterized by disordered eating, weight and body shape concerns and body image disturbances. Until recently, that is until the Fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; APA, 2000), the chapter of "Eating Disorders" included only three diagnostic categories: Anorexia Nervosa (AN), Bulimia Nervosa (BN) and the Eating Disorder Not Otherwise Specified (EDNOS). However, research suggested that according to this classification, the majority of individuals seeking treatment for an ED were classified as EDNOS, which was deemed to be a heterogeneous residual category providing little clinical utility (Call et al., 2013; Le Grange et al., 2012; Smink et al., 2012). For example, in a nationwide study of adults and adolescents in the United States, Le Grange and colleagues (2012) found that 80.97% of adolescents and 75.38% of adults with an ED were classified as having EDNOS, making it overwhelmingly the most commonly diagnosed ED.

To overcome this issue, a DSM task force, the Eating Disorders Work Group, redefined the family of EDs. In the last and Fifth edition of the DSM (APA, 2013), the chapter has been restructured under the name of "Feeding and Eating Disorders" (FEDs), criteria defining AN and BN have been slightly amended, and additional diagnoses have been included in the chapter. Specifically, the DSM 5 FEDs chapter now encompasses avoidant/restrictive food intake disorder (ARFID), rumination disorder (characterized by repeated regurgitation of food), and the pica (characterized by a persistent eating of non-nutritive, non-food substances), which were previously categorized in the section "Feeding and Eating Disorders of Infancy or Early Childhood" (APA, 2013; ICD-11, 2018).

Alongside, Binge Eating Disorder (BED), which was previously considered an EDNOS, has been formally recognized as an ED. Another two possible diagnoses conclude the chapter, which are the Other Specified Feeding or Eating Disorder (OSFED) and the Unspecified Feeding or Eating Disorder (UFED). Both diagnoses encompass residual clinical cases that do not meet the full criteria for any of the disorders in the FED diagnostic class. However, the former label is used in situations in which it is possible to report a diagnosis and specify the criteria that are not met, while the second is preferred when there is insufficient information to make a more specific diagnosis (APA, 2013).

The DSM 5 classification of FEDs is in agreement with the classification reported in the last version of the International Classification of Diseases-11 (ICD-11; 2018), which indeed includes the diagnoses of AN, BN, BED, ARFID, rumination-regurgitation disorder, pica, other specified FED, and unspecified FED.

Although the proliferation of ED diagnostic labels was posited as one of the goals for the DSM 5 with the aim to identify clear-cut psychopathological profiles, the different ED diagnoses continue to share different diagnostic criteria making the boundaries between diagnoses still tenuous. The key diagnostic features of the main EDs are presented in Table 1 (Hay, 2020).

Table 1.1

Key diagnostic features of the main feeding and eating disorders according to international DSM 5 and ICD-11 criteria

	Anorexia Nervosa	**Bulimia Nervosa**	**Binge Eating Disorder**	**Avoidant/restrictive food intake disorder**
Eating	Severe restriction	Irregular, skipping meals common as well as restriction	Irregular but no extreme restriction	Severe restriction of all or selected foods
Binge Eating	May occur	Regular with compensatory behaviours	Regular without compensatory behaviours	NA
Weight	Underweight	Normal or above normal	Normal or above normal	Underweight and/or with nutrition deficiency
Body Image	Overvaluation with or without 'fear of fatness'	Overvaluation	Overvaluation but not mandatory	No overvaluation
Purging, fasting, driven exercise weight control behaviour(s)	One or more is present	Regular as compensatory behaviours after binges	Not regular	None

As reported in the table, both AN and BN patients are characterised by the presence of an overvaluation of body weight and shape, which are considered of paramount importance to determine self-worth. Specifically, AN and BN patients usually present with an internalised ideal of thinness which is associated with extreme weight-control behaviours (restriction of food intake and/or compensatory behaviours such as purging and compulsive exercise). In both disorders, the presence of body image concerns is a mandatory diagnostic criterion. It most commonly takes the form of overvaluation of weight and shape, which in turn is linked to a negative self-worth evaluation. AN is described as a condition of self-starvation, where patients are underweight and engage in behaviours to prevent weight gain. AN diagnosis includes patients who do and do not binge eat or purge (i.e., induce vomiting or misuse laxatives/diuretics). Conversely, BN is defined by the presence of cycles of binge eating and compensatory behaviours (purging and/or fasting/compulsive exercise), and women with BN usually present with a weight within the normal range. Unlike AN and BN, BED and ARFID are the first FEDs that do not have body image concerns as core diagnostic criteria. The former is characterised by the presence of recurrent binge eating without regular purging, while the latter of avoidance and aversion to food and eating (APA, 2013; ICD-11, 2018; Hay, 2020).

1.1.2 Prevalence and Mortality Rate

According to the DSM 5, the 12-month prevalence of AN and BN (i.e., the proportion of people presenting AN or BN symptoms in a window of 12 months) among young women are respectively 0.4% and 1%-1.5%. Less is known about prevalence among men. However, the DSM 5 posits that both AN and BN are far less common in men than in women, with clinical populations reflecting approximately a 10:1 female-to-male ratio. Moreover, as reported in the DSM 5, the 12-month prevalence of BED among U.S. adult women and men is 1.6% and 0.8%, respectively, with a gender ratio far less skewed in BED as compared to AN and BN (APA, 2013). Recent systematic reviews have expanded on these data by analysing the prevalence of EDs across the life span. Results showed the lifetime prevalence of AN to be 1.4% (0.1–3.6%) for women and 0.2% (0–0.3%) for men. The lifetime prevalence for BN has been found to be slightly higher with 1.9% (0.3–4.6%) for women and 0.6% (0.1–1.3%) for men. Lastly the lifetime prevalence for BED has been found to be the highest with 2.8% (0.6–5.8%) for women and 1.0% (0.3–2.0%) for men (Smink et al., 2012; Dahlgren et al., 2017; Galmiche et al., 2019). The prevalence of the ARFID, alike the prevalence of pica and the rumination disorder, is still unclear as the inclusion of these diagnoses within the family of FEDs is fairly recent (APA, 2013). Coherently, the data on BED should be interpreted cautiously, as research on this diagnosis is more recent when compared to research on AN and BN.

Lastly, it should be noticed that research on male populations of ED patients is also novel. Indeed, until the fourth edition of the DSM (APA, 2000) criteria defining EDs were outlined based on the observation of female patients only. For example, one of the criteria defining AN was the presence of amenorrhea, which is now, in the DSM 5 (APA, 2013), no longer a mandatory criterion owing to its lack of applicability in men. However, it has been argued that EDs have different phenomenological and behavioural manifestations in males that have been overlooked by researchers and that are still not accommodated in the current ED classification schemes (Murray et al., 2017). Therefore, female-to-male ratios may be biased towards an underestimation of male patients driven by the fact that diagnostic criteria tend to be more representative of females.

The prevalence of EDs, and specifically of AN, in Europe rose significantly between 1960 and 1970, and since then seems to have been rather stable, with small regional fluctuations (Van Son et al., 2006; Hoek, 2006, Smink et al., 2012). EDs are associated with a general decrease in the quality of life, and significant impairments in psychosocial functioning and physical health, with problems affecting mainly the gastrointestinal, the cardiac, and the endocrine systems (APA, 2013; Jenkins et al., 2011; Smink et al., 2012).

Indeed, EDs have shown the highest mortality rate of any mental illness. Among the different ED diagnoses, AN has been found to show the highest mortality rate with a weighted crude mortality rate (CMR) of 5.1 (95 % CI: 3.99-6.14) per 1000 person-years, which means that 0.51 % of AN patients die per year (around 5% per decade). One in five individuals with AN who died had committed suicide, indicating a high suicide risk in AN. However, in the majority of AN patients, death results from medical complications associated with the disorder itself. BN has been found to have a lower mortality rate with a weighted CMR of 1.74 (95 % CI: 1.09-2.44) per 1000 person-years, translating into 0.17 % deaths per year (around 2% per decade). Given the recent introduction of the other FEDs diagnoses, less is known about the associated mortality rate (APA, 2013; Arcelus et al., 2011; Smink et al., 2012).

1.2 Limitations in the definition and treatment of Eating Disorders

As previously mentioned the different ED diagnoses show several commonalities and overlapping symptomology that blurs the dividing lines between diagnoses. In addition, ED patients have been found to be characterized by a strong diagnostic instability, with patients diagnosed with one ED often showing symptoms of other ED diagnoses either concurrently or later in life (Tozzi et al., 2005; Castellini et al., 2011). Symptomatic proximity, high comorbidity and diagnostic crossover have led authors from different psychological schools to consider EDs as a continuum spectrum rather than as distinct diagnoses (Aquilar, 2005; Comer, 2012).

Following this line of reasoning, Fairburn (one of the main exponents of the cognitive-behavioural approach applied to EDs) has formulated a transdiagnostic cognitive-behavioural theory (CBT-E) that considers EDs as a single psychopathological category with different phenomenological manifestations (Therefore considering EDs as a spectrum; Fairburn & Harrison, 2003). Similarly, psychoanalytic approaches to the treatment of EDs shift their focus of attention from phenomenological and symptomatic manifestations of EDs to underlying mechanisms that are transdiagnostic (Recalcati, 2005; Abbate-Daga et al., 2016). Specifically, psychoanalytic approaches to the treatment of EDs generally focus on the subjective and narrative meanings that underline the repetition of eating-related symptomatic thoughts, feeling and behaviours. These meanings have their roots in the personal and interpersonal history of patients and are therefore transdiagnostic rather than diagnostic-specific (Marzola et al., 2015).

If on the one hand a stream of research has emphasized the existence of porous boundaries and commonalities between the different ED diagnoses, another concomitant stream of research has taken the opposite direction by indicating the existence of heterogeneous personality profiles within the same ED diagnoses (Westen et al., 2006; Thompson-Brenner et al., 2008b). In other words, while some researchers have underlined how different ED diagnoses are linked to one another and therefore more homogenous than previously thought, other researchers have underlined how transdiagnostic profiles, characterized by distinct personality traits, comorbidity, treatment response and long-term outcomes, increase the heterogeneity between ED patients, although they may report the same diagnosis (Westen et al., 2006; Thompson-Brenner et al., 2008b).

More specifically, multiple studies using Q-factor analysis (i.e., a form of factor analysis that allows to group individuals based in their commonalities) identified three separate personality profiles in adult and adolescent samples of ED patients, namely the emotionally dysregulated, the high-functioning/perfectionistic and the constricted/overcontrolled profiles (Westen & Harnden-Fischer, 2001; Thompson-Brenner & Westen, 2005; Thompson-Brenner et al., 2008a). The emotionally dysregulated profile is characterized mainly by high levels of impulsivity and difficulties in affect regulation. ED patients belonging to this profile tend to express emotions in exaggerated ways, to spiral out of control and to be impulsive, overall presenting commonalities and comorbidity with borderline personality disorder (BPD). Conversely, the high-functioning/perfectionistic profile is defined by high levels of perfectionism, a need to achieve, and strong moral and ethical standards that the individual strives to live up to. Patients presenting with this personality profile are deemed psychologically insightful, they often show areas of achievement, and rarely present with other disorders in comorbidity. Lastly, the constricted/overcontrolled profile has been described as dominate by anxious feelings, emotionally constricted, rigid and shy, especially in social situations. Patients belonging to this profile tend to appear passive and unassertive, and often present comorbidities with anxiety disorders and personality disorders characterized by anxious and fearful feelings (Westen & Harnden-Fischer, 2001; Thompson-Brenner & Westen, 2005; Thompson-Brenner et al., 2008a).

Of relevance here, while the high-functioning/perfectionistic and constricted/overcontrolled subtypes have been proven to have better remission rates after treatment, the emotionally dysregulated subtypes have been shown to be more resistant to treatment, to have the worst levels of functioning and to have the highest rate of comorbidity (Thompson-Brenner et al, 2008b).

Overall, these streams of research question the validity and utility of descriptive atheoretical criteria, as those used by international classification schemes, to define EDs (Kendell & Jablensky, 2003). On the one hand, these descriptive criteria have the advantage to create a common language, easily usable by different professionals from the clinical and the research field dealing with psychopathology. This, in turn, allows for an easy dissemination and comparison of data collected in different contexts (APA, 2013). On the other hand, different clinical communities have suggested descriptive criteria not to be informative about the aetiology, prognosis, and causal mechanisms underlying the ED symptomatology. Subsequently, international diagnostic schemes have been deemed to provide little indications about therapeutic directions (Kendell & Jablensky, 2003; Recalcati & Rugo, 2019).

Consented gold standards on the treatment of EDs are still far to be reached. Up to date, 27 national and international clinical guidelines for the treatment of EDs have been published. Nine of these guidelines are evidence-based and analyse the different ED diagnoses separately, in teenage and/or adult populations (Hilbert et al., 2017).

However, recommendations reported in these guidelines do not completely agree with one another, with different advised psychological treatments for each diagnostic category, diverse definitions of recovery and normal/abnormal weight, and different medical and psychopharmacological protocols (see Hilbert et al., 2017 for more information). Moreover, despite distortions in body image being key diagnostic features of the main feeding and eating disorders, none of the before mentioned guidelines address specifically distortions in body image and body misperception in EDs (Cuzzolaro, 2018; Hilbert et al., 2017).

A comprehensive analysis of available treatments for EDs is beyond the scope of this thesis. However, across the different guidelines the treatments most commonly recommended were cognitive-behavioural therapy, followed by guided or unguided cognitive-behavioural self-help treatment (Hilbert et al., 2017). Cognitive-behavioural approaches to the treatment of EDs mainly focus on psychopathological cognitions and behaviours, with the aim to amend detrimental thoughts (e.g., thoughts of unworthiness) and to correct unhealthy behaviours (e.g., abnormal eating behaviours; Fairburn & Harrison, 2003; Hilbert et al., 2017).

However, it should be noted that existing treatments have been found to be limited in their effectiveness with only around 50% of patients fully recovering after treatment in evidence-based clinical trials (Keski-Rahkonen et al., 2009; Hay et al., 2015). Indeed, in around 20% of patients EDs have been shown to take a chronic course, with non-significant or even negative changes after treatment (Steinhausen, 2009). Moreover, ED patients have been found to show high relapse rates after treatment (Grilo et al., 2012; Cuzzolaro & Fassino, 2018) as well as high drop-out rates during treatment (DeJong et al., 2012).

In light of these data, further research is needed to better understand the factors that contribute to the aetiology and maintenance of EDs, and therefore to foster the development of more targeted treatment programs with lower relapse and drop-out rates. In this respect, it has been argued that available treatments may benefit from a better understanding of the bodily dimension in EDs (Cuzzolaro & Fassino, 2018).

1.3 Body image distortions in Eating Disorders

Body image can be defined as the internal mental representation and appreciation of one's own body. Body image is a multifaceted concept encompassing: (i) an affective component, that is the subjective feelings (satisfaction/dissatisfaction) towards one's own body's appearance, including body size and shape; (ii) a cognitive component, constituted by thoughts on body shape and body mental representation; (iii) and a perceptual component, that is the accurate estimation and identification of one's own body weight, size and shape (Cash et al., 1986; 1991).

Importantly, it has been advocated that body image distortions play a pivotal role in the aetiology and maintenance of EDs (Stice, 2002; Levine & Piran, 2004). In this regard, individuals with AN and BN have been found to display a greater extent of body dissatisfaction, (Cash & Deagle, 1997) and more negative emotions and body-related cognitions (Bauer et al., 2017; Vocks, et al., 2007b). Moreover, a negative body image was found to incorporate not only body dissatisfaction and disturbed body image cognitions (Thompson, 2004), but also body-related checking and avoidance behaviour (Kraus et al., 2015), a misjudgement of one's own body size (Vocks, et al., 2007a), and a body-related attentional bias (Bauer et al., 2017).

Of relevance here, different variables indicating the presence of a negative body image have been found to be associated with the onset, the severity and the duration of EDs (Cuzzolaro & Fassino, 2018).

For example, body dissatisfaction has been shown to be an important risk factor and predictor of future onset of an ED (Stice, 2002). Moreover, body dissatisfaction has been shown to predict duration of illness, with patients more dissatisfied about their physical appearance also showing a longer illness duration (Cuzzolaro & Fassino, 2018). Alongside, body dissatisfaction has been found to be a predictor of relapse in both AN and BN (Garner, 2004). Lastly, body dissatisfaction and overestimation of body size have been found to be associated with a more severe symptomatology in BN and BED patients (Grilo et al., 2019).

Overall, these data highlight the relevance and importance of body image disturbances and body misperception in EDs for clinical assessment and formulation. Conversely, current treatment guidelines may have overlooked the bodily dimension in the treatment of EDs. Given the limited efficacy of existing treatments for EDs, further research should aim to develop a better understanding of the mechanisms underpinning the putative role of body perception in EDs (Cuzzolaro & Fassino, 2018). In turn, such development in the research field may be pivotal to improve existing treatments.

Diagnostic schemes and previous research on body misperception in EDs have typically focused on perceptual body image distortions, i.e., visual overestimation of body size and shape that fails to reflect the true dimensions of the body (APA, 2013). Recent reviews on overestimation of body size in AN agree in indicating that overall AN patients tend to perceive their bodies as bigger than in reality (Farrell et al., 2005; Gardner & Brown, 2014). Results were consistent across studies using different methods, such as silhouette methods (Bell et al., 1986), distorting mirrors (Traub & Orbach, 1964), and photograph and video techniques altering pictures of one's own body (Gardner & Moncrieff, 1988; Probst et al., 1995; Shafran & Fairburn, 2002). However, some studies suggested overestimation of body size to be specific for sensitive body areas rather than to generalize to the whole body (Gila et al., 2005; Schneider et al., 2009). For example, Gila and colleagues (2005) found AN patients to overestimate specifically the size of hips, thighs and shoulders, when asked to adjust the size of different body sites on a silhouette representing their own body. Accordingly, Schneider and colleagues (2009) found a sample of mixed ED patients to overestimate especially the size of thighs and waist when asked to estimate the circumference of different body sites using strings.

Overestimation of the body size and shape have been found also in BN patients to an equal (Cash & Deagle, 1997) or even higher degree as compared to AN samples (Sepúveda et al., 2002). Moreover, body size overestimation in BN was found to correlate with the duration and severity of illness (Freeman et al., 1985). Importantly, studies on recovered individuals show that perceptual body image disturbances persist also after recovery for both AN (Bachner-Melman et al., 2006) and BN (Stein et al., 2003). These results indicate that body misperception represent the most callous symptomatic areas in EDs, and suggest that available treatments may fail in tackling body misperception.

Given its recent inclusion in the EDs diagnostic schemes, less clear is how the body is perceived in BED. Recent reviews have suggested BED patients to present levels of body dissatisfaction (weight and shape overconcerns), and body-related checking and avoidance behaviours similar to AN and BN (Ahrberg et al., 2011; Lewer et al., 2015; Lewer et al., 2017). However, up to date it is unclear whether BED patients also manifest overestimation of body size (Lewer et al., 2017). Accordingly, it has been proposed to include body image disturbances in the symptomatology of BED as an additional diagnostic criterion or as a diagnostic specifier (Grilo, 2013; Lewer et al., 2017).

Recent evidence suggests body misperception in EDs to be more widespread and severe than previously recognised involving different components of somatic perception. For example, it has been found that overestimation of body size also manifests itself in the tactile modality when using a tactile estimation or a tactile distance task (Keizer et al., 2011; 2012; 2019; Spitoni et al., 2015). These tasks entail judging the distance between two tactile stimuli simultaneously pressed to the skin (i.e., tactile discrimination). Results of all four studies found that AN patients tended to overestimate the distance between the two tactile stimuli and especially in sensitive body areas (i.e., body areas that are linked to negative evaluations and emotions): the abdomen, forearm/underarm, sternum, and thigh (Keizer et al., 2011, 2012, 2019; Spitoni et al., 2015). Furthermore, Spitoni and colleagues (2015) showed this difference to be more pronounced when stimuli were presented on the horizontal axis rather than on the vertical axis, suggesting that AN patients experience their body as wider rather than taller. Moreover, this difference in tactile distance estimation between AN patients and healthy controls was found, in most cases, to persist also after treatment, further validating the hypothesis that available treatments may fail in addressing body misperception in EDs (Keizer et al., 2019).

Alongside, body image disturbances have also been shown to extend to the body schema, that is the neural representation of the spatial properties of the body in action and interaction with the environment (Berlucchi & Aglioti, 2010). Indeed, healthy subjects reporting body image concerns and AN patients have been found to underestimate the width of an aperture they could pass through, and performing the action as if their body was larger than in reality (i.e., the aperture task; Guardia et al., 2010; Guardia et al., 2012; Keizer et al., 2013; Metral et al., 2014; Irvine et al., 2019). Alongside, Keizer and colleagues (2019) used a similar task, that is the hoop task, which entails participants to make judgments about the smallest hula hoop they could step through. Like in the previous studies using the aperture task, it was found that AN patients overestimated the smallest opening they could pass through. Interestingly, while AN patients were found to be inaccurate in judging their own ability to pass through an aperture/hoop, no impairments were found in the judgement of other individuals' ability (Guardia et al., 2012), thus suggesting that these results cannot be accounted for by general impairments in visual processes.

In continuity with the results on AN, a previous study by Vocks and colleagues (2007) showed overestimation of body size to extend to the body schema also in a sample of women with BN using a motion distortion technique. During this paradigm, participants were asked to alter the motion pattern of a walking figure in order to make it representative of their own motion pattern. Results showed bulimic patients to perceive their own motion pattern as more ponderous (corresponding to a higher BMI) than healthy controls.

1.4. Interoception in Eating Disorders

In addition to overestimating body size and shape, EDs have been linked to deficits in the processing and perception of internal body signals, namely interoception. Interoception is defined as the sense of the physiological condition of the body, and includes the perception of internal organ functions, muscular and visceral stimuli, hunger, thirst, pain, and pleasure (Craig, 2002). Interoceptive processes are pivotal for the maintenance of the physiological stability of the organism (i.e., homeostasis). However, the impact of interoception has been proposed to extend beyond homeostatic reflexes. Indeed, interoception has been shown to be fundamental also for complex psychological functions, such as motivation, emotion, social cognition and self-awareness (Tsakiris & Critchley, 2016). Coherently, alterations in the perception and elaboration of interoceptive signals has been linked to a decrease in general wellbeing and to psychological disorders, such as anxiety, depression, and eating disorders (Tsakiris & Critchley, 2016).

In this regard, different samples of ED patients have been found to have a reduced interoceptive sensibility, that is, a lower self-reported propensity to focus on internal bodily sensations, such as sensations of hunger and fullness (Herbert et al., 2013; Garfinkel et al., 2015; Fassino et al., 2004; Matsumoto et al., 2006).

These findings were partially supported also by some studies assessing objective accuracy in detecting interoceptive signals such as the heartbeat and breathing sensations (Garfinkel et al., 2016; Pollatos et al., 2008; Klabunde et al., 2013; Khalsa et al., 2015). Interoceptive accuracy is usually quantified using behavioural measures, such as the Heartbeat Perception Task (HPT; Schandry, 1981; Garfinkel et al., 2016). The HPT entails having the participant count the number of their heartbeats in a given interval of time and then comparing the participant's count to the actual number of heartbeats recorded by a monitor (Schandry, 1981). The HPT has been often used to assess interoceptive accuracy in ED patients, leading to mixed results.

While some studies found ED patients to have impairments in performing this task (Fischer et al., 2016; Pollatos et al., 2008; 2016), other studies showed ED patients to be equally accurate in detecting their heartbeat as compared to controls (Eshkevari et al., 2014; Khalsa et al., 2015; Lutz et al., 2019; Ambrosecchia et al., 2017; Demartini et al., 2017). Overall, while there is a general consensus that ED patients tend to have a reduced propensity to focus on internal bodily sensations (i.e., interoceptive sensibility; Fassino et al., 2004; Mehling et al., 2009; Arciero et al., 2004; Mazzola et al., 2014), results on interoceptive accuracy seem to be less straight forward. Accordingly, it has been proposed that certain domains of interoception, such as the accuracy in perceiving heartbeat sensations (i.e., cardiac interoceptive accuracy), may remain intact in EDs (Pollatos & Georgiou, 2016; Eshkevari et al., 2014). Following this line of reasoning, deficits in cardiac interoceptive accuracy reported in some of the previous studies may be better conceptualized as state-dependent behaviours secondary to malnutrition, possibly mediated by alterations in the cardio-vascular system (e.g., bradycardia and reduced diastolic and systolic pressure; Teaford et al., 2021).

Alterations in interoception in EDs have been found also in another interoceptive modality that is affective touch (Crucianelli et al., 2016). Affective touch refers to a slow caress-like touch (3 cm/s), associated with perceived pleasantness and with activation of a specialised system of mechanosensory afferents (the CT system; Loken et al., 2009; McGlone et al., 2014). Indeed, receiving affective touch, and the subsequent activation of the CT system, has been linked to a greater perception of pleasantness during touch as compared to slower or faster touch stimulations (Löken et al. 2009; Essick et al. 2010; Croy et al. 2016).

However, AN patients have been found to exhibit significantly lower pleasantness ratings compared to healthy controls when administered with affective touch (Löken et al., 2009; Crucianelli et al., 2016), indicating an impairment in the ability to correctly link interoceptive signals with their potential pleasant consequences. Interestingly, reduced pleasantness rating after affective touch have been found also in recovered AN patients, suggesting this effect to be an enduring trait of this clinical population rather than an artefact secondary to acute conditions (Crucianelli et al., 2020). Furthermore, it has been shown that AN patients display a reduced responsivity to the anticipation of receiving affective touch, both in terms of predicted pleasantness of touch, and in terms of anticipatory neural response localized to the ventral mid-insula (Crucianelli et al., 2020; Bischoff-Grethe et al., 2018). Taken together, these findings suggest that in AN there is a dysregulation in the ability to correctly predict and interpret incoming interoceptive stimuli, including pleasantness of touch.

Overall, while some findings show ED patients to have an impairment in the elaboration of interoceptive information (e.g., interoceptive sensibility), some findings failed to find a difference in interoception between ED patients and healthy controls (e.g., cardiac interoceptive accuracy). Therefore, some researchers have hypothesized the existence of a dissociation between different domains of interoception, with only some of these domains presenting with an impairment in EDs. In this regard, it has been proposed that ED patients may present with altered interoceptive abilities mostly in self-reported measures (i.e., in the subjective experience of interoception) as compared to experimentally measured interoceptive abilities (i.e., in the primary encoding of interoceptive information; Pollatos & Georgiou, 2016; Eshkevari et al., 2014).

1.5 Multisensory integration in Eating Disorders

Given previous evidence that body misperception in EDs concerns not only visual body image distortions but also alterations in the perception of external touch, the body schema and interoception, it has been suggested to rethink body misperception in EDs in a multisensory framework, as a general impairment in the elaboration and integration of perceptive information involving different sensory modalities (Keizer et al., 2016; Gadsby, 2017; Riva & Gaudio, 2018). Multisensory integration refers to the synthesis of sensory information from two or more sensory modalities, and has been advocated to be central to body perception and body misperception in clinical samples (Ehrsson, 2012; Stein & Stanford, 2008). Accordingly, a fairly new line of research has investigated multisensory integration abilities in samples of ED patients (Teaford et al., 2021).

In this respect, informative data come from studies employing the Rubber Hand Illusion (RHI; Botvinick & Cohen, 1998) as a proxy to assess visual, tactile and proprioceptive multisensory integration in EDs. The RHI is a perceptual illusion in which participants are induced to perceive a fake hand as if it was their own, when the experimenter brushes the fake hand and the participant's hand in the same place at the same time (i.e., visuo-tactile synchrony), while the participant's hand is out of sight and the fake hand is visible (Botvinick & Cohen, 1998). When the brushing of the real and fake hand is asynchronous, this illusion is typically abolished. The illusion can be quantified in a number of ways including a body ownership questionnaire assessing the subjective experience of ownership of the fake hand as part of the participant's body (example item: "I felt as if the rubber hand was my own hand"). Another measure of the illusion are changes in perceived hand localization before and after visuo-tactile stimulation (typically toward the fake hand; referred to as proprioceptive drift).

Research in ED patients has shown this population to be more inclined than controls to perceive this bodily illusion both in terms of a stronger subjective experience of ownership of the fake hand (Eshkevari et al., 2012; Keizer et al., 2014; Zopt et al., 2016) and in terms of a more pronounced proprioceptive drift (Eshkevari et al., 2012; Keizer et al., 2014). It was therefore proposed that people with EDs may have an increased sensitivity to the visual aspects of body perception and a decreased sensitivity to proprioceptive information, which in turn determines alterations in visuo-tactile-proprioceptive multisensory integration, and ultimately a stronger illusion in the context of the RHI (Eshkevari et al., 2012; Caglar-Nazali et al., 2014).

Interestingly, these results were found consistently in currently ill and in recovered ED patients as well as in healthy participants presenting with subclinical ED symptoms (Mussap & Sultan, 2006; Keizer et al., 2014; Cuzzolaro & Fassino, 2018). It was therefore advocated that alterations in multisensory integration are more likely to be a core and stable characteristic of ED patients (i.e., trait) rather than an artefact secondary to malnutrition (i.e., state-dependent). An alternative non-mutually exclusive interpretation of these results is that current treatments available fail to address multisensory integration abnormalities in EDs.

Similar findings were found in regard to the Size Weight Illusion (SWI, Charpentier, 1891), which involves the integration of visual, haptic and proprioceptive information. The SWI is a perceptual illusion in which participants are given two objects that are identical in shape and mass but are different sizes. They are then asked to compare the two objects and determine which of the two is heavier. Typical individuals usually claim the smaller object to be heavier (even though it is not) due to an implicit assumption that weight scales with size. Case and colleagues (2012) found a sample of AN patients to have an atypical response to the illusion. Indeed, while patients did experience the SWI, they did so significantly less than the healthy controls. It was therefore hypothesized that abnormalities in multisensory integration in EDs may manifest also when visuo-haptic-proprioceptive information are administered.

Relatedly, to further address the multisensory components of body image distortions in

AN, Full Body Illusions (FBI) using virtual reality have been performed (Slater et al., 2010; Keizer et al., 2016). Similar to the RHI, during the FBI participants experience ownership over an entire virtual body after synchronous visuo-tactile stimulation of the actual and virtual body. Keizer and colleagues (2016) used this paradigm with a virtual body in which they manipulated the body size, to assess whether the overestimation of body size in AN patients would be affected by this illusion. AN patients reported a decrease of the overestimation of their shoulders, abdomen and hips after the FBI was induced. Although healthy controls showed similar results, this effect was stronger in AN participants than in healthy controls (Keizer et al., 2016).

Another study by Provenzano and colleagues (2020) assessed differences in embodiment of a virtual body using the FBI in a sample of AN patients compared to healthy controls. The authors used avatars reproducing the participant's perceived body size and modified it by increases and losses of 15% in the different experimental conditions. In this study, AN patients did not differ from controls in their levels of embodiment. However, it should be noted that the standard avatar used with no body size modifications did not represent participants' body size but rather the body size perceived by participants, which in the case of AN patients is usually distorted, and can therefore distort subsequent manipulations.

Overall, these studies suggest body misperception in EDs not only to manifest in affective, cognitive and perceptual alterations in the body image, but also to encompass primary sensory processes as well as the integration of these perceptual processes in more complex perception. In other words, current models of body misperception in EDs may benefit from a reconceptualization that takes into account the variety of sensory processes that come into play in the multifaceted perception of the body (Gaudio et al., 2014). To this aim, further research should investigate body perception in EDs in a multisensory context, for example using paradigms assessing multisensory integration.

1.6 Vision of the body

1.6.1 Vision of the body in ED treatments

Body dissatisfaction, body image disturbances and distorted body size estimation in EDs have been targeted by some therapeutic attempts developed with the aim to enhance patients' accuracy in body perception through providing objective feedback. For example, one stream of research has tried to address body misperception in EDs using body exposure and mirror therapy. These approaches aim to improve body satisfaction and perception through exposing patients to the vision of their body and manipulating attention to the bodily self

(Vocks et al., 2008).

During mirror therapy patients are exposed to the vision of their body as reflected in a mirror, and they are asked to examine and describe their body in a neutral and non-judgemental way. This, in turn, is deemed to foster a more objective perception of one's own body shape, and to decrease negative feelings and cognitions associated with one's own body. These protocols have been shown to be effective in reducing body dissatisfaction at the end of treatment (Moreno-Domínguez et al., 2012; Díaz-Ferrer et al., 2015; Porras-Garcia et al., 2021). Nevertheless, such treatment approaches are not fully standardized and manualized, and evidence is lacking on their effectiveness and long-term outcomes (Cuzzolaro & Fassino, 2018). Moreover, somatosensory processes involved in these protocols have not been explained up to date. A better understanding of the relationship between vision of body and body perception in EDs (i.e., information on how vision of the body may have an impact on multisensory processes of body perception) may be pivotal to update current models on body perception in this family of disorders and subsequently clinical protocols.

1.6.2 Visual enhancement of tactile perception

A body of literature already exists analysing the effects of vision of the body on somatosensory processes in healthy individuals and clinical samples. In this respect, some studies have shown that directing visual attention towards a body part enhances tactile perception at that stimulated body part, both when the visual information provides useful information about the tactile stimulation (Halligan et., 1996; Làdavas et al., 1998; 2000) and when it does not (Serino et al., 2007), that is, when the visual input is non-informative.

The effects of informative visual information on tactile perception were studied mostly in sample of right-brain damaged patients presenting with a contralesional tactile extinction (Halligan et., 1996; Làdavas et al., 1998; 2000). These patients were therefore unable to perceive touch on the left hand. However, when patients could see their hands while receiving the touch, touch perception was partially restored, and patients were better able to report the appropriate tactile sensation (Halligan et., 1996; Làdavas et al., 1998; 2000). Accordingly, in this condition, patients could also estimate the pressure with which touch was applied to the hand (Halligan et., 1996). It was therefore concluded that when limited tactile information is available, correlated visual information can boost this tactile information into conscious awareness. These findings were explained by referring to the activity of bimodal neurons in premotor and parietal cortex, which have corresponding tactile and visual receptive fields on the hand. It was therefore suggested that the activation of these neurons in response to visual inputs could enhance also cross-modal perception of tactile information in the same receptive fields (Halligan et., 1996; Làdavas et al., 1998; 2000).

These effects were extended also to non-informative vision of the body (Serino et al., 2007; Kennett et al., 2001). For example, Serino and colleagues (2007) showed that vision of the arm increased tactile discrimination performance (i.e., tactile acuity) in a two-point discrimination task (that is, the ability to discriminate two points touching the skin as being two instead of one), although vision of the arm per se was not providing any additional information about the tactile stimulation received. This visual enhancement of touch was found both in a sample of brain damaged patients suffering a reduced tactile sensitivity, and in a sample of healthy participants. Importantly, visual enhancement of touch in healthy participants was found to be stronger for those participants presenting with a worse tactile acuity at baseline. It was therefore proposed that in a multisensory context, when the information derived from unisensory channels is weak (e.g., tactile perception), other sensory modalities (e.g., visual inputs) can compensate this deficit, and therefore ameliorate the perception in the weaken sensory channels (e.g., touch; Serino et al., 2007).

Further research in healthy participants showed non-informative vision of the body to enhance tactile acuity not only in terms of reduced two-point discrimination, but also in terms of enhanced amplitude discrimination of above-threshold stimuli and reduced tactile detection thresholds (Tipper et al., 1998, 2001; Kennett, Taylor-Clarke & Haggard, 2001; Serino et al., 2009; Keizer et al., 2012: Harris et al., 2007). Alongside, non-informative vision of the body was also found to enhance tactile perception in grating orientation tasks (which involve discriminating the orientation of grating patterns) by decreasing discrimination thresholds and increasing discrimination accuracy (Taylor-Clarke et al., 2004; Cardini, et al., 2011). It was therefore proposed that even in the absence of tactile deficits at baseline, vision of the body can enhance the perception of tactile stimuli, possibly by sharpening tactile receptive fields in bimodal visuo-tactile neurons (Haggard, et al., 2007).

Vision of the body has been found to facilitate not only the perception of exteroceptive tactile stimuli, but also the perception of internal body signals (interoception). In this respect, Ainley and colleagues (2012; 2013) demonstrated that non-informative vision of one's own face could enhance the detection of heartbeat sensations (i.e., interoceptive accuracy) during a Heartbeat Perception Task (HPT; Schandry, 1981). Participants performed the HPT in two conditions: while watching their reflection in a mirror (Ainley et al., 2012) or a photograph of their face (Ainley et al., 2013), and while watching a blank screen as a control condition. In both studies, participants were more accurate in perceiving their heartbeat whilst looking at their face, although vision of the face was not providing informative data for the completion of the task per se. The authors therefore concluded that non-informative vision of the body can enhance the perception of inner body signals by shifting participants' attention towards their bodily self (Ainly et al., 2012; 2013).

1.6.3 Caveats to the evidence for visual enhancement of tactile perception

However, other research has shown that vision of the body does not enhance tactile perception in all conditions. Visual enhancement of touch can be influenced by the body part targeted (Tipper et al., 1998: Serino et al., 2007). For example, Tipper and colleagues (1998) reported that familiarity of the stimulated body part could modulate the effects of vision on somatosensory processes. In their study, non-informative vision of a familiar body site (such as the face) was found to facilitate the detection of supra-threshold tactile pulses; in contrast, vision of a less familiar body part (such as the back of the neck) was found to have little impact (neither facilitatory nor inhibitory) on supra-threshold tactile detection.

Moreover, it has been shown that vision of the body can either enhance or diminish tactile acuity depending on the type of task used. Longo and Sadibolova (2013), for example, found that vision could actively distort touch perception, rather than increase accuracy, when participants are asked to estimate the size of a tactile stimulus. In their study, vision of the stimulated body part significantly reduced the perceived size of a tactile stimulus, as compared to vision of an object or of a non-stimulated body part.

Alongside, Press and colleagues (2004) showed that the complexity of the task could play a role in determining the effects of vision on tactile perception. In their study, non-informative vision only enhanced tactile perception when the task was both difficult and involving a spatial component (making speeded responses in an at-threshold two-point discrimination task). Performance on an easier non-spatial discrimination task (detecting a brief gap in a 250 ms above-threshold vibration) was actually worse when participants viewed the targeted body part as compared to a neutral object.

In this respect, Harris and colleagues (2007) proposed that non-informative vision of the body does not simply enhance somatosensory processing, but rather it induces adaptive changes in tactile sensitivity within a visuo-tactile bimodal sensory system. According to this reasoning, after adaptation of tactile receptive fields subsequent to vision of the body, discrimination of stimuli is enhanced, while detection of near-threshold stimuli is impaired.

Accordingly, Mirams and colleagues (2010) found that non-informative vision of the hand increased errors on a non-spatial touch detection task - the Somatic Signal Detection Task

(SSDT, Lloyd et al., 2008). The SSDT involves detecting near-threshold vibrations delivered on the fingertip, where on 50% of trials there is a simultaneous LED flashing next to the targeted finger. During this task, the presence of the light increases false alarms, that is, reports of feeling the vibration when it did not actually occur (Lloyd et al., 2008). Mirams and colleagues (2010) used the SSDT to assess the effects of a second visual variable, that was vision and no vision of the stimulated hand, on touch perception. Specifically, the study investigated whether non-informative vision of the hand compared to no vision of the hand (hand and arm covered with the LED still visible) would reduce or increase incorrect reports of feeling touch during the task.

Results of the study showed that during the vision condition, participants were more inclined to make false reports of feeling the touch, and especially on trials when the light flash occurred. The authors suggested that vision of the hand might have raised the focus on interoceptive information to a detrimental degree that led participants to misinterpret internal signals as external touch, which resulted in more errors during the SSDT. This led to the conclusion that non-informative vision of the body may lead to higher somatic interference and ultimately to a less accurate perception of near-threshold vibrations during the SSDT. Importantly, this is partially in agreement with the previously mentioned hypothesis from Harris and colleagues (2007), according to which vision of the body can have a detrimental effect on the detection of near-threshold stimuli due to adaptation of receptive fields.

1.6.4 Research on the perceptual effects of vision of the body in EDs

Less information is available about the effects of vision of the body on somatosensory processing and multisensory integration in the context of EDs. A single study replicated Ainley and colleagues' (2012; 2013) paradigm on a sample of AN patients. Participants completed a Heartbeat Perception Task (HPT) in two conditions: while viewing a photograph of themselves or another person (Pollatos et al., 2016). In contrast with previous results with healthy participants, patients showed lower interoceptive accuracy when viewing the photograph of themselves as compared to another person. It was hypothesized that AN patients might find it distressing viewing their own photograph due to high levels of body dissatisfaction, and might therefore be less accurate in elaborating body signals in this condition.

However, it should be noted that recent research has questioned the validity of the HPT as a measure of interoceptive accuracy, suggesting that performance on this task is highly influenced by non-interoceptive processes that can therefore bias participants' results, such prior knowledge or personal decision thresholds (Desmedt et al., 2018). Thus, further research should be carried out in order to have a comprehensive picture on the effects of vision of the body on perception and multisensory integration. This holds true especially in the context of EDs, where available data are scarce, and knowledge on the effects of exposing patients to the vision of their bodies is important to inform clinical practice.

1.7 Aims and outline

This thesis aims to expand on the state of knowledge on body misperception in EDs. Specifically, according to previous research underlining the importance of multisensory processes in the perception of the body, the first aim of this thesis was to investigate the relationship between ED symptoms and multisensory integration abilities. Multisensory integration was analysed using the Somatic Signal Detection Task (SSDT; Lloyd et al., 2008), a paradigm for the assessment of the processing and integration of exteroceptive visuo-tactile information (see Chapter 2). In the first two studies (see Chapters 3 & 4), we investigated whether participants presenting with higher ED symptoms would show abnormalities in the perception of external touch and in visuo-tactile multisensory integration during the SSDT as compared to participants reporting low ED symptoms.

The second aim was to determine the effects of non-informative vision of the body on SSDT performance in participants presenting with different levels of ED symptoms. In other words, we wanted to investigate whether exposing participants to the vision of their body would alter multisensory integration processes during the SSDT, and whether this effect would be different in high versus low ED symptomatic participants. To this aim, participants repeated the SSDT while exposed to non-informative vision of their face (Chapter 3) or their hand (Chapter 4) in comparison to neutral conditions.

A third aim of the current thesis was to investigate whether a caress-like tactile manipulation intervention (i.e., affective touch) could alter subsequent SSDT performance as compared to a neutral condition (Chapter 5). Results of this study are particularly important to inform possible interventions to enhance multisensory integration during the SSDT for those subjects performing worse on the task. In turn, understanding the effects of receiving affective touch on multisensory integration could be informative for the development of treatments targeting the bodily dimension and abnormal multisensory integration in EDs.

A fourth aim was to understand possible physiological mechanisms explaining the effects of vision of the body and self-focused attention on SSDT performance found in the studies above mentioned. Specifically, we investigated whether participants' level of arousal (i.e., Skin Conductance Levels, SCLs, that is an index of the activation of sympathetic autonomic activity) could explain results of these previous studies and therefore individual differences in SSDT responses (Chapter 6). Overall conclusions and future directions of the thesis are outlined in Chapter 7.

Chapter 2

Methodology

The main paradigm used in the studies of this thesis was the Somatic Signal Detection Task (SSDT; Lloyd et al., 2008). The SSDT is a measure for the assessment of visuo-tactile cross-modal perception (and misperception) and multisensory integration. Participants' responses during the SSDT are analysed using the Signal Detection Theory (SDT; Macmillan & Creelman, 1991), that is a technique to evaluate perceptual decision-making in sensory detection tasks. The current chapter provides a detailed introduction to the SSDT. Section 2.1 gives an overview of SDT. Section 2.2 describes in detail the SSDT materials, thresholding procedure, experimental phase, and data processing. Section 2.3 describes individual differences in the propensity of participants to make false alarms during the SSDT. Lastly, section 2.4 gives an overview of previous research investigating how manipulating attention to the self can influence SSDT performance.

2.1 Signal detection theory

Signal Detection Theory (SDT, e.g., Macmillan & Creelman, 1991) provides a framework to describe how well observers can discriminate or recognize certain signals given the background noise and therefore the possibility to make errors. SDT was first designed as an instrument to assess the ability of an observer to decide whether the source of a voltage change was noise or signal plus noise (Peterson et al., 1954). Soon afterward, SDT was adopted by cognitive psychologists to measure human decision making in perceptual studies (i.e., in studies analysing the detection of sensory signals; Tanner and Swets, 1954; Swets et al., 1961).

SDT has typically been employed in yes/no tasks, where participants are asked to decide whether a stimulus has been presented ("Yes"), or not ("No"), on each trial. Stimuli are generally presented under conditions of uncertainty (i.e., with a varying or constant intensity that make it difficult for participants to detect the stimulus). Participants' responses are categorised as presented in Table 2.1.

Table 2.1

Categorisation of participants' responses on signal detection yes-no tasks according the Signal Detection Theory

	Responses	
	"Yes"	"No"
Stimulus present	Hit (i.e., true positive)	Miss (i.e., false negative)
Stimulus absent	False Alarm (i.e., false positive)	Correct Rejection (i.e., true negative)

According to SDT, based on participants' raw responses, a rate of correct "Yes" responses (Hits) across all trials during which the stimulus was present (Hits + Misses) is calculated (Hit Rate; HR). Complementary, a rate of incorrect "yes" responses (False alarms; FA) is calculated considering all trials during which the signal was absent (False alarms + Correct Rejection). Importantly, SDT utilises both these rates (HR and FA) in order to derive measures of perceptual sensitivity and response criterion. Perceptual sensitivity (*d'*) indicates participants' ability discriminate signal-present from signal-absent trials based on the number of hits (HR), relative to false alarms (FA). Whereas response criterion (*c*) indicates participants' tendency to respond "yes" or "no" independently from the presence or absence of the stimulus. Without considering both correct and incorrect responses (HR and FA) when evaluating participants' performance, a distorted picture may emerge. The following paragraphs explain more in detail the theory underlying the calculation of perceptual sensitivity and response criterion.

The assumption of SDT is that when asked to detect a sensory signal, both in signal-present and in signal-absent trials, there is a background sensory noise from the same sensory system that can be misinterpreted as signal. Therefore, in signal-present trials (signal + noise) a stronger sensory signal is elicited compared to signal-absent trials (noise only). Participants decide whether the trial contained a signal based on the perceived strength of the signal relative to the noise. However, due to fluctuations in neuronal responses over time, sensory noise is not constant. Therefore, keeping the intensity of the signal constant does not result in an equally constant detection rate across trials (Stanislaw & Todorov, 1999). In SDT, the variation in detection rates across trials is conceptualised using probability distributions (see Figure 2.1).

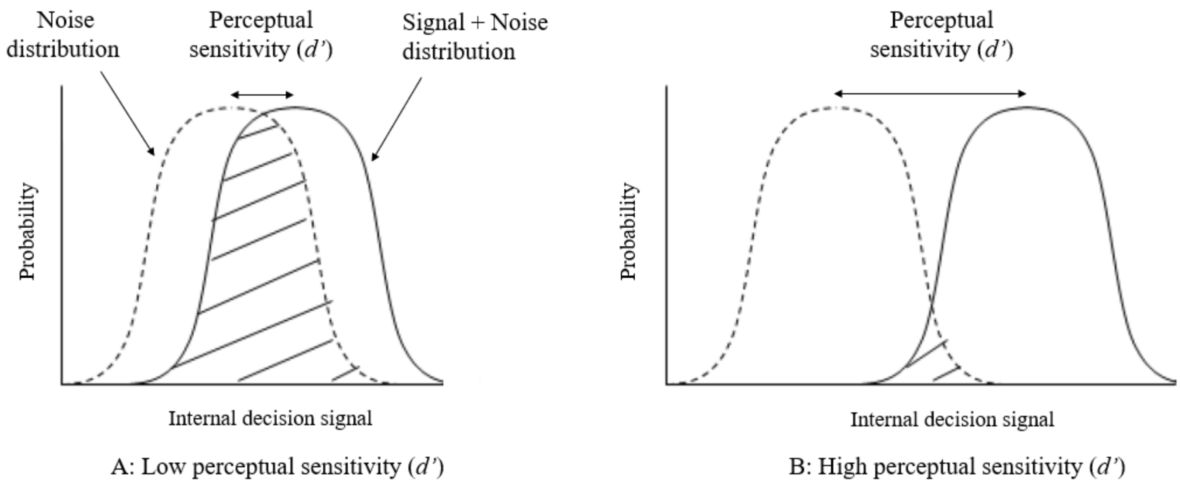
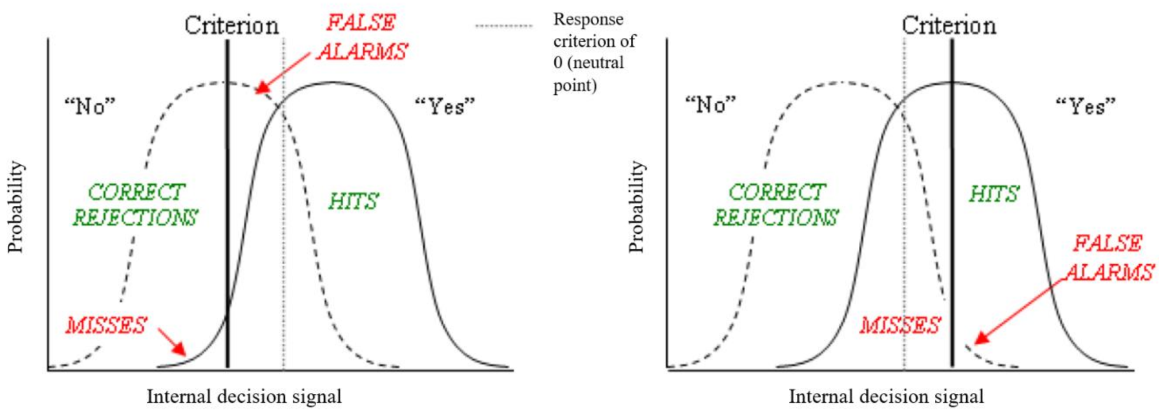


Figure 2.1. Degree of overlap between noise and signal + noise probability distributions in relation to perceptual sensitivity. Part A represents a case of low sensitivity in which there is an increased overlap between the two distributions (noise and signal + noise), and therefore also an increased chance of errors. Part B represents a case of high sensitivity in which there is a reduced overlap between the two distributions (noise and signal + noise), and therefore also a decreased chance of errors (Figures from Mirams, 2011).

When there is overlap between the noise and the signal + noise probability distributions (corresponding to the shaded regions in Figure 2.1), participants are more likely to make errors in detecting the signal. How much the two distributions overlap depends on an individual's ability to distinguish between signal and noise (i.e., perceptual sensitivity, known as *d'*). As shown in Figure 2.1, a greater overlap between the two distributions is indicative of a lower perceptual sensitivity (*d'*), and therefore a higher difficulty to distinguish signal from noise, providing more opportunities to mistake noise for signal and signal for noise.

While individual perceptual sensitivity is an index of whether errors are made, the individual's response criterion (known as *c*) is an index of the type of errors made (false alarms or misses). Specifically, the response criterion (*c*) is a measure of the willingness of a participant to report a perceptual signal as present or absent in an ambiguous situation across signal-present and signal-absent trials. On any given trial participants are comparing the strength of the signal with their response criterion (*c*). If the sensory signal is perceived as sufficiently strong and exceeding the individual *c*, participants will report the signal as present (i.e., make a "yes" response). If the sensory signal is perceived as insufficiently strong and below the individual *c*, participants will report the signal as absent (i.e., make a “no” response).

As shown in Figure 2.2, a participant with a low/liberal response criterion (*c*) will report the signal as present (i.e., “yes” response) more often, as the strength of the perceived signal will regularly exceed *c*. However, a liberal response criterion not only increases the chances to detect the signal when presented (hits), but also the chances of making type I errors (i.e., false positive), that is the propensity to mistakenly report the signal as present when absent (i.e., false alarms). Conversely, a participant with a high/stringent response criterion will report more often the signal as absent (i.e., make more “no” responses), as the strength of the perceived signal will rarely exceed *c.* This translates with a greater propensity to report the signal as absent in signal-absent trials, but also with a greater probability to make type II errors (i.e., false negative), that is the propensity to mistakenly report the signal as absent when present (i.e., misses).



A: Low/Liberal response criterion (*c*)

B: High/Stringent response criterion (*c*)

Figure 2.2. The consequences of adopting a liberal or stringent response criterion. Part A represents a liberal response criterion (i.e., participants respond “yes” more frequently) which results in a higher number of hits and false alarms, and a lower number of misses and correct rejections. Part B represents a stringent response criterion (i.e., participants respond “no” more frequently), resulting in a lower number of hits and false alarms and a higher number of misses and correct rejections (Figures from Mirams, 2011).

2.2 SSDT paradigm

2.2.1 General introduction

A fairly novel approach to cross-modal perception based on the principles of Signal Detection Theory (SDT) is the Somatic Signal Detection Task (SSDT; Lloyd et al., 2008). The SSDT is a paradigm for the assessment of visuo-tactile perception, and was developed based on a previous study by Johnson and colleagues (2006), who found that the presence of a light can change the response criterion for reporting touch. The SSDT involves detecting near-threshold tactile pulses (20ms, 100Hz vibrations) delivered on the fingertip on 50% of trials. In each trial, a light placed close to the targeted fingertip may or may not flash. Light flashings occur on 50% of trials independently from whether the tactile pulse was administered or not. At the end of each trial, participants are asked to report whether or not they perceived the tactile pulse (vibration).

Responses are classified as false alarms (tactile pulse reported as present when absent), hits (tactile pulse reported as present when present), correct rejections (tactile pulse reported as absent when absent), and misses (tactile pulse reported as absent when present). These classification data are then used to estimate perceptual sensitivity (*d'*) and response criterion (*c*) using standard signal detection formulae.

The SSDT allows the investigation of how visual and tactile information are integrated, and more specifically how visual information can lead to the misperception of touch. Previous studies have shown that neurotypical subjects tend to erroneously report perceiving the tactile pulse when it was not present (i.e., make false alarms) especially on trials when the light flash occurs (Lloyd et al., 2008; Mirams et al., 2010). According to the authors, false alarms on the SSDT can be thought of as illusory touch experiences, during which internal sensory noise is mistaken as external touch. The presence of a concomitant light flashing has been found to augment participants' tendency to confuse a sensory noise as signal, thus indicating that non-informative visual information can elicit a false perception of touch.

Visual input has been proposed to affect tactile perception due to the high correlations that hold between vision and touch in everyday life (Botvinick & Cohen, 1998). People often rely on incoming visual information when making judgements about tactile events, particularly when tactile information is ambiguous (Lloyd et al., 2008). As simultaneous inputs from different sensory modalities usually signifies a single event (Johnson et al., 2006), the brain may associate sets of redundant signals (Bresciani et al., 2005). It is possible that during the SSDT the light resolves uncertainty about the presence or absence of the vibration.

Unlike other paradigms typically used to assess cross-modal perception and multisensory integration, among which the Rubber Hand Illusion (RHI; Botvinick & Cohen, 1998) is the best known (see Chapter 1), the SSDT takes advantage of the use of the SDT for analysing participants' responses. In turn, the SDT allows to obtain a more thorough description of the data, with separate measures of sensitivity (*d*', i.e., the ability to correctly discriminate whether the vibration was present or absent) and response criterion (i.e., the propensity to report feeling the vibration regardless of the type of trial; Smeets et al., 1999). Moreover, in contrast to other paradigms assessing multisensory illusions (i.e., paradigms assessing the potential for visual information to lead to the misperception of body sensations) such as the RHI, during which participants are aware of a distortion in their experience of an existing touch, during the SSDT participants are unaware of whether or not their experience of touch is genuine. Therefore, it could be argued that the SSDT provides a more objective measure of exteroceptive experience.

2.2.2 Materials

Participants sat in a light-attenuated room approximately 40 cm (Experiments 1 and 3; see Chapters 3 and 5) 60 cm (Experiment 2; see Chapter 4) in front of a computer monitor (5:4 ratio; 270mm × 330mm). In the original version of the paradigm, participants sat with their non-dominant left hand resting on a table in front of and central to the computer monitor. The participant's left index fingertip was fixed to a tactor delivering vibrations (Z-Voom phones type YVE-01B-03, Yeil Electronics, South Korea) using a double-sided adhesive pad to prevent movements. The tactor was mounted into a polystyrene block. Tactile stimuli (20ms, 100Hz vibrations) were produced by sending amplified sound files (.wav files, sine wave), controlled by E-Prime software (Psychology Software Tools Inc., Pittsburgh, PA, USA), to the tactor. The volume dial on the amplifier was set at the quarter-to-twelve position for each participant. A 4mm red LED was also mounted on the polystyrene block close to the end of the participant's finger to provide the visual stimulus (light). The monitor was used to deliver instructions to participants. Participants responded via the computer keyboard, using their right hand. Throughout the experiment, participants listened to white noise via headphones to mask any informative sounds produced by the tactor. The experimental set-up of the classic version of the SSDT is illustrated in Figure 2.3. In some of the experiments of this thesis the original paradigm was modified in order to target the face rather than the hand. The modifications made are described in detail in each experimental chapter (see Chapters 3 and 5).

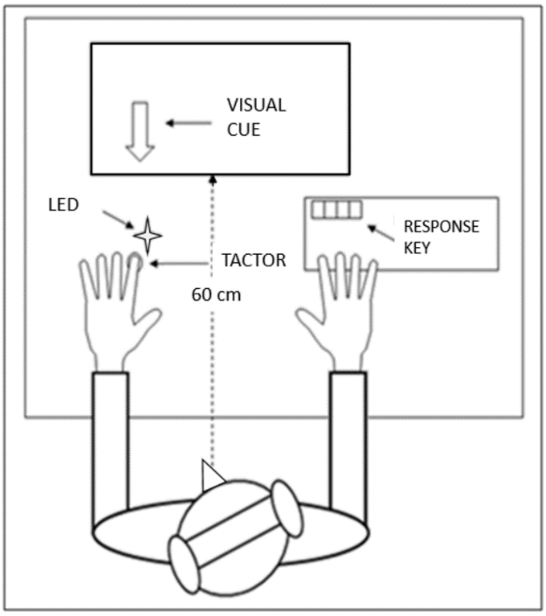


Figure 2.3. Schematic depiction of the experimental set-up for the original version of the SSDT.

2.2.3 Thresholding procedure

Before undergoing the testing phase of the SSDT, participants performed a procedure to calibrate the intensity of the vibration at the individual threshold level, that it is at a level that is equally ambiguous for all participants considering individual differences in tactile perception. Specifically, the thresholding procedure determines the level of tactile stimulation necessary to elicit a correct “yes” response in 40-60% of light-present trials. This level of stimulation is referred to as the participant’s tactile threshold. The intensity of the stimulation derived in the thresholding procedure determines the strength of the decision signal in subsequent experimental trials.

The original thresholding procedure of the SSDT involved calibrating the strength of the vibration manually (Lloyd et al., 2008; Mirams et al., 2010). A threshold was found for each participant using a staircase procedure (Cornsweet, 1962) in which participants were presented with blocks of 13 trials: 10 tactile present (Touch) and 3 tactile absent (No Touch) trials. The beginning of each trial was signalled by a 250ms beep sound administered through a pair of earphones. This was followed by a 1020ms stimulus window. In Touch trails, a 20ms tactile pulse was administered in the middle of the stimulus window (preceded and followed by a 500ms interval). In No Touch trials, an empty 1020ms period occurred. A prompt was then displayed instructing participants to report whether they had felt the vibration ("Yes") or not ("No") by pressing the corresponding keyboard keys Y and N (see Figure 2.4 for a schematic of a trial). The vibration was initially presented at the same intensity to all participants. At the end of each block, the strength of vibration was decreased if the stimulation was perceived on more than 60% of Touch trials. If the vibration was perceived on less than 40% of Touch trials, the intensity was increased. This procedure was repeated until the intensity of vibration reached the participant's 50% threshold, defined as the intensity necessary for participants to perceive the vibration on 40%-60% of Touch trials. Participants had to score within this range for two consecutive blocks at the same stimulus intensity (Mirams et al., 2010). The manual thresholding procedure took approximately 15 minutes.

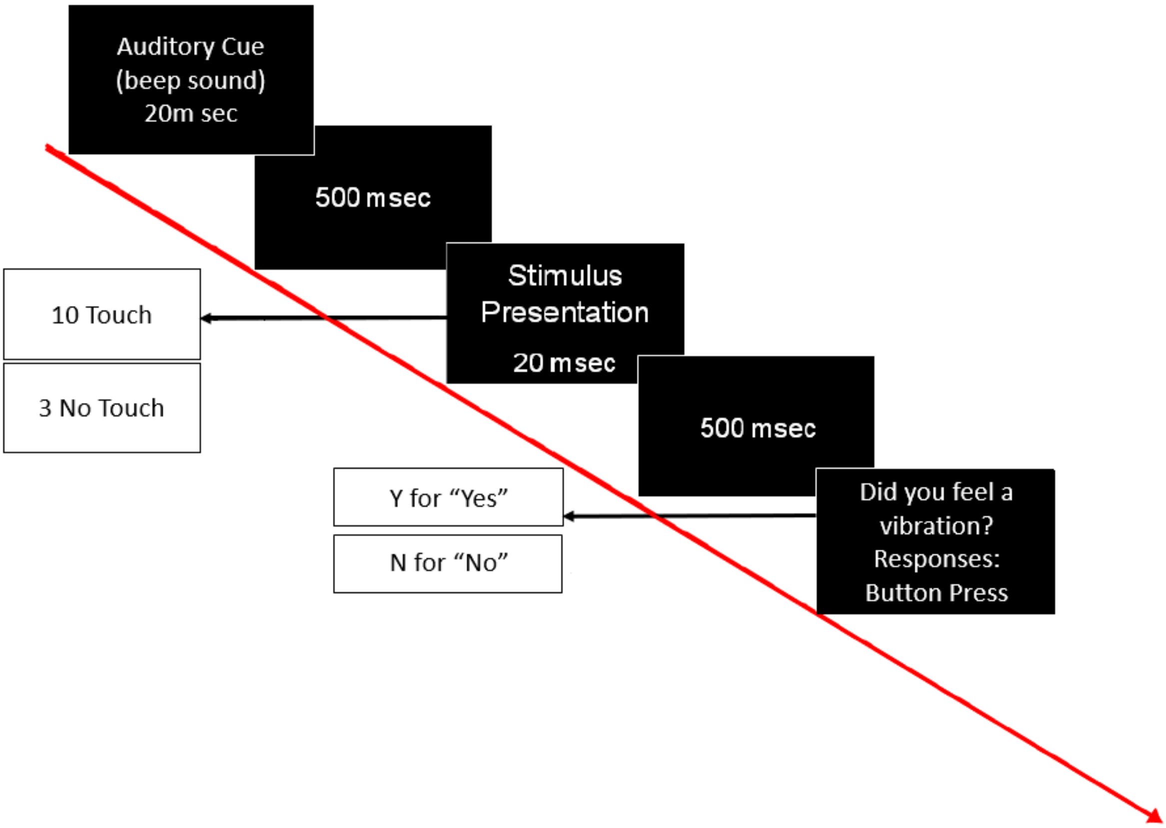


Figure 2.4. Schematic of a trial during the manual single interval original thresholding procedure of the SSDT.

However, Katzer and colleagues (2011) identified a disadvantage with the thresholding procedure used in earlier SSDT studies (Lloyd et al., 2008). Specifically, it was proposed that using a single interval (yes/no) trial task, in which a tactile pulse may or may not be presented, carries the risk that participants' response bias may affect their performance, and therefore the accuracy of the thresholding procedure. In the attempt to reduce the effects of response bias, Katzer and colleagues (2011) employed a two-interval trial 'forced choice' task, during which participants were asked to say whether they perceived the tactile pulse during a first ("one") or second ("two") time-interval. Using a two forced choice task was considered to be a more objective method, as minimal amounts of individual characteristics and response bias are deemed to impact the choice of the time interval ("one" or "two") during which a stimulus was presented (Green & Swets, 1966). Thus, in a two forced choice task, tactile threshold is arrived at in a more objective way (i.e., based on tactile sensitivity rather than response bias).

Using this methodology, Katzer and colleagues (2011) achieved an average hit rate (HR) in light-present trials of 57% (*SD* 20%), which is within the 40-60% HR expected in studies using the single interval thresholding, and suggesting their procedure to be effective. In order to assess reliability the authors asked participants to repeat the same thresholding procedure at the end of the SSDT. The test-retest correlation indicated their method to be highly reliable (r = .84).

However, the procedure used by Katzer and colleagues (2011), like the original thresholding procedure (Lloyd et al., 2008), was delivered manually, so that the experimenter manually adjusted the stimulus intensity by turning the volume dial on the amplifier. The manual thresholding procedure has the disadvantage to be exposed to a greater potential for variability in technique and human error to affect the procedure. In addition, using the manual thresholding procedure, the tactile threshold itself cannot be empirically quantified.

For these reasons, further studies developed a computerised two forced choice task to determine the threshold intensity of the vibration to be delivered during the testing phase of the SSDT. The selection of the vibration level is made using a computer algorithm known as PEST: Parameter Estimation by Sequential Testing. PEST is an adaptive method which calculates fast and efficient estimates of psychophysical parameters such as tactile thresholds (Taylor & Creelman, 1967).

A series of pairs of trials are presented. The beginning of each trial is signalled by a white arrow appearing on the left corner of the computer monitor for 250ms and pointing towards the participant's left index finger. Each trial has a duration of 1,020ms. During either the first or the second trial, a 20ms tactile pulse (Touch) were delivered with a delay of 500ms on either side. In the other trial, an empty 1,020ms period occurs (No Touch). Participants are then asked to decide whether they had felt a pulse during the first or second trial by pressing the “1” or “2” key on the computer keyboard (a two alternative forced choice design). See Figure 2.5 for a schematic of a trial. If participants could not feel a vibration in either trial, they are instructed to guess which time period the vibration had occurred in. Participants are instructed to keep their hand still throughout the experiment including break and rest periods.

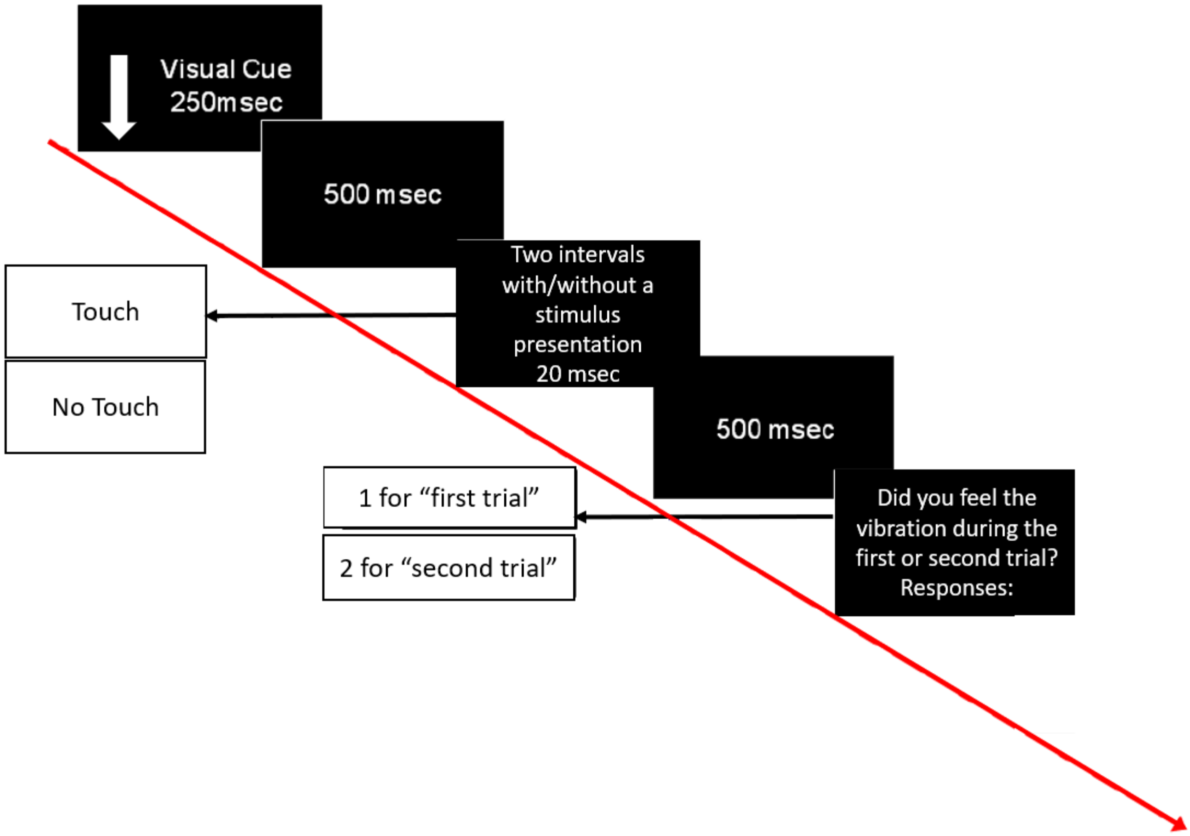


Figure 2.5. Schematic of a trial during the computerized two forced choice thresholding procedure of the SSDT.

In the current thesis, the manual single interval thresholding procedure was used in the study presented in Chapter 3, while in the studies of Chapter 4 and 5 the computerized two forced choice thresholding procedure was preferred. Chapter 6 examines some data collected in the studies presented in Chapter 3 and 5. Therefore, in the data analysed in Chapter 6 both thresholding procedures were employed.

In the experiments reported in Chapters 4 and 5, the PEST procedure was set at a threshold of 75%, as previous research showed that setting the PEST at a 75% threshold led participants to detect the vibration in 40-60% of trials, which is consistent with participants' behaviour using the manual thresholding (Mirams et al., 2017). The procedure began by presenting the same above threshold vibration to all participants. This vibration level was painless but quite strong so that it would be clearly felt by participants. The intensity of the vibration was defined using a scale of arbitrary units that ranged from 0 (maximal stimulation corresponding to the initial above-threshold vibration level) to -10,000 (minimum stimulation). A Wald (1947) sequential likelihood-ratio test was used to determine when to change the strength of the vibration: [N(c) (no. of correct responses) - Pt.N (T) (probability threshold value (0.75) multiplied by current trials completed) ≥ W (W's limits were: 1 to -1)]. If participants responded correctly on a series of trials (> 75% correct responses; W > 1), the programme automatically reduced the strength of the vibration (step-down). If they began to respond incorrectly (< 75% correct responses; W < -1), the programme automatically increased the vibration strength (a reversal). Initial step size (i.e., the difference between vibration levels) was set at 800, the minimum step size was set at 50 and the maximum at 3200. Step size was determined according to the following rules:

1. The second step in a given direction is the same size as the first.

2. After each reversal, halve the step size unless it follows a double.

3. After each reversal that follows a double, no change to the step size.

4. If the third step in a row is in the same direction, double the step size.

5. The fourth and subsequent steps in a given direction are each double their predecessor.

6. End the procedure when the minimum step size is reached.

The computer algorithm was programmed to complete a maximum of 120 trials. If the minimum step size was not reached after 120 trials, the vibration strength was set to the average stimulus strength over the last 50 thresholding trials. The visual stimulus (light) was not presented during the thresholding procedure. The procedure took approximately 15 minutes.

2.2.4 Experimental phase

After completing the thresholding procedure, participants underwent the experimental phase. The experimental phase of the original SSDT paradigm consisted in of two blocks of 80 trials[1]. The tactile pulse was administered in 50% of trials. Simultaneously, the LED flashed in 50% of trials, giving the following four trial types: light only (Light/No Touch); light and touch (Light/Touch); touch only (No Light/Touch); and catch (No Light/No Touch). Each trial type was presented 20 times per block in a random order. As for the thresholding procedure, the beginning of each trial was signalled by the appearance of visual (a white arrow on the left corner of the monitor) or an auditory (a beep sound) cue lasting for 250ms. In Touch trials, the tactile stimulus was presented at the threshold level previously established. In No Touch trials, no stimulation was administered. Touch only and catch trials were equivalent to those of the thresholding procedure. In light and touch trials, the LED flashed for 20ms at the same time as the vibration. In light only trials, the LED flashed for 20ms alone. At the end of each trial, participants were asked to report whether or not they felt a vibration. In accordance with Mirams and colleagues (2010), participants were given four response options and they were instructed to press the keyboards buttons '1' for 'definitely yes', '2' for 'maybe yes', '3' for 'maybe no', or '4' for 'definitely no'. Using these four response options enable researchers to have a more detailed picture of the decision making processes of participants, and possibly allow for the assessment of the confidence of their decisions. However, for the purposes of the studies of this thesis, 'definitely' and 'maybe' responses were combined in a yes/no binary coding, as confidence in decision making was not part of the research questions. A schematic of a trial is presented in the Figure 2.6 below. Participants were naive to the significance of the visual stimulus and were informed that a vibration would not be present on all trials. No other instructions were given.

[1] In Experiment 1, the number of trails per block was decreased to 40, as explained in Chapter 3, to avoid an excessive duration of the testing session. This is coherent with another study analysing SSDT responses using the fMRI (Llyod et al., 2011). However, in Lolyd and colleagues (2017) the number of trials was limited because of the methods used (i.e., the fMRI), which required shorter testing time windows.

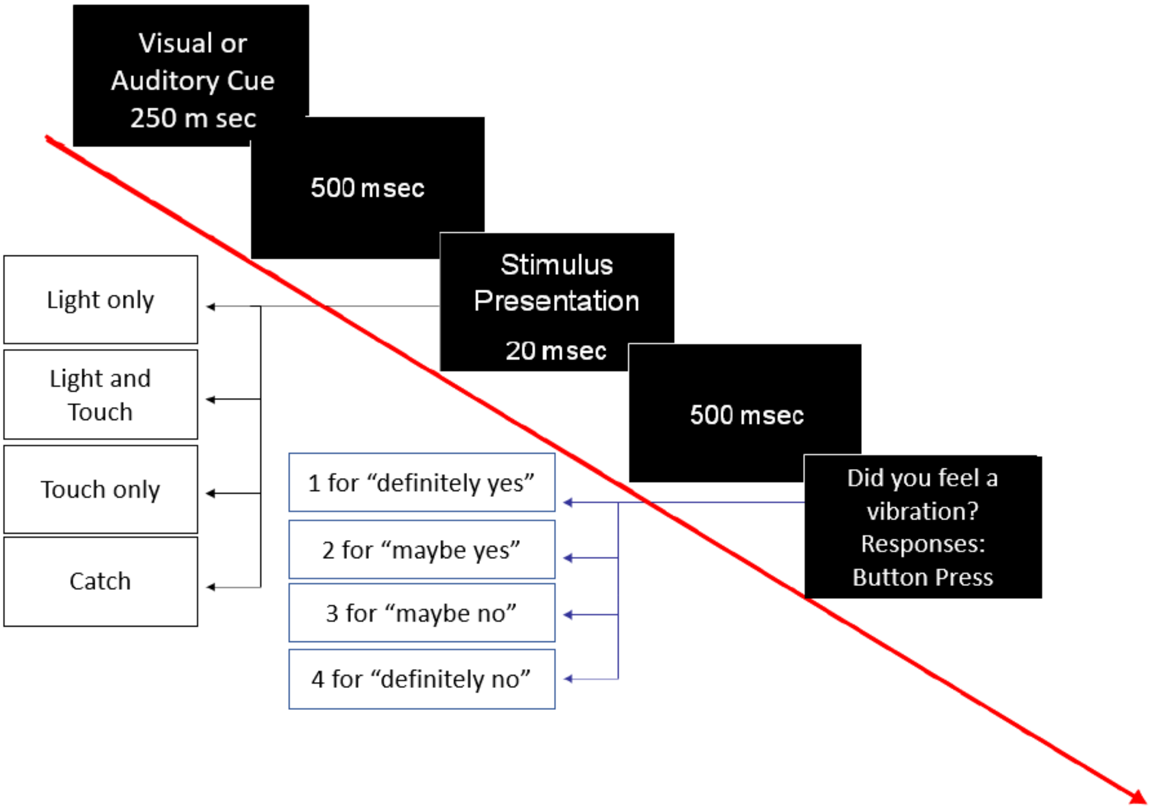


Figure 2.6. Schematic of a trial during the testing phase of the SSDT.

2.2.5 Data Processing

Participants' responses on the SSDT were classified as hits (reports of feeling the touch on touch-present trials), false alarms (erroneous reports of feeling the touch on touch-absent trials), misses (reports of not feeling the touch on touch-present trials), or correct rejections (reports of not feeling the touch on touch-absent trials; Mirams et al., 2010). According to the log-linear correction, hit rates (HR) were calculated using the formula: [hits + .5/(hits + misses +1)], and false alarm rates (FA) using the formula: [false alarms + .5/(false alarms + correct rejections +1)] (Snodgrass and Corwin, 1988) [2]. HR and FA were then used to calculate the signal detection theory test statistics d' and c. The sensitivity index d' indicates participants' ability to discriminate between touch-present and touch-absent trials [zHR − zFA]. A value of 0 indicates an inability to distinguish between signal and noise, while higher values indicate a greater ability to distinguish between signal and noise. The response criterion index c indicates participants' tendency to report stimuli as present regardless of the type of trail

[2] In the formulas for calculating HR and FA, 0.5 is added to the numerator and 1 to the denominator to eliminate potential errors due to having any zeros in the hit or false alarm rate data.

[−.5*zHR + zFA] (Macmillan and Creelman, 1991). Lower scores on c (c < 0) indicate a higher tendency to report touch (answer “yes”) across trials, while a value of 0 indicates no bias towards a particular response.

2.2.6 Interpretation of SSDT outcomes

In the context of the current thesis, we were interested in analysing how accurate participants’ tactile perception was in the different experimental conditions. We defined accuracy in tactile perception as higher HR and sensitivity *d’*, and lower FA. Conversely, lower HR and *d’*, and higher FA were considered to indices of a less accurate in tactile perception (Macmillan & Creelman, 1991). The response criterion was further used to describe participants’ shift in their tendency to report having perceived the touch regardless of the trial type (Macmillan and Creelman, 1991).

2.3 Individual differences in the propensity to make false alarms during the SSDT

Different studies investigated individual differences in the propensity of participants to make false reports of touch (FA) during the SSDT, with a particular focus on somatoform dissociation (i.e., pseudo-neurological physical symptoms) and somatization (i.e., the conversion of a mental state into physical symptoms).

Brown and colleagues (2010), for example, tested the differences in SSDT performance in a group of participants presenting with high vs. low sub-clinical somatoform dissociation symptoms (i.e., somatic manifestations in the form of pseudo-neurological symptoms secondary to trauma and/or stressors and/or internal psychological conflicts). Participants self-reporting high somatoform dissociation symptoms overall perceived the touch more often during the SSDT, compared to participants presenting with a low symptomatology, as indicated by a more liberal response criterion (*c*). However, this effect was mainly driven by an increase in the number of false reports of touch (FA) in the high symptomatic group. It was therefore suggested that participants presenting with greater somatoform dissociation symptoms are also more likely to experience illusory perceptual events under conditions of sensory ambiguity (such as during the SSDT).

Following this stream of research, another study by Brown and colleagues (2012) analysed the link between somatization symptoms and false reports of touch (FA) during the SSDT, in a sample of healthy participants and in a sample of endoscopy patients who were identified as having either medically explained or medically unexplained physical symptoms (i.e., symptoms without an apparent medical cause). In accordance with the findings of Brown and colleagues (2010), in the sample of healthy participants, self-reported somatization and physical symptoms were associated with an increased tendency to misperceive touch (FA rates) in light-present trials of the SSDT. Results were replicated in the clinical sample, where self-reported somatization and physical symptoms were found to be significantly correlate with false reports of touch (FA) not only in light-present but also in light-absent trials. Results remained significant after controlling for depression, and trait and state anxiety in both samples, and also for somatosensory amplification and hypochondriacal worry in the clinical sample only. Overall, findings of this study indicated a robust link between somatization symptom reporting and the tendency to experience somatoform distortions in the form of illusory perceptual events (FA) during the SSDT.

Similar results were found in another study by Katzer and colleagues (2012), where SSDT performance was assessed in individuals suffering from somatoform disorders (SFD; a family of psychiatric disorders characterized by the presence of unexplained physical symptoms) compared to healthy controls. Indeed, within the SFD group, the report of somatoform symptoms was positively correlated with FA during the SSDT.

There are therefore individual differences in the tendency to experience false reports of touch (FA) during the SSDT that can be ascribed to participants' levels of somatoform and somatization clinical and subclinical symptoms. Coherent with these results, different clinical models of somatoform and somatization symptoms have characterized patients suffering from this symptomatology as having an excessive focus on benign bodily sensations that are mistaken for evidence of serious illness (Mehling et al., 2009; Brown et al., 2012). Results of the studies here presented can be therefore conceptualized as an epiphenomenon of this distorted perceptual processing, according to which a raised focus on subtle bodily sensations manifested with a greater tendency to confuse these sensations with external tactile stimuli (Brown et al., 2010; Brown et al., 2012).

Moreover, results of these studies (analyzing the relationship between somatoform and somatization symptoms and SSDT performance) suggest that participants' psychological characteristics, in terms of personality traits and psychopathological symptoms, can influence SSDT performance. Partially confirming this hypothesis, McKenzie and colleagues (2010) showed that the tendency to report false alarms (FA), in both the presence and the absence of the light, appeared to have a stable trait like component in a study analyzing the test re-test reliability of the SSDT. However, up to date no study has investigated whether also the presence of ED symptoms can have an impact on SSDT performance. Given the evidence that EDS are associated with altered interoception and multisensory processing (see Chapter 1), it is possible that individual differences in SSDT performance relate also to ED symptoms.

2.4 Attention to the self and SSDT performance

Previous research has investigated the effects of manipulating attention to the self on SSDT performance. Mirams and colleagues (2010) for example tested whether vision of the body (enhanced attention to the bodily self) leads to a more accurate perception of touch (higher HR and lower FA) during the SSDT. To test this hypothesis, participants repeated the SSDT under two conditions: (non-informative) vision of the hand and no vision of the hand. Contrary to expectations, participants were more inclined to mistakenly report perceiving the touch (FA) in light trials when their hand was visible (non-informative vision condition) as compared to light trials during which their hand was hidden from the sight (no vision condition). No other significant differences between the two conditions were found. It was suggested that vision of the body may have induced a greater focus on internal bodily sensations that were mistaken for external tactile pulses (i.e., increased somatic interference) during the SSDT, resulting in higher FA. Overall results indicated that vision the body can have a detrimental effect on simple detection of near-threshold tactile stimuli, with a higher propensity to report touch in the absence of stimuli.

In another study, Mirams and colleagues (2012) investigated the effects of shifting participants' attention towards interoceptive or exteroceptive sensations on SSDT performance. Specifically, in one experiment participants repeated the SSDT twice: before and after performing a Heartbeat Perception Task (HPT). During the HPT, participants were asked to focus on and count feelings of their pulse (related to their heartbeats) in their fingertip After performing the HPT, participants were more inclined to report feeling the tactile pulse (presented to the same fingertip) during the SSDT, both in trials during which the tactile pulse was present and in trials during which the tactile pulse was absent, leading to a more liberal response criterion (*c*). The authors proposed that raising participants` interoceptive attention may have caused a confusion between signal (i.e., the tactile pulse) and sensory noise, reducing the criterion for reporting sensations.

In the second experiment, participants repeated the SSDT before and after performing a grating orientation task, during which they were asked to detect the orientation of grating patterns using their fingertip. This task was deemed to shift participants' focus on exteroceptive tactile sensations. After performing the grating orientation task, participants showed a decrease in touch reports during the SSDT, both in touch-present and in touch-absent trials, overall indicating a more stringent response criterion (*c*). It was therefore proposed that, opposite to the previous experiment, performing an exteroceptive task may have reduced the levels of sensory noise, heightening the criterion for reporting sensations.

Taken together these results suggested that shifting participants' attention towards interoceptive or exteroceptive sensations during the SSDT may lead to opposite effects on subsequent somatic perceptual decision making, with an overall increase in touch reports when attention is shifted interoceptively and an overall decrease when attention is shifted exteroceptively. However, few further studies attempted to replicate these results using different paradigms. Therefore, to date, it is not possible to state whether these results were specific for the tasks used or whether results could be generalized to other paradigms used as proxies to increase the focus on interoceptive vs. exteroceptive sensations.

In this respect, another study by Mirams and colleagues (2013) further investigated the effects of directing participants' attention towards inner body signals (i.e., interoception) on SSDT performance using a body-scan meditation training instead of the HPT. During the body-scan meditation training participants were asked to attend to different areas of their body consecutively, while focusing on any inner somatic sensations in a non-evaluative manner. After the training, participants showed an increase in their ability to discriminate when the tactile pulse was presented and when it was not (i.e., sensitivity, *d'*), with a decrease in their false reports of touch (FA) during the SSDT. Therefore, contrary to findings from the previous study (i.e., Mirams et al., 2012) in which interoceptive attention was found to induce an overall increase in touch reports regardless of whether the tactile pulse occurred or not, in this study interoceptive attention was found to enhance accuracy in tactile perception. The authors concluded that interoceptive attention may have differential effects on somatosensory processing depending on the type of tasks used and therefore on the *nature* of the attentional processes manipulated. Specifically, a localized and non-mindful interoceptive attention (such as during the HPT) may lead to a more liberal criterion in the reports of touch during the SSDT, while a generalized, mindful interoceptive attention (such as during a body-scan meditation) may lead to a more accurate perception of touch.

Another experiment by Durlik and colleagues (2014) investigated whether a different form of attention to the self could affect participants' responses during the SSDT. Specifically, in Durlik and colleagues' study (2014), attention to the self was enhanced by inducing the feeling of being watched by an external observer. This manipulation is known as *social self-focus attention*, and it postulates that simulating the presence of external observers can draw participants' attention towards the external, aspects of the self that are observable to others (Carver & Scheier, 1981; Davies, 2005). It was hypothesized that social self-focused attention could alter the way participants elaborate and process exteroceptive visuo-tactile information during the SSDT. To test this hypothesis, participants repeated a modified version of the SSDT (targeting the face instead of the hand) in two conditions: in front of a camera that was recording to enhance social self-focus, and in front of a camera switched off as control condition. When the camera was turned on, tactile perception was enhanced, as reflected by an increased accuracy in discriminating touch-present form touch-absent trials (*d'*), and a higher HR. Moreover, in this condition, , participants were less inclined to misperceive the touch in trials during which the light was presented but the tactile pulse was absent (FA). It was therefore concluded that social self-focused attention may enhance tactile perceptual accuracy and the correct detection of touch during the SSDT.

Overall these results indicate that enhancing attention to the self affects participants' SSDT performance differently, depending on a number of variables: (i) the *direction* where participants' attention is drawn to, for example whether it is directed towards interoceptive or exteroceptive information; (ii) the *perspective* from which attention to self is elicited, for example in the presence vs. absence of an external observer (social vs. private self-focus); (iii) the *type of task* used as proxy to induce self-focused attention, although the direction and perspective may be comparable.

However, up to date it has never been tested whether these results could be generalized to clinical samples of patients presenting with alterations in body perception, such as ED patients. Results of these previous studies were therefore used to inform the present thesis with the aim to better characterize how self-focus attention can influence SSDT performance in relation to ED symptoms. In turn, this could improve current understanding of how self-focused attention can alter multisensory perception in ED patients, and therefore inform treatment programs tackling body misperception in EDs.

2.5 Questionnaires

2.5.1 Dysmorphic Concern Questionnaire (DCQ; Oosthuizen, Lambert, & Castle, 1998)

The DCQ is a 7-item self-report investigating participants' concern about their physical appearance. Items cover topics such as the belief of being misshapen or malformed despite others' opinion; belief in bodily malfunction (e.g. malodour); consultation with cosmetic specialists; spending excessive time worrying about appearance; and spending a lot of time covering up perceived defects in appearance. Participants were asked to rate each item on a Likert scale from a minimum of 0 (“not at all”) to a maximum of 4 (“much more than most people”). Total scores range from 0 to 28 with a critical value of 9 indicating clinical concern (Mancuso, Knoesen & Castle, 2010). The DCQ was found to have a good internal consistency with $\alpha = .80$ (Jorgensen et al., 2001). This scale was selected among other measures for the assessment of dysmorphic concerns because it is fairly fast to administer. Moreover, the DCQ is not thought merely for clinical populations but also for subclinical samples, and it was therefore suitable for the studies of this thesis which employed subclinical samples of participants.

2.5.2 Eating Disorder Inventory 3 (EDI-3; Garner, 2002)

The EDI-3 is a self-report questionnaire for the assessment of EDs. The instrument comprises 91 items organized into 12 primary scales. Three of these scales focus on ED core symptoms: Drive for Thinness, Bulimia and Body Dissatisfaction. The sum of their scores constitutes an index of the risk to develop an ED: the ED Risk Composite. The remaining 9 subscales measure general psychological functioning and other personality traits that are often related to ED symptoms: Low Self-esteem, Personal Alienation, Interpersonal Insecurity, Interpersonal Alienation, Interoceptive Deficit, Emotional Dysregulation, Perfectionism, Ascetism and Maturity Fear. In the studies of this thesis, we have focused particularly on the ED Risk Composite, which was used to identify participants who were at a higher or at a lower risk to develop an ED. Participants were asked to rate to which extent they considered each item descriptive of themselves on a 6-point Likert scale ranging from “never” to ”always”. The EDI-3 includes items such as “I eat sweets and carbohydrates without feeling nervous”, “I think about dieting” and “I eat when I’m upset”. The EDI-3 was selected among different measures for the assessment of ED symptoms as it has been validated not only in clinical but also in non-clinical samples, and across different cultures (Clausen et al., 2011). The EDI-3 was therefore thought to be more suitable for the studies of this thesis which employed subclinical samples than other measures more specifically designed for clinical populations, such as the Eating Disorder Examination-Questionnaire (EDE-Q; Cooper & Fairburn, 1987). Moreover, as compared to the EDE-Q (which is together with the EDI-3 the gold standard for research on EDs), the EDI-3 provides not only a clear picture of participants’ ED symptoms but also different indices of ED-related symptomatology, that were relevant for the research questions of this thesis on body perception in EDs, such as the Interoceptive Deficit subscale. Lastly, the EDI-3 has been found to have a good internal consistency ($\alpha =$ between .75 and .92 for each subscale), excellent sensitivity and specificity as well as good discriminative validity (Clausen et al., 2011).

2.5.3 State-Trait Anxiety Inventory (STAI; Spielberger, 2010)

The STAI is a 40-item self-report questionnaire for assessing anxiety. The measure includes two subscales of 20 items differentiating between State-Anxiety and Trait-Anxiety. The State-Anxiety scale assesses the intensity of anxious feelings perceived “at this moment” while the Trait-Anxiety scale assesses the tendency to experience worry and anxiety “in general”. The STAI includes items such as “I feel calm”, “I am worried” and “I feel nervous”. Items are rated on a 4-point Likert Scale ranging from “not at all” to “very much so”. Total scores range from a minimum of 20 and a maximum of 80. The STAI was selected among other measures for the assessment of anxiety because it allows to differentiate between anxious temporary responses and more callous symptomatic anxious traits, which was relevant for assessing possible perticipants’ anxious responses to our experimental manipulations. Moreover, the STAI has been found to have an excellent internal consistency for both scales: State-Anxiety and Trait-Anxiety (α = between .89 and .92; Bieling, Antony & Swinson, 1998; Kabacoff et al., 1997).

2.5.4 Body Perception Questionnaire-Very Short Form (BPQ-VSF; Porges, 1993)

The BPQ consists of 12 items assessing participants’ awareness about different bodily states associated with changes in the activity of the autonomic nervous system, such as “muscle tension”, “goose bumps”, “stomach and gut pains”, breathing and heart-beat rates. Items are rated on a 5-point Likert scale ranging from 1 (“Never”) to 5 (“Always”). Total scores range between 12 and 60, with higher values reflecting a greater sensitivity and lower values a hyposensitivity to bodily sensations. The BPQ was selected among other measures for the assessment of body awareness because it is a fairly fast instrument while providing with a complete picture of how participants are aware of different domains of body perception that are connected to changes in the autonomic nervous system. The BPQ has been validated in different samples and has been shown to have a good internal consistency (α = between .88 and .97), and an excellent test-retest reliability (Cabrera et al., 2018).

Chapter 3

Self-focused attention and sensitivity to touch in women at risk from eating disorders

As discussed in Chapter 1, EDs have been associated with widespread abnormalities in body perception and alterations in the multisensory integration of visuo-tactile-proprioceptive (Eshkevari et al., 2012) and visuo-haptic-proprioceptive information (Case et al., 2012). In the current study (Experiment 1), we investigated whether alterations in multisensory integration in EDs also encompass the integration of exteroceptive visuo-tactile information as assessed using the SSDT (see Chapter 2). Moreover, as discussed in Chapter 1 and Chapter 2, a variable that has been found in previous research to influence somatosensory processes and multisensory integration is self-focus attention (elicited through exposure to the vision of the body). Following this reasoning, in Experiment 1 we investigated whether self-focused attention enhances, or is detrimental to somatosensory processing during the SSDT, in people with different levels of ED symptoms.

3.1 Introduction

3.1.1 Eating disorders and multisensory integration

As discussed in Chapter 1, it has been argued that body misperception plays a pivotal role in the aetiology and maintenance of EDs (Stice, 2002; Levine & Piran, 2004) with recent evidence suggesting that body misperception in EDs involves different components of somatic perception. In this respect, EDs have been found to be characterized by the presence of distortions in body image and overestimation of body size, with ED patients, and especially patients with AN, showing a tendency to perceive their bodies as bigger than in reality (Farrell et al., 2005; Gardner & Brown, 2014; APA, 2013).

Moreover, overestimation of body size in ED patients has been found to manifest itself also in the tactile modality. Indeed, ED patients overestimate distances between two tactile stimuli simultaneously pressed to the skin (i.e., 2-point discrimination (2PD) test), suggesting that they elaborate tactile stimuli as if their body was larger than in reality (Keizer et al., 2011; 2012). Alongside, body image disturbances were also shown to extend to the body schema (i.e., the neural representation of the spatial properties of the body in action and interaction with the environment; Berlucchi & Aglioti, 2010) with healthy subjects reporting body image concerns, and anorexic patients, underestimating the width of an aperture they could pass through, and performing the action as if their body was larger than in reality (Guardia et al., 2012; Keizer et al., 2013; Irvine et al., 2019).

Moreover, EDs have also been linked to deficits in interoception, with ED patients showing a reduced propensity to focus on internal bodily sensations (i.e., interoceptive sensibility; Garfinkel et al., 2015; Fassino et al., 2004; Matsumoto et al., 2006). As discussed in Chapter 1, these findings were partially supported also by some studies assessing objective accuracy in detecting interoceptive signals (i.e., interoceptive accuracy) such as heartbeat and breathing sensations, and pleasantness of touch (gentle stroking, 3cm/s; Pollatos et al., 2008; Klabunde et al., 2013; Khalsa et al., 2015; Crucianelli et al., 2016; Bischoff-Grethe et al., 2018). However, while findings on reduced interoceptive sensibility are consistent across studies, some studies failed to find a difference in interoceptive accuracy between ED patients and healthy controls, possibly indicating a dissociation between self-reported and experimentally measured interoceptive abilities (Pollatos & Georgiou, 2016; Eshkevari et al., 2014).

Body misperception in EDs has been found also to encompass alterations in multisensory integration, with abnormalities in the elaboration and integration of perceptive information involving different sensory modalities (Keizer et al., 2016; Gadsby, 2017; Riva & Gaudio, 2018). In this regard, informative data come from studies analysing somatosensory illusions elicited by the integration of conflicting multisensory information, such as the Rubber Hand Illusion paradigm (RHI; Botvinick & Cohen, 1998; see Chapter 1). During the RHI, the integration of contrasting tactile and visual information induces participants to mis-locate the position of their own hand as closer to the fake hand. Research in ED patients has shown this population to be more inclined than healthy controls to perceive the bodily illusion (Eshkevari et al., 2012; Caglar-Nazali et al., 2014). It was suggested that people with EDs might have an increased sensitivity to the visual aspects of body perception, which in turn might lead to alterations in the multisensory integration of visual, tactile and proprioceptive information during the RHI (Eshkevari et al., 2012; Caglar-Nazali et al., 2014).

Similar findings were found in regard to the Size Weight Illusion (SWI, Charpentier, 1891; see Chapter 1). Indeed, Case and colleagues (2012) found a sample of anorexic patients to have an atypical response to the SWI as compared to healthy controls. In accordance with the previous studies using the RHI, it was suggested that anorexic patients might have alterations in the integration of visual, haptic and proprioceptive information, leading to abnormal responses during the SWI.

The first aim of Experiment 1 was therefore to establish whether ED symptoms are related to alterations in visuo-tactile multisensory integration as assessed using the SSDT (see

Chapter 2). To address this aim, we compared SSDT performance in two samples of participants presenting with lower vs. higher levels of subclinical ED symptoms.

In comparison to the RHI, and other paradigms assessing multisensory integration, the SSDT takes advantage of the use of the Signal Detection Theory, which provides a more comprehensive description of participants responses, with separate measures of sensitivity (*d'*, i.e., the ability to correctly discriminate whether the tactile pulse was absent or present) and response criterion (i.e., the propensity to report feeling the tactile pulse regardless of the type of trial; Smeets et al., 1999). Furthermore, it has been argued that participants' responses during the RHI can be driven by suggestibility (demand characteristics), since during the illusion participants are aware of a distortion in their experience of an existing touch (Marotta et al., 2016; Lush, 2020). Conversely, during the SSDT, participants are unaware of whether or not their experience of touch is accurate or distorted, and so this paradigm may provide a more objective measure of tactile distortions due to multisensory integration.

Sampling a non-clinical population allows controlling for possible confounding variables that can affect research in clinical samples, such as cognitive and perceptual impairments secondary to starvation, or medication treatment. Moreover, research on subclinical populations has the advantage of indicating whether somatosensory disturbances anticipate the onset of EDs, therefore giving a direction for preventive measures. As EDs are associated with body misperception and heightened propensity to experience multisensory illusions, we hypothesized that subjects with higher ED symptoms would show a stronger influence of the light on touch reports and ultimately a lower sensitivity (*d*') in discriminating when touch was present or absent during the SSDT.

3.1.2 Self-focused attention and body perception

To further understand the psychological processes affecting body misperception in EDs, we also investigated the potential influence of self-focused attention on SSDT performances. Previous studies suggest that multisensory integration and somatosensory processes can be affected by the manipulation of attention. Self-focused attention can be enhanced by exposing participants to the vision of their body or their face (Mirams et al., 2010; Taylor-Clarke et al., 2004; Kennet et al., 2001; Serino et al., 2009; Harris et al., 2007; Ainley et al., 2012; 2013). As discussed in Chapter 1 (Section 1.5) In previous studies, vision of the body has been found to enhance tactile perception in terms of decreased grating discrimination thresholds (Taylor-Clarke et al., 2004), reduced 2PD thresholds (Kennett et al., 2001; Serino et al., 2009), and enhanced amplitude discrimination of above-threshold stimuli (Harris et al., 2007). Similarly, Ainley and colleagues (2012; 2013) demonstrated that vision of one's own face can enhance interoceptive accuracy. Participants were asked to perform a heartbeat perception task (HPT) while looking at a photograph of their face or their reflection in a mirror, as compared to a blank screen. Participants were more accurate in perceiving their heart rate when self-focused attention was augmented by looking at their face (both as reflected in a mirror and as presented in a photograph).

However, to date, little information is available about the effects of self-focused attention on perceptual processes and multisensory integration in samples of ED patients. A single study analysed the effects of self-focused attention on interoceptive accuracy on a sample of anorexic patients replicating the paradigm used by Ainley and colleagues' (2012; 2013). Participants completed an HPT in two conditions: while viewing a photograph of themselves or another person as a control condition (Pollatos et al., 2016). Results showed anorexic patients to have lower interoceptive accuracy when viewing the photograph of themselves, as compared to another person. This is in contrast with previous results on healthy participants, where vision of one's own face was found to enhance interoceptive accuracy. The authors of the study hypothesized that anorexic patients might be less accurate in elaborating body signals while viewing their own photograph as they might find it distressing to be exposed to the vision of their face because they are dissatisfied with their physical appearance.

The second aim of our study, therefore, was to determine whether self-focused attention enhances or is detrimental to somatosensory processing in people with different levels of ED symptoms. This is particularly important to inform the design of interventions to reduce body misperception in EDs, such as body exposure and the mirror therapy, which concern manipulating attention to the bodily self to improve body satisfaction and (mis)perception (Vocks et al., 2008).

To address our aims participants underwent a modified version of the original SSDT, during which the vibration was administered to participants' cheeks (rather than their fingertips as in its classic version) and the light was placed in front of participants (similar to Durlik et al., 2014). The face was chosen as it represents a body part more salient for the construction of one's own identity and body image as compared to the hand, and it was therefore more relevant for this study (Haxby, Hoffman & Gobbini, 2000). Participants completed the task in three experimental conditions: (i) while looking at a photograph of their own face for eliciting self-focused attention (Self); (ii) while looking at a photograph of another person's face (as in Pollatos et al., 2016; Other); (iii) while looking at a scrambled face (Scrambled) as an additional control condition.

Physiological arousal levels, anxiety, and attitudinal components of body image including body dysmorphic symptoms were measured in order to test whether differences in participants' performance could be accounted for by these variables.

Following previous studies (e.g., Pollatos et al., 2016), we expected that participants presenting with higher levels of ED symptoms would find the Self condition more distressing due to higher levels of anxiety, dysmorphic symptoms and body image concerns. We also expected these participants to show a stronger response in terms of physiological arousal in the Self condition compared to participants presenting lower levels of ED symptoms. In turn, we expected this response in physiological arousal to lead to a disruption in perceptual processes and therefore to a lower sensitivity (*d'*) during the SSDT in this condition. Conversely, we expected that participants presenting lower levels of ED symptoms would show the classic self-focused attention effect, with no signs of physiological distress and higher *d*' during the Self condition.

Lastly, participants completed an HPT to assess the relationship between SSDT performance and interoceptive accuracy. A previous study by Durlik and colleagues (2014) showed that participants exhibiting lower interoceptive accuracy were also more inclined to misperceive touch during the SSDT as indicated by higher false alarm rates. As body misperception in EDs has been found to encompass interoception, we expected worse performance during the SSDT for high ED participants to be coupled with poorer interoceptive accuracy.

3.2 Methods

Participants attended one single testing session during which they performed the SSDT in the three experimental conditions: Self, Other and Scrambled. Thus, a mixed-design was employed with Condition and Light during the SSDT (light present/light absent) as within-subjects variables, Group (High vs. Low ED) as a between subjects variable, and hit rate (HR), false alarm rate (FA), *d*' and c as dependent variables.

3.2.1 Participants

Fifty-nine female participants were initially recruited from the staff and student population at Liverpool John Moores University (LJMU) via flyers and advertisements placed around the campus, and from the general population via an LJMU database of people from the general public interested in taking part in research studies. The sample size was based on a power analysis using G*Power 3.0.10 (Faul et al., 2007), which indicated that a minimum total sample of 44 participants was needed to detect a medium effect (f = .25) with 95% power, using a mixed design ANOVA with alpha at .05 (two tailed). However, given that it is deemed good practice to exceed the minimum number of participants indicated by an a priori power analysis, the sample size was increased to 59 participants (Faul et al., 2007; Field et al., 2013).

However, 4 participants were excluded from analysis because a consistent tactile threshold level during the SSDT could not be achieved [(HR) > 90% or < 10% during at least one condition of the SSDT and across Light and No Light trials]. Furthermore, another 2 subjects were excluded for having outlying scores (> 2 *SD*) in all SSDT outcome measures. Therefore, we report data from 53 subjects between 18 and 39 years of age (*M* = 23.94; *SD* = 4.90). Only females were recruited due to the fact that literature on EDs in males is still scarce, and EDs have been shown to differ significantly in terms of prevalence and phenomenological manifestations between men and women (Stanford & Lemberg, 2012).

In accordance with previous research using the SSDT, participants were right-handed (as assessed using the Edinburgh Handedness Inventory; Oldfield, 1971), with no history or present diagnosis of any psychiatric disorder, with no impairments in tactile perception of the cheek, with no uncorrectable vision problems and not being pregnant.

Participants were preselected based on their scores on the ED Risk Composite of the Eating Disorder Inventory-3 (EDI-3; Garner, 2002. See the Materials and methods section), which is an index of the risk of developing an ED. Specifically, we preselected subjects whose scores fell into the first (below Q1 = 19) and last quartile (above Q3 = 30) of the normative distribution in the general population (Clausen et al., 2011). Participants who scored 19 or below were deemed to be at very low risk for the development of an ED and formed the Low ED group (n = 27; Age: *M* = 24.70; *SD* = 5.31). Conversely, participants who scored 30 or above were at a higher risk for EDs and were included in the High ED group (n = 26; Age: *M* = 23.15; *SD* = 4.38).

The study was carried out in accordance with the Helsinki declaration of ethical standards. The study protocol was approved by the LJMU's University Research Ethics Committee (UREC) 18/NSP/059. All participants gave their written informed consent to take part in the study. Participants were naïve as to the true purpose of the study and were debriefed by the experimenter at the end of the testing session. Participation was rewarded with a £5 shopping voucher or course credits.

3.2.2 Material and measures

3.2.2.1 The Somatic Signal Detection Task (SSDT; Lloyd et al., 2008) – Face Version. The original set-up presented in Chapter 2 was slightly amended in order to target the face rather than the hand. To this aim, participants sat in a light attenuated room approximately 40 cm in front of a computer monitor (5:4 ratio; 270mm × 330mm). The tactor delivering vibrations (Z-Voom phones type YVE-01B-03, Yeil Electronics, South Korea; 1.8cm *diameter*) was fixed to participants' left cheeks using double sided adhesive tape and a bandage tape to prevent movements.

In the Self condition, a mirror-reversed photograph of the participant's face was presented on the computer screen during trials to induce self-focused attention. In the Other condition, a photograph of another person was presented, and in the Scrambled condition, a scrambled version of the photograph of the participant's own face was presented (see the Procedure section for more details). The face displayed in the Other condition matched participants' age and gender and was selected from the Chicago Face Database for average attractiveness (Ma, Correll, & Wittenbrink, 2015). Photographs were 768 × 583 pixels in size. During the experimental phase, a 4mm red light emitting diode (LED) was fixed to the computer monitor mirroring the location of the tactor on the participant's face (see Figure 3.1). Therefore, during the Self and the Other conditions, the LED location corresponded to the cheek of the face depicted on the monitor. A similar version of the SSDT, in which the tactile stimulus was presented to the face, and the light was presented approximately 100 cm in front of participants, was used previously by Durlik and colleagues (2014), who found significant effects of the light on sensitivity and response criterion.

Gaze direction, and distance from the computer monitor during the task was controlled using a chin-rest that discouraged participants from moving their head. Throughout the experiment, participants listened to white noise via headphones to mask any informative sounds from the tactor. Underneath the headphones, participants wore a second pair of small earphones which administered auditory cues for signalling the beginning of each trial of the SSDT. The experimental set-up of the SSDT is illustrated in Figure 3.1.

To control for possible confounding variables, at the end of the SSDT, participants were asked to rate on 15cm Visual Analogue Scales (VASs) the age and attractiveness of the person shown in the Other condition. Alongside, 15cm VASs were used to assess whether subjects interpreted the photographs presented in the Self and Other conditions assuming a first or third-person perspective. In other words, whether they interpreted themselves as active observers of the photographs or whether they perceived themselves as being watched by an external observer. No differences between groups were found in any VAS. Material and measures and results are presented in Appendix A.

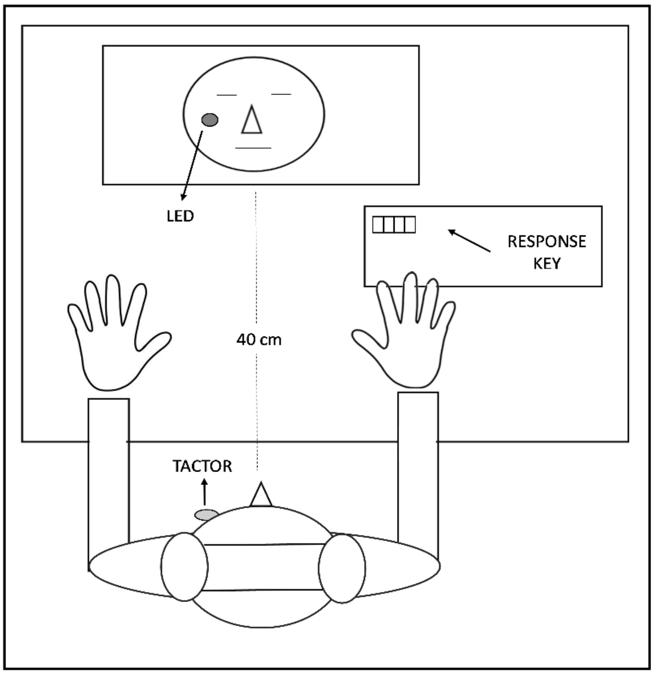


Figure 3.1. Schematic depiction of the experimental set-up for the Self /Other conditions during the SSDT in Experiment 1.

3.2.2.2 Physiological arousal measures. Electrodermal Activity (EDA) and Electrocardiogram (ECG) signals during the SSDT were recorded using Biopac (MP150) Systems (Version 4.2, Biopac Systems Inc., CA, USA). For each condition of the SSDT, data were recorded at baseline for 5 minutes before the beginning of the task, and continuously throughout the whole task. ECG data were registered via a set of three electrodes applied on the right and left shoulders and on the left hip (Einthoven's triangle). EDA data were registered via an additional set of two electrodes applied on the middle finger and index of the left hand. Both sets of electrodes were connected to the Biopac (MP150) Systems and the Biopac Student Lab Pro 3.7 software. The software was programmed to filter in real time ECG data with a band-pass of .5–35 Hz and EDA data with a band-pass of 0–35 Hz. The sampling rate for data acquisition was set at 1000 Hz.

EDA and ECG data were then used for calculating two well-known physiological measures of arousal: Skin Conductance Levels (SCLs) and High Frequency Heart Rate

Variability (HF HRV). SCLs are a measure of background tonic EDA and represent an index of the activity of the sympathetic nervous system (SNS; Sztajzel, 2004; Mendes, 2009). The SNS is activated in response to stress and emotional stimuli. In turn, SNS activation modulates the electrical activity of the skin resulting in increased sweating and therefore increased SCLs (Critchley, 2002). Conversely, HF HRV (HRV in the range of 0.15-0.4 Hz) represents an index of the activity of the parasympathetic nervous system (PSNS, Camm et al., 1996) which controls functions of the body at rest. Resting states are associated with an increased activity of the PSNS and with a corresponding increase in HF HRV. Therefore, higher arousal can be associated either with higher SCLs, or with lower HF HRV, or with a combination of the two (Berntson, Cacioppo & Quigley, 1991).

In the current study, changes in arousal were found to be driven by modifications in the SNS but not the PSNS. Indeed, participants reported changes in SCLs across the different experimental conditions but fairly stable levels of HF HRV. HF HRV data extrapolation and results are therefore reported in Appendix A.

3.2.2.3 The Heartbeat Perception Task (HPT; Schandry, 1981). Interoceptive accuracy (IAcc) was assessed using the mental tracking method HPT (Schandry, 1981). Participants were instructed to mentally count their heartbeats only by concentrating on their body but without taking the pulse in 4 signalled time intervals ranging between 20 and 55 seconds. The duration of the sum of the intervals was set at 150 seconds for each participant. Participants were not aware of the duration of time intervals, and had no access to any indication of time (e.g. no computer or wrist watch). At the end of each interval, participants were asked to verbally report the number of heartbeats counted in that time window starting from 0 in case no heartbeats were felt. They were specifically encouraged not to use any prior knowledge about their heart rate when performing the task. Simultaneously, the actual number of heart beats occurring in each interval was recorded through a sensor fitted to the participants' fingertips and connected to the physiological data unit Biopac (MP150) Systems. IAcc was then calculated relating the reported number of beats counted with the actual number of beats recorded (see below for data processing; Ainley et al., 2013).

3.2.3 Self-report questionnaires

3.2.3.1 Dysmorphic Concern Questionnaire (DCQ; Oosthuizen, Lambert, & Castle, 1998). The DCQ is a 7-item self-report investigating participants' concern about their physical appearance (see Chapter 2, Section 2.5.1). The scale was administered to investigate whether

Low and High ED participants differ in their levels of physical appearance concern, therefore suggesting a different interpretation of the photograph presented in the Self condition.

3.2.3.2 Eating Disorder Inventory 3 (EDI-3; Garner, 2002). The EDI-3 is a self-report questionnaire for the assessment of ED and ED-related symptoms (sse Chapter 2, Section 2.5.2). In this study the EDI-3 was administered prior to the testing session, and the ED Risk Composite was used for selecting eligible participants as explained above.

3.2.3.3 State-Trait Anxiety Inventory (STAI; Spielberger, 2010). The STAI is a 40-item self-report questionnaire for assessing anxiety. The measure includes two subscales of 20 items differentiating between State-Anxiety and Trait-Anxiety (see Chapter 2, Section 2.5.3). Scores were used to analyse whether state or trait anxiety differed in the Low versus the High ED group, possibly suggesting a different emotional response (State-Anxiety) due to the experimental manipulation.

3.2.4 Design and Procedure

At the beginning of each testing session, the experimenter took a photograph of the participant's face. Photographs were taken using a Nikon D50 digital SLR camera, with a flash. Participants were standing against a grey background in a windowless testing cubicle, and they were photographed with a neutral facial expression, without hair covering their face. Each participants' original photograph was flipped horizontally to recreate the effect of a mirror. In case the face was not perfectly centred, photographs were adjusted and cropped using Microsoft Picture Manager 2013. The mirrored photograph of the participant then was used during the Self condition of the SSDT. Subsequently, a 70×70 pixel scrambled version of the Self photograph was created using Matlab 9.5. The picture was then used in the Scrambled condition of the SSDT. Electrodes for recording physiological measures (EDA and ECG) were placed on participants as previously explained.

After that, participants were administered the SSDT protocol, which consisted of a thresholding procedure and an experimental phase. The SSDT protocol was repeated three times, once in each experimental condition: Self, Other and Scrambled. Photographs were displayed during both the thresholding procedure and the experimental phase. In this fashion, the thresholding was recalibrated for each experimental condition to avoid the possibility that the experimental manipulation would lead to differences in SSDT outcomes due to changes in participants' tactile threshold. Each participant underwent all conditions in a repeated measure fashion, and the order of conditions was randomized between participants and counterbalanced. Two breaks of 5 minutes were administered between conditions. Throughout the SSDT, EDA and ECG data were recorded.

After completing the SSDT, participants were asked to perform the HPT, and to complete the VAS, the EHI, the STAI and the DCQ. Lastly, height and weight were measured with a stadiometer and a scale for calculating the Body Mass Index (BMI; kg/m^2) according to the NHS online calculator. The testing procedure lasted approximately 90 minutes per participant.

3.2.4.1 SSDT Thresholding Procedure

Before the beginning of the testing phase, participants completed a manual single interval thresholding procedure (see Chapter 2) to individually calibrate the strength (amplitude) of vibration. During the thresholding procedure instructions appeared on the top section of the computer screen in order not to hide the photograph displayed according to the experimental condition. Immediately after completing the thresholding procedure, participants started the experimental phase of the SSDT.

3.2.4.2 SSDT Experimental Phase

Before the beginning of the experimental block, the experimenter placed the LED on the computer monitor. The experimental phase was then administered as described in Chapter 2. In this study, the number of trials per block was decreased to 40, given the total length of the study. As for the thresholding procedure, the beginning of each trial was signalled by an auditory cue, and instructions appeared on the top section of the computer screen.

3.2.5 Statistical Analysis and Statistical Software

All Statistical analysis were performed using Statistica 8.0 (StatSoft Inc, Tulsa, Oklahoma software). All data are reported as Mean (M) and Standard Deviation (SD). A significance threshold of $p < .05$ was set for all effects. Effect sizes were estimated using partial eta square (η2) and Cohen's d.

A series of t tests were conducted to investigate whether there were differences in age, BMI, Handedness, IAcc, DCQ, STAI, EDI-3 subscales, and VASs between the High and Low ED groups.

To determine whether the two ED groups differed in their SSDT performance, four mixed design ANOVAs were then performed using Group (High vs. Low ED) as the between-subject factor, Light (Light/No Light) and Condition (Self/Other/Scrambled) as within-subject factors, and HR, FA, d' and c as dependent variables. Duncan post-hoc comparisons were performed to follow-up significant interactions.

To determine whether the two ED groups differed in arousal in each condition of the SSDT, we performed a mixed-design ANOVA with Group as the between-subject factor, Condition as the within-subject factor, and SCLs as dependent variable.

For HR, d' and SCLs, significant results were followed-up also with t tests comparing change scores between the different experimental conditions.

Before performing the ANOVAs, all dependent variables were tested for normality, homogeneity of variance and sphericity assumptions. Whilst, HR, d' and c were found to be normally disturbed for all experimental conditions, FA and SCLs data were found to be not normally distributed in some experimental conditions. The data remained not normal after attempting for different transformations. However, given that the F test is fairly robust against violation of assumptions (Faul et al., 2007; Field et al., 2013), parametric tests were performed for FA and SCLs in coherency with the other outcome variables.[3]

After controlling that the assumptions of bivariate normality and linearity were met, Pearson's *r* partial correlations were used to further investigate relationships between variables.

3.3 Results

3.3.1 Data Processing

3.3.1.1 SSDT scores. HR, FA, d′ and *c* outcomes of the SSDT were calculated as indicated in Chapter 2.

3.3.1.2 HPT scores. IAcc was calculated for each participant as the mean score across the four trials using the formula {1/4 ∑[1-(|recorded heartbeats - counted heartbeats|/recorded heartbeats)]} where higher scores indicate increased IAcc (Schandry, 1981; Ainley et al., 2013).

3.3.1.3 SCLs data extrapolation. EDA data were recorded continuously during each condition of the SSDT. For each of the 3 conditions, 2 recordings were obtained: at baseline and during the experimental phase, resulting in a total of 6 recordings per participant. Each

[3] Please note that significant findings in FA and SCLs were tested also using non-parametric tests. Because results were substantially the same when using parametric tests, we then decided to report the results of parametric tests for the sake of consistency with other results.

recording was visually inspected for artefacts, which were manually removed using Biopac (MP150) Systems. Six SCLs per participant were extrapolated averaging across the EDA signal in each baseline and experimental recording. No differences between groups (Low vs. High ED) were found in baseline SCLs (bs SCLs) in any of the experimental conditions (bs SCLs Self: $t(51) = |1.32|$, $p = .10$, $d = .36$; bs SCLs Other: $t(51) = |1.61|$, $p = .11$, $d = .44$; bs SCLs Scrambled: $t(51) = |1.71|$, $p = .09$, $d = .56$). Three baseline-corrected SCLs were then calculated by subtracting baseline SCLs from their respective experimental SCLs. The baseline-corrected SCLs were later used for all the analyses described in the below results section.

3.3.2 Preliminary analyses

Results of the t tests are presented in Table 3.1. The two groups were comparable in age and IAcc. A significant difference was found in BMI with the High ED group having a higher BMI compared to the Low ED group. The High ED group also had significantly higher scores on the DCQ and on the State-Anxiety subscale of the STAI, indicating that subjects with higher ED traits have also stronger dysmorphic concerns and experienced more anxious feelings on the day of testing. However, the two groups were comparable on the Trait-Anxiety subscale, indicating that High and Low ED groups experience similar levels of anxiety on a day to day basis. Interestingly, both groups exhibited Trait-Anxiety scores that were higher than normative scores in the general population. However they did not reach clinical standards (Bieling et al., 1998). The High ED group had significantly higher scores on all the subscales of the EDI-3 (Low Self Esteem, Personal Alienation, Interpersonal Insecurity, Interpersonal Alienation, Interoceptive Deficit, Emotional Dysregulation, Perfectionism and Ascetism) apart from the Maturity Fear subscale.

Table 3.1

Descriptive statistics for age, BMI, Handedness and scores on the IAcc, DCQ, STAI and EDI-3 subscales in each group, together with t-test statistics.

	Low ED	High ED				
	M (SD)	M (SD)	t	df	p	d
Age	24.70 (5.31)	23.15 (4.38)	1.15	51	.25	.32
BMI	21.30 (2.10)	28.02 (7.91)	4.26	51	.000	1.16
IAcc	.63 (.22)	.63 (.25)	0.05	51	.96	.01
DCQ	3.89 (2.15)	8 (3.68)	4.99	51	.000	1.36

State-Anxiety	29.92 (6.74)	37.35 (8.49)	3.45	51	.000	.97
Trait-Anxiety	50.58 (2.14)	49.38 (2.98)	1.66	51	.10	.46
Low Self-esteem	2.74 (3.59)	7.81 (5.41)	4.03	51	.000	1.10
Personal Alienation	2.18 (3.47)	7 (4.70)	4.25	51	.000	1.17
Interpers. Insecurity	4.77 (4.10)	8.11 (5.57)	2.48	51	.026	.68
Interpers. Alienation	4 (4.20)	7.88 (4.63)	3.20	51	.002	.88
Interoceptive Deficit	4.26 (4.89)	8.58 (4.42)	3.37	51	.001	.93
Emotional Dysreg.	2.81 (3.54)	6 (4.75)	2.77	51	.008	.76
Perfectionism	6.44 (4.34)	9.69 (4.85)	2.57	51	.01	.71
Ascetism	2.26 (1.95)	6.30 (4.62)	4.13	51	.000	1.14
Maturity Fear	7.33 (4.04)	9.38 (4.72)	1.70	51	.09	.47

Note. IAcc = Interoceptive Accuracy assessed by the HBP task. S-Anxiety and T-Anxiety are the two subscales of the STAI. Low Self-esteem, Personal Alienation, Interpersonal Insecurity, Interpersonal Alienation, Interoceptive Deficits, Emotional Dysregulation, Perfectionism, Ascetism and Maturity Fear are all subscales of the EDI-3.

3.3.3 Main analyses

Descriptive statistics for HR, FA, d′ and c in each Light and Condition of the SSDT, in each group are presented in Table 3.2.

Table 3.2

Descriptive statistics for hit rate, false alarm rate, *d’* and *c* in each Face and Light condition during the SSDT, in each ED group.

Low ED		HR (%)	FA (%)	FA (%)	*d’*	*c*
		M (SD)	Mdn (IQR)	M (SD)	M (SD)	M (SD)
Self	Light	54.05 (17.56)	.03 (1)	10.07 (11.54)	1.59 (.87)	.67 (.29)
	No Light	55.67 (22.75)	.03 (0)	6.60 (4.69)	1.79 (.86)	.70 (.36)
Other	Light	61.23 (23.24)	.03 (0)	7.06 (5.24)	1.93 (.86)	.60 (.39)
	No Light	51.74 (24.90)	.03 (0)	6.83 (6.31)	1.65 (.88)	.78 (.45)

Scrambled	Light	61.92 (24.65)	.03 (0)	7.99 (7.22)	1.91 (.89)	.57 (.49)
	No Light	52.89 (23.61)	.03 (0)	7.99 (7.62)	1.64 (.83)	.71 (.41)
<u>High ED</u>		HR (%)	FA (%)	FA (%)	*d'*	*c*
		M (SD)	Mdn (IQR)	M (SD)	M (SD)	M (SD)
Self	Light	66.34 (21.75)	.03 (0)	8.65 (8.90)	2.08 (.87)	.47 (.42)
	No Light	57.93 (22.45)	.03 (0)	5.77 (7.11)	1.93 (.68)	.74 (.41)
Other	Light	60.10 (24.83)	.03 (1)	5.05 (3.86)	2 (.76)	.68 (.44)
	No Light	56.25 (26.47)	.03 (0)	5.05 (4.25)	1.95 (.76)	.74 (.50)
Scrambled	Light	57.45 (24.98)	.09 (0)	9.13 (8.19)	1.69 (.80)	.61 (.48)
	No Light	55.77 (22.58)	.03 (0)	7.21 (5.29)	1.76 (.84)	.67 (.39)

<u>3.3.3.1 Hit Rate</u>

A significant main effect of Light ($F(1,51) = 12.02$, $p = .001$, $\eta^2 = .19$) was found with higher HR in Light (*M* = 60.2, *SD* = 16.17) compared to No Light (*M* = 55, *SD* = 15.43) trials. Importantly, the Light × Condition × Group interaction was significant ($F(2,102) = 3.99$, $p = .02$, $\eta^2 = .07$). Post-hoc comparisons showed that for the Low ED group there was a significant effect of Light in the Other condition, with higher HR in Light (*M* = 61.23, *SD* = 23.24) compared to No Light trials (*M* = 51.74, *SD* = 24.90; *p* = .02, *d* = .47). Likewise, there was a significant effect of Light in the Scrambled condition, with higher HR in Light (*M* = 61.92, *SD* = 24.65) compared to No Light trials (*M* = 52.89, *SD* = 23.61; *p* = .02, *d* = .45). However, no effect of Light was found in the Self condition (see Figure 3.2).

Conversely, for the High ED group, there was a significant effect of Light only in the Self condition, with an increase in HR in Light (*M* = 66.34, *SD* = 21.75) compared to No Light trials (*M* = 57.93, *SD* = 22.45; *p* = .03, *d* = .57). However, no effects of Light were found in the Other or Scrambled conditions. Moreover, HR in Light trials of the Self condition were significantly higher than those of the Scrambled condition (*M* = 57.45, *SD* = 24.98; *p* = .02, *d* = .35). The opposite pattern was found in the Low ED group, which showed higher HR in Light trials of the Scrambled (*M* = 61.92, *SD* = 24.65) condition as opposed to the Self (*M* = 54.05, *SD* = 17.56) condition. However, this difference was found only to approach significance (*p* = .05, *d* = .27).

We further investigated these results by calculating HR change scores in Light trials from the Scrambled to the Self condition, and performed an independent sample t test to analyse group differences. Change scores showed an increase in HR from the Scrambled to the Self condition for the High ED group ($M = 8.89$, $SD = 25.13$) and a decrease for the Low ED group ($M = -7.87$, $SD = 29.34$), and the difference in change scores between the two groups was significant ($p = .03$, d = .62). There were no significant main effects of Condition ($F(2,102) = .09$, $p = .91$, $\eta^2 = .002$) or group ($F(1,51) = .44$, $p = .51$, $\eta^2 = .009$), and no significant Condition × Group ($F(2,102) = .62$, $p = .54$, $\eta^2 = .01$) or Light × Group ($F(2,102) = .47$, $p = .62$, $\eta^2 = .009$) interactions.

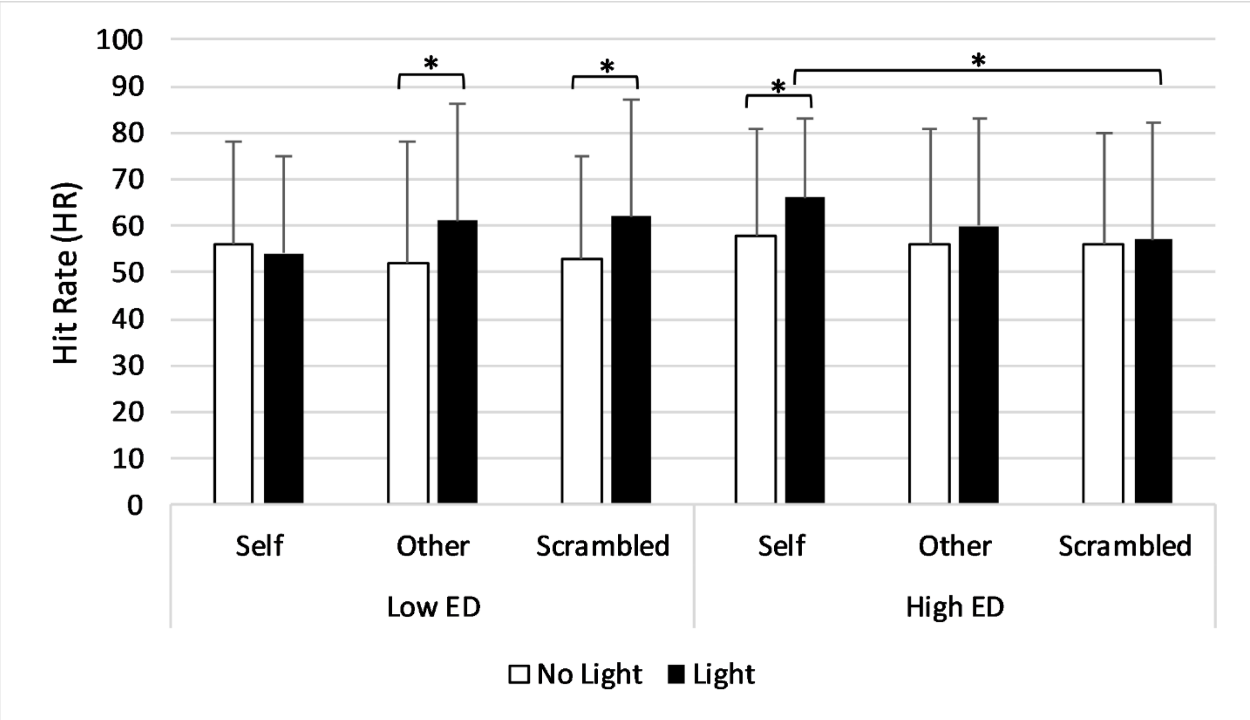


Figure 3.2. Mean HR during the SSDT in Light and No Light trials of each condition in the Low and the High ED groups. Error bars show the standard deviation. For the Low ED group, there was a significant effect of the Light in the Other ($p = .02$) and the Scrambled conditions ($p = .02$). For the High ED group, there was a significant effect of the Light in the Self condition ($p = .03$) and significantly higher hit rates in Light trials of the Self compared to the Scrambled condition ($p = .02$).

3.3.3.2 False Alarm Rate

There was a significant main effect of Light ($F(1,51) = 7.30$, $p = .009$, $\eta^2 = .13$) with higher FA in Light ($M = 8$, $SD = 5.96$) compared to No Light trials ($M = 6.58$, $SD = 4.38$). Alongside, there was a significant main effect of Condition ($F(1,51) = 4.30$, $p = .02$, $\eta^2 = .08$, see Figure 3.3). FA were significantly higher in the Scrambled ($M = 8$, $SD = .06$) and Self ($M = 8$, $SD = .07$) conditions compared to the Other ($M = 6$, $SD = .04$) condition ($t(52) = |2.93|$, $p = .005$, d = .40; $t(52) = |2.34|$, $p = .02$, d = .32). Conversely, no difference in FA was found between the Self and the Scrambled conditions ($t(52) = |2.93|$, $p = .71$, d = .40), indicating overall a greater tendency to report false alarms in both the Scrambled and the Self-conditions compared to the Other condition. There was no significant main effect of group on FA ($F(1,51) = .49$, $p = .49$, $\eta^2 = .01$), and no significant interactions between Condition × Group ($F(2,102) = .94$, $p = .38$, $\eta^2 = .02$), Light × Group ($F(1,51) = .12$, $p = .73$, $\eta^2 = .002$), or Condition × Light × Group ($F(2,102) = .36$, $p = .70$, $\eta^2 = .007$).

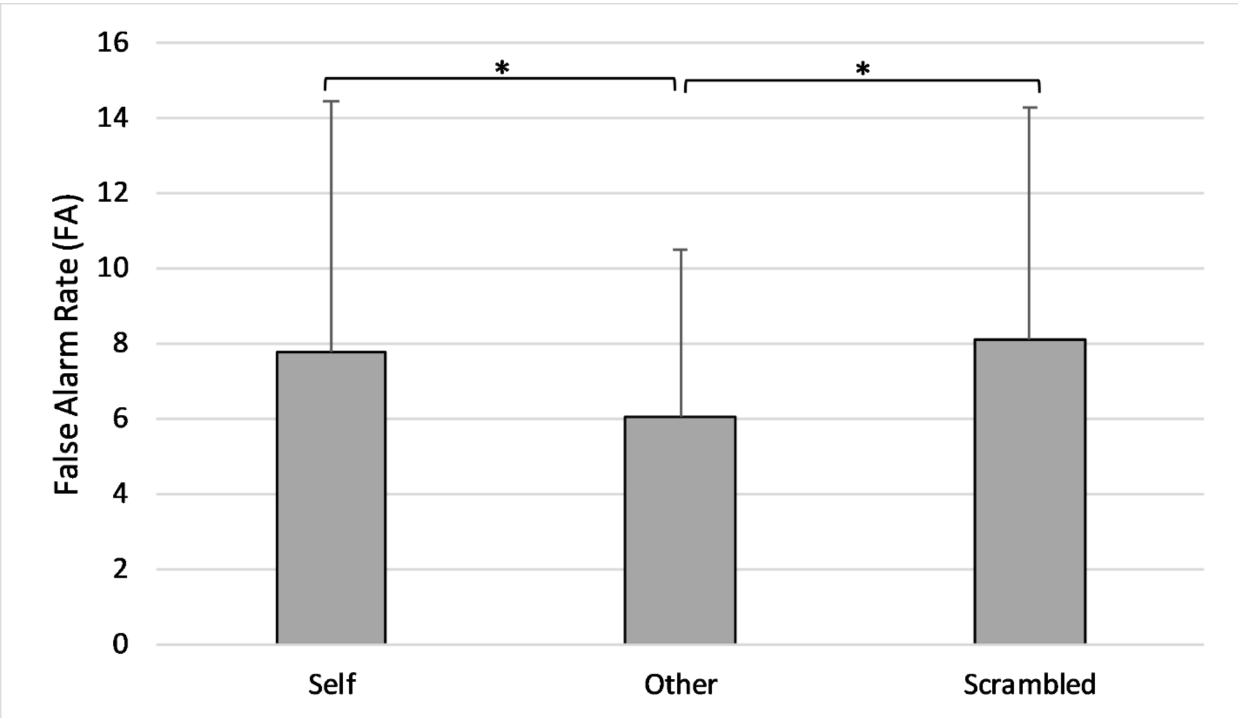


Figure 3.3. Mean FA during the SSDT in each experimental condition. Error bars show the standard deviation. FA were significantly higher in the Scrambled ($p = .01$) and the Self ($p = .02$) condition as compared to the Other condition.

3.3.3.3 *Sensitivity (d')*

There was a significant Condition × Light × Group interaction (F(2,102) = 3.37, p = .04, η^2 = .06). Post-hoc comparisons showed that for the Low ED group *d'* was significantly higher in Light trials of both the Other (M = 1.93, SD = .86) and the Scrambled (M = 1.91, SD = .89) conditions as compared to the Self condition (M = 1.59, SD = .87; p = .039, d = .28; p = .048, d = .28). Conversely, for the High ED group, *d'* was significantly higher in Light trials of the Self condition (M = 2.07, SD = .87) compared to the Scrambled condition (M = 1.69, SD = .80, p = .02, d = .48). Moreover, the Low ED group tended to show a lower *d*' (M = 1.59, SD = .87) in Light trials of the Self condition compared to the High ED group (M = 2.07, SD = .87; p = .08, d = .56) (see Figure 3.4).

To better understand these results, we performed an independent sample t test with change scores in *d*' from the Scrambled to the Self condition during Light trials as the dependent variable. The test revealed a significant between-groups difference (t(51) = |2.60|, p = .01, d = .72) with an increase in *d*' from the Scrambled to the Self condition for the High ED group (M = .39, SD = .82) and a decrease for the Low ED group (M = -.33 SD = 1.16). No main effects of Condition (F(2,102) = .58, p = .56, η^2 = .01), Light (F(1,51) = 2.10, p = .15, η^2 = .04) or Group (F(1,51) = 1.04, p = .00, η^2 = .92) were found. Alongside, the two-way interactions Condition × Group (F(2,102) = 1.12, p = .33, η^2 = .02) and Light × Group (F(1,51) = .54, p = .47, η^2 = .01) were not significant.

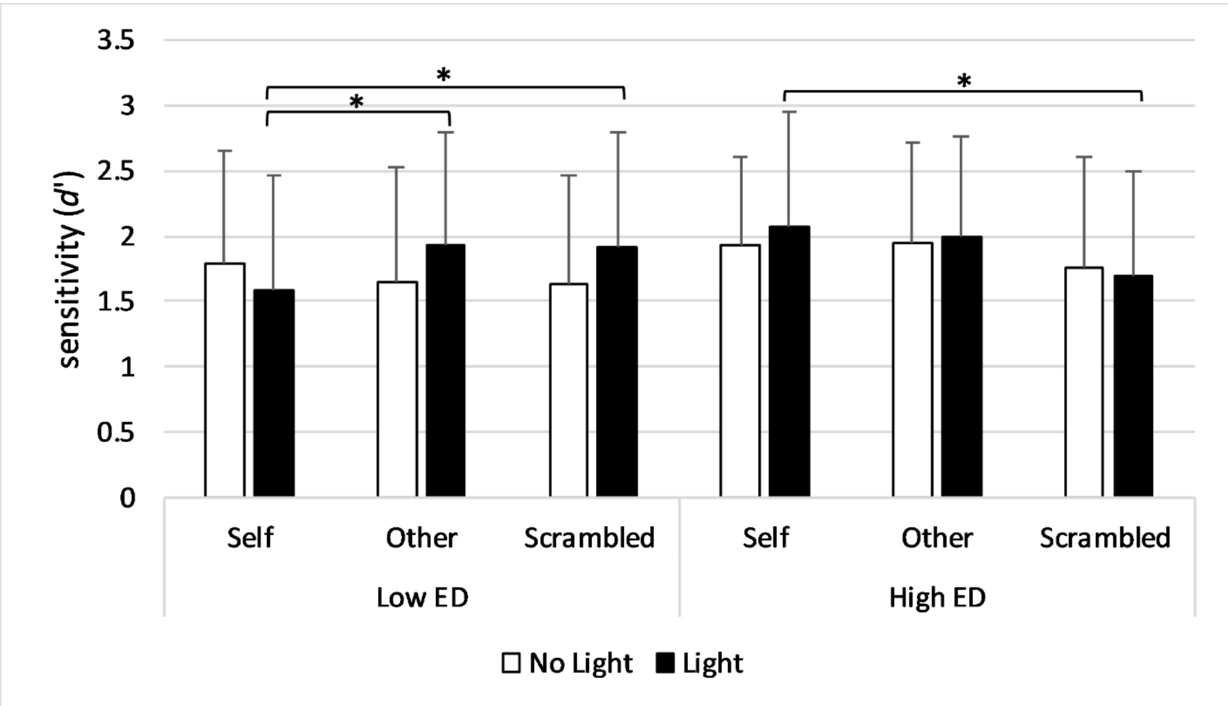


Figure 3.4. Mean *d*' during the SSDT in the Light and No Light trials of each condition in the Low and High ED groups. Error bars show the standard deviation. For the Low ED group, *d*' was significantly higher in Light trials of the Other (p = .039) and the Scrambled (p = .048) conditions as compared to the Self condition. Conversely, for the High ED group, *d*' was significantly higher in Light trials of the Self condition compared to the Scrambled condition (p = .02).

3.3.3.4 Response criterion (c)

There was a main effect of Light ($F(1,51) = 19.57$, $p = .000$, $\eta^2 = .28$) with a lower *c* in Light ($M = .60$, $SD = .29$), compared to No Light ($M = .72$, $SD = .30$) trials, indicating an overall greater tendency to report touch when the Light was present. This was corroborated by a significant interaction of Condition × Light × Group ($F(2,102) = 3.37$, $p = .04$, $\eta^2 = .06$) that mirrored the results in HR. Indeed, post-hoc comparisons showed that for the Low ED group, there was an effect of the Light in the Other condition, with a lower *c* in Light ($M = .67$, $SD = .29$), compared to No Light trials ($M = .78$, $SD = .45$, $p = .04$, $d = .35$), probably driven by the greater effect of the light on HR in the Other condition. Conversely, for the High ED group, there was an effect of the Light in the Self condition, with a lower *c* in Light ($M = .47$, $SD = .42$), compared to No Light trials ($M = .74$, $SD = .41$, $p = .002$, $d = .87$), driven by a greater effect of the light on HR in this condition. Alongside, in accordance with results in HR, for the High ED group, *c* in Light trials was found to be lower in the Self ($M = .47$, $SD = .42$) condition compared to the Other condition ($M = .68$, $SD = .44$, $p = .01$, $d = .37$). No main effects of Condition ($F(2,102) = .64$, $p = .53$, $\eta^2 = .01$) or Group ($F(1,51) = 1.04$, $p = .00$, $\eta^2 = .92$) were found. Alongside, the two-way interactions Condition × Group ($F(2,102) = 1.12$, $p = .33$, $\eta^2 = .02$) and Light × Group ($F(1,51) = .54$, $p = .47$, $\eta^2 = .01$) were not significant.

3.3.3.5 Skin Conductance Levels

Results showed a significant interaction between Group × Condition ($F(2,102) = 5.01$, $p = .008$, $\eta^2 = .09$; Figure 3.5). Post hoc analyses revealed a significant difference between groups in SCLs in the Self condition with the High ED group reporting significantly higher SCLs ($M = 1.70$, $SD = 3.36$) compared to the Low ED group ($M = -.38$, $SD = 2$, $p = .009$, $d = .75$). SCLs of the two groups were similar in the Other and in the Scrambled conditions (all *ps* > .10). Moreover, the Low ED group showed significantly higher SCLs in the Scrambled ($M = 1.19$, $SD = 3.12$) compared to the Self ($M = -.38$, $SD = 2$, $p = .30$, $d = .44$) condition, while the

High ED group exhibited an opposite trend with higher SCLs in the Self (*M* = 1.70, *SD* = 3.36) compared to the Scrambled (*M* = .04, *SD* = 1.72, *p* = .058, *d* = .39) condition. However, this last difference was found to only approach significance. No other comparisons showed significant results (all *ps* > .10).

Lastly, we calculated change scores in SCLs between Conditions and analysed group differences using independent sample t tests. In accordance with previous results, we found the two groups to be significantly different in their change scores from the Scrambled to the Self condition ($t(51) = |3.01|$, $p = .004$, d = .82). While the High ED group displayed a positive change score with an increase in SCLs in the Self condition (*M* = 1.66, *SD* = 4.25), the Low ED group showed a negative change score with SCLs decreasing from the Scrambled to the Self condition (*M* = -1.57, *SD* = 3.55, *p* = .004, *d* = .82). No significant main effect of Condition ($F(2,102) = .18$, $p = .84$, $\eta^2 = .003$) or Group ($F(1,51) = .64$, $p = .43$, $\eta^2 = .012$) were found in SCLs. Results in SCLs are illustrated in Figure 3.5.

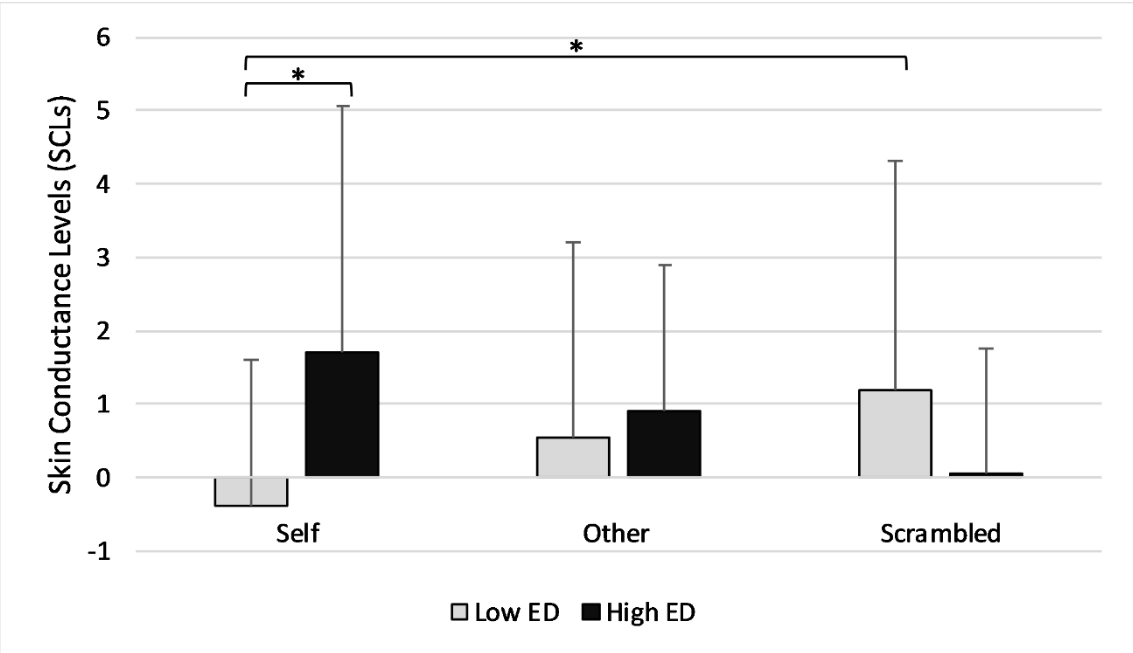


Figure 3.5. Mean SCLs in the different experimental conditions of the SSDT for the Low and the High ED groups. Error bars show the standard deviation. The High ED group showed significantly higher SCLs in the Self condition as compared to the Low ED group (*p* = .039). Moreover, for the Low ED group, SCLs in the Self condition were significantly lower compared to the Scrambled condition (*p* = .03).

3.3.4 Correlational analyses

3.3.4.1 Physiological arousal and ED symptoms in the Self condition

Further correlational analyses were performed to test the hypothesis that ED symptoms in the overall sample would be associated with increased SCLs in the Self condition. Indeed, we found significant positive correlations between SCLs during the Self condition and the ED Risk Composite ($r(53) = .36, p = .01$) as well as the Body Dissatisfaction EDI-3 subscale ($r(53) = .45, p = .001$). These results suggest that participants with higher levels of ED symptoms and specifically with a higher dissatisfaction towards their body have a stronger physiological response when exposed to a photograph of themselves.

3.3.4.2 Physiological arousal and SSDT outcomes

Following our finding that the high ED group had higher SCLs, together with higher HR and d′ in the Self condition, we investigated whether higher physiological arousal would be associated with better performance during the SSDT. Therefore, we examined whether changes in HR and d′ from the Scrambled to the Self condition were associated with the corresponding change in SCLs. This hypothesis was partially confirmed, with a positive correlation between the change score in d′ from the Scrambled to the Self condition in Light trials and the corresponding change score in SCLs ($r(53) = .30, p = .03$), indicating that overall an increase in SCLs from the Scrambled to the Self condition was associated with a parallel increment in the ability to discriminate touch in Light trials (d').

3.3.4.3 Interoceptive accuracy, Interoceptive Deficit and SSDT outcomes

Lastly, we tested whether IAcc (as measured by the HPT) and Interoceptive Deficit were associated with poorer SSDT performances. However, no significant correlations were found (all *ps* > .15).

3.4 Discussion

The first aim of Experiment 1 was to investigate the relationship between ED symptoms and multisensory integration as assessed using the SSDT. Based on previous literature linking EDs with widespread abnormalities in body perception, we expected High ED participants to be less accurate in detecting tactile stimuli during the task (show lower *d*') as compared to the Low ED group. The second goal of the study was to investigate the effects of self-focused attention on SSDT performance. To address this issue, participants completed the SSDT in three conditions: while looking at a photograph of themselves to elicit self-focused attention

(Self); while looking at a photograph of another person (Other) and whilst looking at a photograph of a scrambled face (Scrambled).

Results of the study only partially support previous research linking high ED symptoms to a greater propensity towards body misperception. In contrast with our first hypothesis, no overall differences between the Low and the High ED group were found in terms of tactile accuracy (*d*') during the SSDT. This is not in agreement with previous findings in which ED patients were found to exhibit atypical responses to alternative paradigms assessing multisensory integration, such as the Rubber Hand Illusion (RHI) and the Size Weight Illusion (SWI; Eshkevari et al., 2012; Case et al., 2012). However, it should be noted that the different paradigms mentioned here manipulate different perceptive processes. While the RHI and the SWI implicate integrating exteroceptive (visual and tactile) and interoceptive information, the SSDT assesses a different type of multisensory processes involving the integration of exclusively exteroceptive (visual and tactile) information. The discrepancy between results could therefore be better explained by the use of different instruments. More specifically, it could be the case that body misperception in EDs manifest in aberrant multisensory integration processes only when both the exteroceptive and the interoceptive modalities are implicated but not when exteroceptive information only are to be integrated.

However, we found evidence to suggest that participants with lower vs. higher ED symptoms were affected differently by our manipulation to induce self-focused attention during the SSDT. In previous research on healthy subjects, vision of one's own face was found to induce a shift in attention toward the bodily self, ultimately enhancing perceptive accuracy (Ainley et al., 2012; 2013). Conversely, we proposed that vision of the face might induce an opposite decrease in perceptive accuracy in ED patients, due to the fact that ED patients may find viewing their own face highly distressing as a result of body dissatisfaction and concerns around physical appearance (Pollatos et al., 2016).

Confirming our expectations, in this study the High ED group showed a higher level of distress during the Self condition of the SSDT, as indicated by a stronger physiological response (higher skin conductance levels; SCLs) in this condition. In addition, the High ED group reported greater scores on the DCQ and the State-Anxiety subscale, indicating higher levels of dysmorphic concerns and anxiety on the day of testing. Accordingly, correlational analyses on the whole sample showed that participants with higher levels of ED symptoms and specifically with a higher dissatisfaction towards their body had a stronger physiological response in the Self condition.

However, contrary to our expectations, increased physiological arousal was associated with an increase, rather than a decrease in tactile accuracy (*d*'). Indeed, the High ED group showed higher HR and *d*' during Light trials of the Self condition, compared to the Scrambled condition. Furthermore, for this group, the presence of the Light only resulted in significantly higher HR in the Self condition but did not increase HR in the control conditions.

For the Low ED group, confirming our expectation, there was no increase in physiological arousal as a response to viewing their own face. Rather, SCLs showed an opposite pattern with lower SCLs in the Self condition and higher SCLs in the control Scrambled condition. Low SCLs in the Self condition could possibly indicate a decrease in arousal and a calming effect in the presence of a highly familiar stimulus (the face of oneself) that is not experienced as distressing for those participants. Conversely, higher SCLs in the Scrambled condition may reflect that attention of Low ED participants was particularly directed towards novel stimuli as opposed to faces that are more familiar. The image of the scrambled face may therefore have been more salient for these participants due to its novelty (Wegner & Giuliano, 1980; Haxby, Hoffman & Gobbini, 2000).

In regard to SSDT outcomes, counter to our hypothesis, for the Low ED group, self-focused attention (induced by exposure to the photograph of oneself) did not enhance perceptive accuracy. Conversely, *d*' and HR were higher in the control conditions. Indeed, Low ED participants were more accurate (*d*') in perceiving touch in Light trials of the Scrambled as well as the Other condition compared to the Self condition. Furthermore, the occurrence of the Light was found to significantly increase HR in both the Scrambled and Other conditions but not in the Self condition.

Previous research by Pollatos and colleagues (2016) proposed that the anxious response experienced by high symptomatic participants in the presence of the photograph of their face might be related to poorer performances in tasks assessing body perception. This claim was formulated based on a previous study during which ED patients were found to be less interoceptively accurate during a HPT when viewing a photograph of their face compared to a control condition (Pollatos et al., 2016). However, results of our study show an opposite pattern with participants in the High ED group being more accurate (*d*') during the SSDT when viewing the photograph of themselves, regardless of distress experienced/increase in arousal.

In this respect, it should be noted that the two studies employed two different tasks for testing body perception tapping into different components of somatic perception. While the HPT employed by Pollatos and colleagues (2016) assesses interoception (the ability to perceive internal body sensations associated with heart beats), the SSDT used in this study measures the ability to perceive a near threshold, external tactile stimulus (exteroception). Therefore, it could be the case that self-focused attention has a differential effect on participants with high ED symptoms depending on the task that they are required to perform.

Furthermore, it is worth noting that body perception in EDs has been linked to a preferential reliance on visual appearance and exteroceptive information (sensory data deriving from the outer world) over perception from inside the body (Mehling et al., 2009). Accordingly, EDs have been described by the phenomenological psychology as having an "outward dispositional affective style", which means that ED patients anchor their sense of self to a greater extent to external bodily reference points in the service of visceral and internal somatic information (Arciero & Guidano, 2000; Arciero et al., 2004; Mazzola et al., 2014). Accordingly, in the current study High ED participants were found to self-report a lower sensibility to internal body signals. However, these findings were not coupled with a lower interoceptive accuracy as measured using the HPT. The discrepancy found between interoceptive sensibility and accuracy replicates results of previous studies assessing interoception in EDs (Pollatos et al.,2016). This discrepancy may be due to the fact that certain domains of interoception (i.e., the accuracy in perceiving heartbeat sensations) remain intact in EDs, or may result from the limitations of the task used. Indeed, as mentioned in Chapter 1, the scientific community has recently shown growing concerns in regard to the validity of the HPT, suggesting that performance in the task may be highly influenced by non-interoceptive processes (Desmedt et al., 2018).

Interestingly, an inverse relation between exteroception and interoception, similar to the one theorized in EDs, has been found also in experimental settings, where subjects with lower interoceptive awareness were found to be more sensitive to exteroceptive stimulations in the context of bodily illusions such as the RHI (Tsakiris, Jiménez & Costantini, 2011). Consistently, it was proposed that in the absence of an accurate interoceptive representation, one's model of the self relies predominantly on exteroception (Fotopoulou & Tsakiris, 2017).

Following this line of reasoning, it could be the case that enhancing self-focused attention in subjects with high ED symptoms exacerbates their predisposition to place more focus on exteroception rather than interoception, ultimately leading to better performances in tasks where they are required to elaborate exteroceptive information and worse performances in tasks assessing interoception. Results of this study also suggested the presence of a link between physiological arousal and participants' variation in SSDT performance. Overall, results indicate that higher arousal was associated with a greater accuracy (*d*') in detecting tactile information and especially in the presence of a concomitant light flashing (therefore suggesting a greater focus on visual and tactile exteroceptive information). For the Low ED group, this link was especially evident in the control Scrambled condition; while for the High ED group, that was the case in the Self condition. Accordingly, correlational analyses on the whole sample indicated that increases in SCLs from the Scrambled to the Self condition were associated with a parallel increment in the accuracy to detect touch (d').

In this regard, it is worth mentioning that previous research has linked arousal to self-focused attention and perceptual accuracy. Specifically, it was proposed that self-focused attention can be induced by higher arousal (associated both with positive and negative valence) and in turn can lead to participants experiencing one's own body as more perceptually salient (Wegner & Giuliano, 1980; Salovey, 1992; Liao & Masters, 2002). Therefore, arousal could either be an alternative non-mutually exclusive explanation for participants' greater focus on exteroceptive information or it could play a role as mediator between self-focus and perceptive processing. However, to better characterize how physiological arousal can influence perception, further studies will be needed assessing arousal levels during different tasks for the measurement of both interoception and exteroception, and in the presence of different type of stimuli (i.e., manipulating novelty and/or the emotional value of stimuli).

Lastly, results of this study showed that all participants reported lower FA on the SSDT in the Other condition. It could be argued the exposure to the face of another person elicited the feeling of being watched by an external observer. This, in turn, could have enhanced attention to the self (in the form of social self-focused attention), ultimately reducing touch misperception. Accordingly, a previous study investigating this area of research using the SSDT, showed that, similar to our results, participants were less inclined to report false sensations of touch in a condition intended to induce a feeling of being watched (using the presence of a video camera; Durlik et al., 2014). These results suggest that the image of a scrambled face may be preferred as a neutral control condition instead of the photograph of another person when manipulating self-focused attention.

In conclusion, the first aim of this thesis was to assess whether ED symptoms would be related to abnormalities in exteroceptive visuo-tactile multisensory integration during the SSDT. Results of this first study (Experiment 1) suggesting ED not to be related to impairments in visuo-tactile multisensory integration, as indicated by no alterations in SSDT responses. However, our main results demonstrate the existence of a link between ED symptoms and responses to the manipulation of self-focused attention. Indeed, participants with different levels of ED symptoms responded differently to self-focused attention when performing the SSDT. Specifically, for subjects presenting with a higher level of ED symptoms, attention to the self is proposed to enhance the perception of exteroceptive signals during the SSDT, as indicated by a greater accuracy in detecting touch in this condition. This is in line with arguments present in the previous literature that EDs are characterized by an over-investment on perceptual information coming from the outer world (exteroception) coupled with a blunted perception of information coming from within the body (interoception; Arciero & Guidano, 2000; Mehling et al., 2009; Arciero et al., 2004; Mazzola et al., 2014). Therefore, in subjects with high ED symptoms, self-focused attention is thought to exacerbate this dispositional perceptive style, leading to a greater shift of attention from internal to external bodily information. Accordingly, self-focused attention may lead to better performances in tasks where subjects with high ED symptoms are required to elaborate exteroceptive information and worse performances in tasks assessing interoception.

Further research will be therefore needed to test the replicability of current findings, and the validity of the hypotheses formulated in discussing these results. For example, it is important to determine whether results of this study are specific to viewing the face (i.e., the elicitation of self-focused attention) or whether they could be replicated with a neutral body part. Therefore, in Experiment 2 we investigated the effects of vision versus no vision of the hand on participants' performance on the original version of the SSDT. This also allowed us to compare the results for low vs. high ED groups to a previous study assessing the effect of vision vs. no-vision of the body on SSDT performance in healthy participants (Mirams et al., 2010).

Chapter 4

In your eyes: Vision of the body alters touch perception in women with Eating Disorder symptoms

As discussed in Chapters 1 and 2, vision of the body can influence touch perception and multisensory integration processes. In Experiment 1, we investigated the effects of exposing participants to the vision of their face while performing the SSDT. The study population consisted of two groups of participants reporting with high vs. low Eating Disorder (ED) symptoms. Vision of one's own face was found overall to enhance tactile accuracy in participants presenting with high ED symptoms. Conversely, participants presenting with low ED symptoms were found to be overall more accurate when performing the SSDT in the control conditions. In the current study (Experiment 2), we investigated whether vision of another, more neutral body part (i.e., the hand) would have similar effects. Therefore, in the current study, high vs. low ED participants performed the SSDT twice: while their hand was visible (vision of the hand) and while it was hidden from sight (no vision of the hand).

4.1 Introduction

The way we perceive bodily sensations depends on a number of environmental and contextual variables that can enhance or reduce perceptive acuity and alter somatosensation (Longo & Sadibolova, 2013). One of the variables that has been found to influence somatosensory perception is vision of the body. For example, as discussed in Chapter 1(Section 1.5), previous research has shown that vision of the body can enhance or diminish tactile perception, although the visual information does not provide information about the tactile stimulation (i.e., non-informative vision; Taylor-Clarke, Kennett & Haggard, 2004; Cardini, Longo & Haggard, 2011; Serino et al., 2007).

For example, non-informative vision of the body was found to enhance tactile perception in grating orientation tasks by decreasing discrimination thresholds and increasing discrimination accuracy. Alongside, non-informative vision of the body was also found to enhance tactile spatial acuity in terms of reduced two-point discrimination, enhanced amplitude discrimination of above-threshold stimuli and reduced tactile detection thresholds (Tipper et al., 1998, 2001; Kennett, Taylor-Clarke & Haggard, 2001; Serino et al., 2009; Keizer et al., 2012: Harris et al., 2007). However, in contrast with these previous results, Longo and Sadibolova (2013) found that vision of the body can actively distort touch perception, rather than increase accuracy, when participants are asked to estimate the size of a tactile stimulus. In their study, vision of the stimulated body part significantly reduced the perceived size of a tactile stimulus, as compared to vision of an object. Moreover, non-informative vision of the body was also found to hinder participants' performance in a task in which participants were asked to detect a brief gap in a 250 ms above-threshold vibration (Press et al., 2004).

In this respect, Harris and colleagues (2007) have proposed that non-informative vision of the body induces adaptive changes in the receptive fields of the bimodal visuo-tactile receptive sensory system. According to this proposal, after adaptation of these receptive fields, detection of near-threshold tactile stimuli is impaired, while discrimination of above-threshold tactile stimuli is enhanced. Therefore, vision of the body would affect touch perception in different ways depending on the type of task that participants are required to performed. Specifically, vision of the body would ameliorate participants' performance in tasks assessing tactile discrimination, while it would impair participants' performance in tasks assessing the detection of near-threshold tactile stimuli.

Partially in agreement with this hypothesis, Mirams and colleagues (2010) found that non-informative vision of the hand increased errors in a task involving the detection of near-threshold vibrations, that is the SSDT (Lloyd et al., 2008). Specifically, the study analyzed whether non-informative vision of the hand compared to no vision of the hand would reduce or increase incorrect reports of feeling touch during the SSDT. The study showed that during the vision condition, participants were more inclined to make false reports of feeling the touch, and especially on trials when the light flash occurred. However, the authors advanced a possible explanation of results alternative to the hypothesis of Harris and colleagues (2007; referring to adaptation of tactile receptive fields). Specifically, it was suggested that vision of the hand may have raised the focus on interoceptive information to a detrimental degree that led participants to misinterpret internal signals as external touch, which resulted in more errors during the SSDT. This led to the conclusion that non-informative vision of the body may lead to higher somatic interference and ultimately to a less accurate discrimination of touch during the SSDT.

Another variable that may influence the way vision of the body impacts on perception refers to individual differences and personality characteristics. A fundamental assumption of cognitive approaches to personality and psychopathology is that individuals differ in their response to similar situations because of differences in the way they process incoming stimuli, in terms of both lower-level and higher-level information processing (Öhman, Lundqvist, & Esteves, 2001; Mineka, Rafaeli, & Yovel, 2003; Yovel, Revelle & Mineka, 2005). Accordingly, psychiatric symptoms (i.e., schizophrenic, eating disorder and somatoform symptoms; Ferri et al., 2014; Peled et al, 2000; Eshkevari et al., 2012) and personality traits (i.e., emphatic abilities and the ability to describe personal experiences; Asai et al., 2011; Haans et al, 2012) have been related to individual differences in the way participants encode bodily related visual information (Costantini, 2014).

As discussed in Chapter 1, body perception in EDs has been linked to a greater focus on visual aspects of the body at the expense of other incoming information (Mehling et al., 2009). On a phenomenological level, this heightened focus on visual bodily information manifests itself with excessive concerns and rumination about one's own physical appearance and body image (Arciero & Guidano, 2000). However, recent evidence suggests this shift of focus to be present also in the context of lower-level sensory processing, with a general over-investment on exteroceptive information coupled with a blunted perception of bodily information coming from within the body (interoceptive deficits). Simply put, ED patients have been deemed to have a preferential reliance on sensory data deriving from the outer world (exteroception) over interoceptive information (Mehling et al., 2009; Arciero & Guidano, 2000). In this regard, informative data come from studies analysing the integration of conflicting visual and internal somatic information about the body, for example using the Rubber Hand Illusion paradigm (RHI; Botvinick & Cohen, 1998). During the RHI, the synchronous visuo-tactile stimulation induces participants to mislocate the position of their own hand as closer to the rubber hand, and especially ED patients who were found to be more inclined to perceive this illusion (Mussap & Salton, 2006; Eshkevari et al., 2012; Caglar-Nazali et al., 2014). Therefore, these results provide experimental support to the hypothesis that people with EDs may have an increased sensitivity to the visual aspects of body perception (Eshkevari et al., 2012).

According to these data, it could be argued that non-informative vision of the body could have a different effect on touch perception in participants with high versus low ED symptoms. To test this hypothesis, the current study investigated the effects of non–informative vision of the body on tactile perception and visuo-tactile integration during the SSDT in participants presenting with low and high ED symptoms. Replicating the design employed by Mirams and colleagues (2010), participants underwent the SSDT in two experimental conditions: non-informative vision of the hand and no vision of the hand.

As the bodily self (that is the global, multimodal awareness of one's own body; Blanke, 2012) in EDs is mostly anchored to exteroceptive coordinates, we hypothesized that vision of the body, by increasing the focus on the bodily self, would lead high symptomatic participants to focus more on exteroceptive tactile information. Therefore, in line with the results of Experiment 1, we expected high ED participants to be more sensitive to touch when performing the SSDT during the non-informative vision condition (i.e., make a higher number of 'hits' and a lower number of 'false alarms').

Conversely, in low ED participants we expected to replicate the results found by Mirams and colleagues (2010) with vision of the body increasing false alarms rather than hits. As suggested by the authors, in non-symptomatic participants vision of the body may enhance awareness of interoceptive information (i.e., sensory 'noise'), that are not relevant for the task, and are therefore erroneously misinterpreted as external touch (the somatic interference hypothesis).

Additionally, in Experiment 2, we further investigated whether individual differences in self-reported interoceptive sensibility (EDI-3), body awareness (Body Perception Questionnaire, BPQ), dysmorphic concerns (Dysmorphic Concerns Questionnaire, DCQ) and body dissatisfaction (the body dissatisfaction subscale on the Eating Disorders Inventory-3) could explain participants responses (hits and false alarms) during the SSDT. Specifically, according to the somatic interference hypothesis, that links false alarms to a misperception of interoceptive sensations, we expected participants self-reporting higher difficulties in recognizing inner bodily signals (as measured by the interoceptive sensibility-EDI-3 subscale and the BPQ) to report higher false alarms during the SSDT. Moreover, we hypothesized that participants showing higher levels of concerns about their physical appearance (as measured by the body dissatisfaction-EDI-3 subscale and the DCQ) would be more strongly influenced by the vision of their body and therefore respond with higher hits in this condition.

4.2 Methods

4.2.1 Participants

Sixty-nine females were initially recruited from the staff and student population at Liverpool John Moores University (LJMU) and from the general population via advertisements placed around the university campus. The sample size was based on a power analysis using G*Power 3.0.10 (Faul et al., 2007), which indicated that overall a minimum sample of n = 44 was needed to detect a medium effect (f = .25) with 95% power, using a mixed design ANOVA (number of groups = 2 × number of measurements = 4) with alpha at .05 (two tailed). The sample size was expanded to 69 participants to increase statistical power and to account for potential outliers. Four participants had overall hit rates of over 90% during the SSDT, suggesting that a consistent threshold level had not been achieved for these participants. Therefore, we report the data from 65 participants.

Participants were right-handed (as assessed using the Edinburgh Handedness Inventory; Oldfield, 1971), between 18 and 62 years of age, with no history or present diagnosis of any psychiatric disorder (including EDs), no impairments in tactile perception of the hand, no uncorrectable vision problems and not pregnant. Only females were recruited due to the fact that literature on EDs in males is still scarce, and EDs have been shown to differ significantly in terms of prevalence and phenomenological manifestations between men and women (Stanford & Lemberg, 2012).

Potential participants completed an online version of the Eating Disorder Inventory-3 (EDI-3; Garner, 2004. See the materials and methods section) and were preselected based on their scoring on the ED Risk Composite. The ED Risk Composite is a subscale of the EDI-3 indicating the level of subclinical ED symptoms in healthy subjects, and it is therefore deemed to be an index of the risk for developing an ED. Individuals scoring in the low (Low ED; n = 31; Age: $M = 25.76$; $SD = 10.37$) and high (High ED; n = 34; Age: $M = 26.45$; $SD = 7.87$) range of the scale were asked to participate in the study. The first (below Q1 = 19) and last quartile (above Q3 = 30) of the normative distribution of the ED Risk Composite in the general population were used as cut-offs for selecting participants (Garner, 2004). The low ED group was therefore formed by participants at a very low risk for developing an ED who scored 19 or below on the ED Risk Composite ($M = 10.58$; $SD = 5.36$), while the high ED group by participants at a higher risk for developing an ED scoring 30 or above on the ED Risk Composite ($M = 47.59$; $SD = 14.77$).

According to the Helsinki declaration of ethical standards, the study was approved by the LJMU's University Research Ethics Committee (UREC; 18/NSP/020), and all participants gave their informed consent to take part. Participation was rewarded with a £5 shopping voucher or 'participation points' for course credit for first year BSc Psychology students.

4.2.2 Material and measures

4.2.2.1 The Somatic Signal Detection Task (SSDT; Lloyd et al., 2008). In the Vision condition, the experiment was set up as indicated in Chapter 2, in the No Vision condition, the participants left arm and hand was covered by a black cardboard box, with the LED still visible (see Figure 4.1).

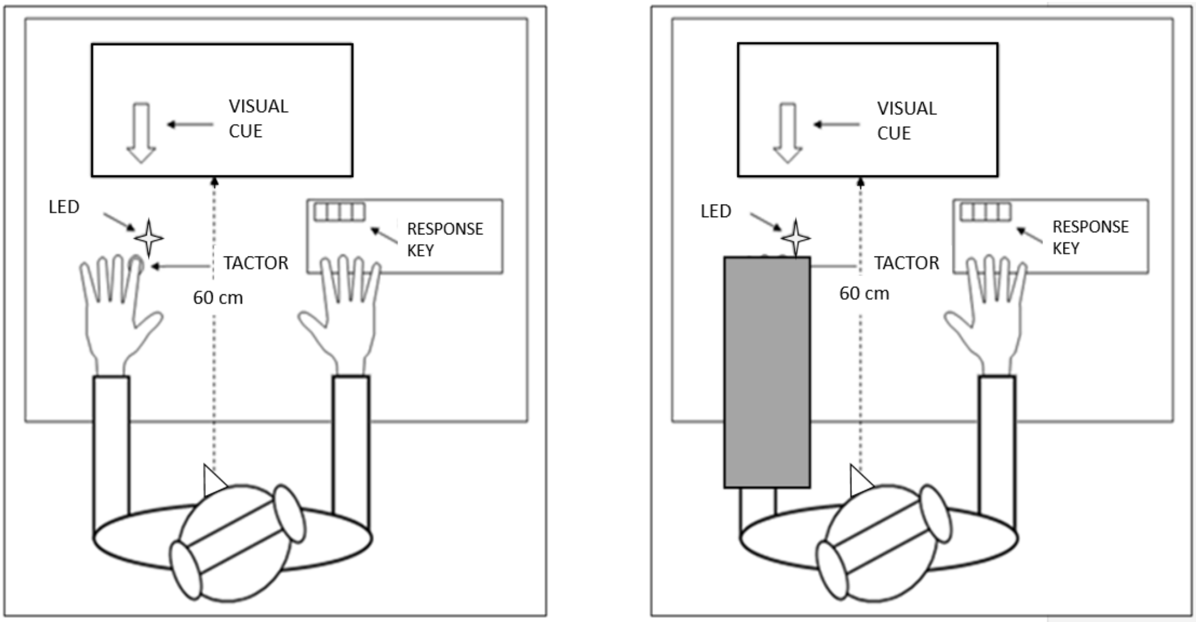


Figure 4.1. The experimental set-up of the SSDT during the Vision and the No Vision conditions.

4.2.3 Self-report questionnaires

4.2.3.1 Dysmorphic Concern Questionnaire (DCQ; Oosthuizen, Lambert, & Castle, 1998). The DCQ consists of 7 items investigating participants' body image preoccupation and dysmorphic concerns regarding their physical appearance (see Chapter 2, Section 2.5.1). The scale was administered to investigate whether individual differences in physical appearance concerns could explain participants' responses during the SSDT.

4.2.3.2 Eating Disorder Inventory 3 (EDI-3; Garner, 2004). The EDI-3 is a 91 item questionnaire for the assessment of ED and ED-related symptoms (see Chapter 2, Section 2.5.2). In this study, the EDI-3 was administered prior to testing, and the ED Risk Composite was used for selecting eligible participants as explained above.

We were particularly interested in results regarding the Interoceptive Deficits subscale of the EDI-3, as an index of participants' self-report ability to correctly recognize and respond to inner bodily states. The subscale was used to investigate whether participants reporting greater difficulties in perceiving interoceptive sensations were also more inclined to report false alarms during the SSDT.

4.2.3.3 Body Perception Questionnaire-Very Short Form (BPQ-VSF; Porges, 1993). The BPQ consists of 12 items assessing participants' awareness about different bodily states associated with changes in the activity of the autonomic nervous system, such as "muscle tension", "goose bumps", "stomach and gut pains", breathing and heart-beat rates (see Chapter 2, Section 2.5.4). Together with the Interoceptive Deficit subscale of the EDI-3, the scale was administered to investigate whether individual differences in body awareness were related to participants' responses during the SSDT. The BPQ has been validated in different samples and has been shown to have a good internal consistency (α = between .88 and .97), and an excellent test-retest reliability (Cabrera et al., 2018).

4.2.4 Design and procedures

The SSDT protocol consisted of a 2 (Vision/No Vision) × 2 (Light/No Light) × 2 (Touch/No Touch) within subjects design. Each participant underwent all experimental conditions in a repeated measures fashion.

The intensity of the vibration was determined using a computerized two forced choice thresholding procedure as indicated in Chapter 2. After completing the thresholding procedure participants underwent the experimental phase of the SSDT as explained in Chapter 2. In this study, the beginning of each trial was signalled by the appearance of a white arrow cue on the left corner of the monitor (both during the thresholding and during the testing phase).

Each participant completed the thresholding and the experimental phase of the SSDT under two conditions: Vision and No Vision of the hand. In this fashion, the thresholding was recalibrated for each experimental condition to avoid the possibility that the experimental manipulation would lead to differences in SSDT outcomes due to changes in participants' tactile threshold. Each experimental phase consisted of one block of 80 trials (giving a total of 160 trials). In the Vision condition, participants were able to see the stimulated hand but not the tactile stimulation (which originated from the tactor affixed to their fingertip). During the Vision condition, therefore, non-informative bodily-related visual information were present. In the No Vision condition, the stimulated hand was not visible but hidden. The experimenter ensured that the LED was still visible. Participants were instructed to direct their gaze towards the stimulated finger in both conditions. The experimenter remained present throughout each experimental session and ensured that each participant followed this instruction. The order of the Vision and No Vision conditions was randomized between participants.

After completing the SSDT, participants were asked to complete the self-report questionnaires. The testing procedure lasted 75 minutes per participant. Participants were naïve as to the true purpose of the study and were debriefed by the experimenter at the end of the testing session.

4.3 Results

4.3.1 Data Processing

4.3.1.1 SSDT scores. HR, FA, *d′* and *c* outcomes of the SSDT were calculated as indicated in Chapter 2.

4.3.2 Demographics and self-reports analyses

Statistical analyses were performed using SPSS (SPPS Inc., Chicago, IL). All data are reported as Mean (*M*) and Standard Deviation (*SD*). A significance threshold of $p < .05$ was set for all effects, and effect sizes were estimated using partial eta square (η^2) and Cohen's *d*.

To test for differences in demographics, SSDT threshold levels, and levels of ED psychopathology between the high and low ED groups, a series of t tests were performed with Group as the independent variable and Age, SSDT threshold, Body Mass Index (BMI), scores on each of the EDI-3 subscales, and scores on the DCQ and BPQ as dependent variables. Results of the t tests are presented in Table 4.1. The two groups were comparable in Age and SSDT threshold levels. There was a significant difference regarding BMI, with the high ED group having a significantly higher BMI than the low ED group. Moreover, the high ED group showed higher scores on most of the subscales of the EDI-3 (Low Self Esteem, Personal Alienation, Interpersonal Insecurity, Emotional Dysregulation, Ascetism and Maturity Fear) indicating a strong link between ED symptoms and other psychological constructs that have been typically related to EDs in our sample. Specifically, the high ED compared to the low ED group reported lower levels of self-esteem, a stronger propensity to feel emotional emptiness and to show reticence in social situations, a tendency toward mood instability and self-denial, and a stronger desire to retreat to the security of childhood. However, differences between the two groups did not reach significance on the Interpersonal Alienation and Perfectionism subscales of the EDI-3, suggesting that the high ED and the low ED groups were comparable in their attitude towards close relationships and in perfectionistic traits. Interestingly, the high ED group also reported a higher difficulty in recognizing and responding to inner body signals as indicated by higher scores on the Interoceptive Deficits subscale of the EDI-3. However, these results were not paired with an equivalent between-groups difference on the BPQ. Conversely, the two groups were found to self-report similar levels of awareness about their bodily states on this scale. The high ED group showed also to have stronger dysmorphic concerns as indicated by higher scores on the DCQ.

Table 4.1

Descriptive statistics for Age, SSDT threshold levels, and questionnaire scores in each group.

	Low ED	High ED				
	M (sd)	M (sd)	t	df	sig	d
Age	26.45 (7.87)	25.76 (10.37)	.30	63	.77	.07
Threshold	-1190.32 (431.07)	-1102.29 (585.09)	.69	63	.49	.17
BMI	22.48 (4.16)	27.07 (5.68)	3.73	63	.000	.92
Low Self-esteem	3.80 (4.17)	8.09 (5.02)	3.72	63	.000	.93
Personal Alienation	3.19 (3.67)	6.26 (4.34)	3.06	63	.003	.76
Interpers. Insecurity	5.03 (4.73)	8.20 (4.80)	2.68	63	.009	.66
Interpers. Alienation	4.81 (4.83)	6.03 (3.41)	1.19	63	.24	.29
Emotional Dysreg.	3.16 (4.24)	6 (5.23)	2.39	63	.02	.60
Perfectionism	9.16 (5.62)	10.06 (5.03)	.68	63	.50	.17
Ascetism	2.80 (2.66)	6.97 (5.25)	4.08	63	.000	1
Maturity Fear	7.23 (4.89)	10.56 (6.13)	2.41	63	.02	.60
Interoceptive Deficit	4.42 (5.23)	8.62 (6.70)	2.80	63	.007	.70
BPQ	35 (11.58)	33.26 (9.97)	.65	63	.52	.16
DCQ	4.90 (2.96)	8.23 (4.33)	3.65	63	.001	.90

Note. Low Self-esteem, Personal Alienation, Interpers. Insecurity, Interpers. Alienation, Interoceptive Deficits, Emotional Dysreg. Perfectionism, Ascetism and Maturity Fear are all subscales of the EDI-3.

4.3.3 Main analyses

Descriptive statistics for HR, FA, *d'* and *c* in each Light and Vision condition of the SSDT, in each group are presented in Table 4.2. Before performing the analyses, outcomes were tested for normality. HR, d' and c were normally distributed, therefore parametric analyses were conducted.

Specifically, three mixed design ANOVAs with Group as the between-subject factor, and Light and Vision condition as within-subject factors were performed using HR, *d'* and *c* as dependent variables. Paired and independent-sample t tests were performed to follow-up significant interactions. Bonferroni correction was used to correct for multiple comparisons.

False alarm rates (FA) in each experimental condition showed a significant positive skewness. As FA remained not normally distributed after attempts to transform the data, non-parametric analyses were conducted.

Pearson's and Spearman's correlations were used to further investigate the relationships between personality traits and subclinical symptoms (as assessed using self-report questionnaires) and behavioural responses during the SSDT.

Table 4.2

Descriptive statistics for hit rate, false alarm rate, *d'* and *c* in each Vision and Light condition and ED group.

Low ED		HR (%)	FA (%)	FA (%)	*d'*	*c*
		M (SD)	Mdn (IQR)	M (SD)	M (SD)	M (SD)
Vision	Light	60.86 (22.31)	16.67 (.24)	17.13 (14.46)	1.47 (.99)	.39 (.45)
	No Light	59.68 (23.15)	11.90 (.14)	13.13 (9.6)	1.60 (.91)	.25 (.69)
No Vision	Light	65.21 (21.26)	11.90 (.24)	18.20 (16.87)	1.53 (.81)	.50 (.46)
	No Light	56.91 (23.52)	11.90 (.19)	14.67 (13.45)	1.41 (.85)	.52 (.47)
High ED		HR (%)	FA (%)	FA (%)	*d'*	*c*
		M (SD)	Mdn (IQR)	M (SD)	M (SD)	M (SD)
Vision	Light	71.20 (15.64)	14.29 (.19)	19.80 (17.21)	1.65 (.93)	.19 (.36)
	No Light	62.76 (22.13)	16.67 (.20)	17.26 (14.43)	1.54 (1.03)	.23 (.53)
No Vision	Light	64.05 (18.25)	14.29 (.25)	21.99 (20.36)	1.35 (.80)	.36 (.44)
	No Light	53.22 (20.56)	12.81 (.19)	14.25 (11)	1.33 (.78)	.50 (.64)

Note**.** Means (M) and the standard deviations (SD) are reported for normally distributed variables (HR, *d'*, *c*), while both M, SD and also medians (Mdn) and inter-quartile ranges (IQR) are shown for the non-normally distributed FA.

4.3.3.1 Hit Rate

There was a significant main effect of the Light ($F(1,63) = 20.70$, $p = .000$, $\eta^2 = .25$) indicating that overall subjects had higher HR in light-present (Light; $M = 60.2$, $SD = 16.17$)

compared to light-absent trials (No Light; *M* = 58.14, *SD* = 20.15). Alongside, there were a significant main effect of Vision ($F(1,63) = 4.06$, $p = .048$, $\eta^2 = .06$), which was further corroborated by a significant Vision × Group interaction ($F(1,63) = 5.93$, $p = .018$, $\eta^2 = .09$; Figure 4.2). Follow-up paired-sample t tests revealed that a significant effect of Vision was present only in the high ED group ($t(33) = |3.22|$, $p = .003$, $d = .55$) but not in the low ED group. High ED participants showed higher HR in trials during which the hand was visible (Vision condition; *M* = 66.98, *SD* = 17.60) compared to trials during which the hand was not visible (No Vision condition; *M* = 58.64, *SD* = 16.03). Conversely, the low ED group seemed not to be affected by the manipulation of the vision of the hand, reporting similar HR in the Vision (*M* = 60.27, *SD* = 21.45) and the No Vision condition (*M* = 61.06, *SD* = 21.88; $t(30) = |.29|$, $p = .77$, $d = .05$). Independent-sample t tests showed no between-group differences in HR neither in the Vision nor in the No Vision condition (all $ts \leq .51$; all $ps \geq .17$).

There was no significant main effect of Group and no other significant two and three-way interactions (all $Fs \leq 3.59$; all $ps \geq .06$). However, the Light × Vision interaction was found to approach significance ($F(1,63) = 3.59$, $p = .06$, $\eta^2 = .05$) indicating an additive effect of Light and Vision with higher HR when both visual stimuli were present (Light and Vision; *M* = 66.27, *SD* = 19.66) and lower HR when both visual stimuli were absent (No Light and No Vision; *M* = 54.98, *SD* = 21.92).

Pearson's r correlations were performed to analyze whether participants' concerns with their physical appearance (assessed using the body dissatisfaction subscale of the EDI-3 and the DCQ) could explain a greater tendency to focus on visual information, as reflected by higher HR during Light trials of the Vision condition. Results showed a significant positive correlation between body dissatisfaction and HR during Light trials of the Vision condition ($r = .28$; $p = .023$), so that in the overall sample participants who showed greater dissatisfaction towards their body were also more inclined to report HR in the presence of both visual information: the Vision of the hand and the Light. Results remained significant after performing a Bonferroni correction. However, the DCQ was found not to significantly correlate with HR in Light trials of the Vision condition (all $rs \leq .16$; all $ps \geq .19$).

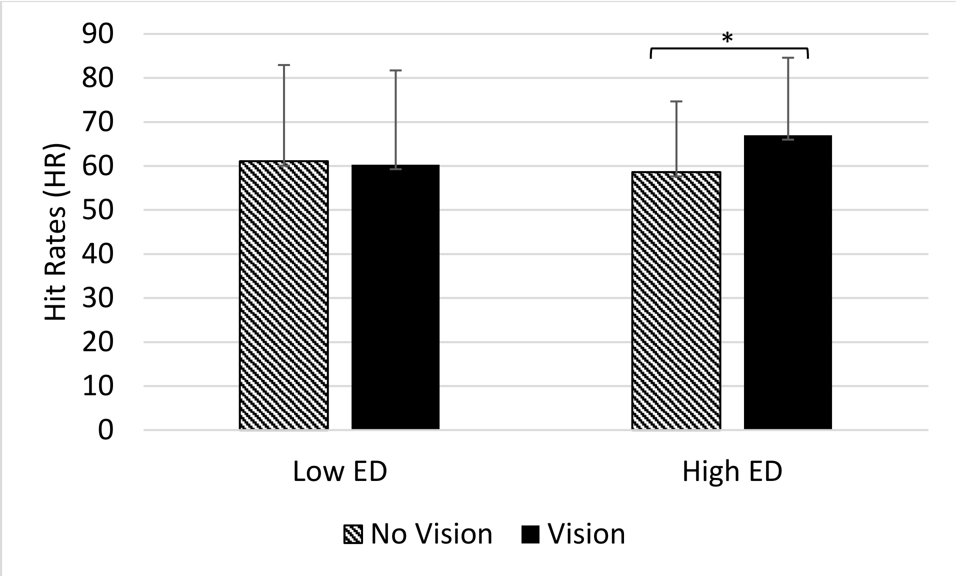


Figure 4.2. Mean hit rates (HR) during the SSDT in the Vision and No Vision condition in the low and the high ED groups. Error bars show the standard deviation. For the high ED group, there was a significant effect of Vision on hit rates (p = .003), with higher hit rates in the Vision compared to the No Vision condition. For the low ED group hit rates in the Vision and No Vision condition were comparable (p = .77).

4.3.3.2 False Alarm Rate

A Wilcoxon test showed that FA were significantly affected by the presence of the Light (z = -3.30, p = .001, r = .41). Participants were more inclined to misperceive the touch in light-present (Light; *Mdn* = 31.26) compared to light-absent trials (No Light; *Mdn* = 25.26). The effect of the Light was present both during the Vision (z = -2.23, p = .025, r = .28) and the No Vision conditions (z = -2.66, p = .008, r = .33). However, when repeating the analyses separately for the high and for the low ED groups, results showed a significant effect of the Light only in the No Vision condition for the high ED group (Light: *Mdn* = 14.29; No Light: *Mdn* = 12.81; z = -2.24, p = .025, r = .38) and a significant effect of the Light only in the Vision condition for the low ED group (Light: *Mdn* = 16.67; No Light: *Mdn* = 11.90; z = -2.12, p = .034, r = .40). Hence, the Light was more likely to induce FA when the hand was not visible in high ED participants, and when the hand was visible in low ED participants (see Figure 4.3).

However, and conversely to the results of Mirams and colleagues (2010), no differences in FA were found between the Vision and the No Vision condition in either Light or No Light trials (all $zs \leq$ -.53; all $ps \geq$ .59). Results remained not significant when the analyses were repeated separately for the low and the high ED group (all $zs \leq$ -.21; all $ps \geq$ .26). Therefore, although visual inspection of the data suggested otherwise, for the low ED group, FA in Light trials were not significantly different in the Vision compared to the No vision condition (all *zs* ≤ -21; all *ps* ≥ .83). Moreover, Mann-Whitney tests revealed no overall differences between the two groups ($U \leq 471$; $p \geq .39$).

Spearman's Rho correlational analyses were run to investigate the relationship between participants' tendency to focus on inner body signals (assessed using both the BPQ and the Interoceptive Deficits subscale of the EDI-3) and FA during the SSDT. Results showed a positive association between FA and scores on the Interoceptive Deficit ($r = .28$; $p = .02$) subscales of the EDI-3. Participants who self-reported to have stronger difficulties in recognizing interoceptive signals were also more inclined to report FA during the SSDT across the different experimental conditions. Results remained significant after performing a Bonferroni correction. However, no significant correlations were found between scores on the BPQ and FA ($r \leq .06$; $p \geq .62$).

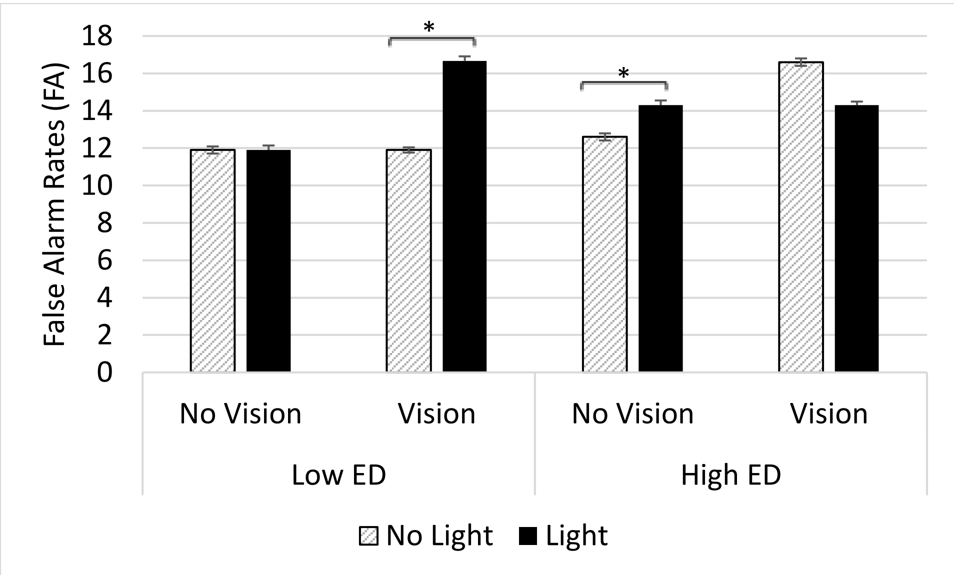


Figure 4.3. Median false alarms (FA) during the SSDT in the Light and No Light trials of the Vision and No Vision condition in the low and the high ED groups. Error bars show the interquartile range. For the high ED group, there was a significant effect of the Light only in the No Vision condition ($p = .025$). For the low ED group, there was a significant effect of the Light only in the Vision condition ($p = .034$). Hence, the Light was more likely to induce false alarms when the hand was not visible (No Vision) in high ED participants, and when the hand was visible (Vision) in low ED participants.

4.3.3.3 Sensitivity (d')

There were no significant main effects of Light, Vision or Group, and no significant two or three-way interactions (all $Fs \leq 2.97$; all $ps \geq .09$). However, there was a tendency towards a main effect of Vision ($F(1,63) = 2.97$, $p = .09$, $\eta^2 = .04$) due to a higher d' in the Vision compared to the No Vision condition, probably driven by the presence of significantly higher HR in the Vision Vs. the No Vision condition for the high ED group (see above).

4.3.3.4 Response criterion

There was a significant main effect of Vision ($F(1,63) = 16.17$, $p = .000$, $\eta^2 = .20$) with higher *c* in the No Vision condition ($M = .47$, $SD = .45$) and lower *c* in the Vision condition ($M = .27$, $SD = 21.45$), indicating that participants were overall more inclined to report feeling the vibration in the Vision condition compared to the No Vision condition, regardless whether the vibration was administered or not. There were no significant main effects of Light and Group, and no two or three way interactions were significant (all $Fs \leq 2.21$; all $ps \geq .14$).

Overall, significant results in HR and FA were not coupled with significant results in *d'* or *c*. Therefore, participants' differences in detecting correctly or not the touch were not better explained by variations in the perceptual sensitivity or in the perceptual bias to report touch regardless the type of trial.

4.4 Discussion

The aim of this study was to investigate the effects of non-informative vision of the body on exteroceptive multisensory integration and touch perception in participants presenting with different levels of ED symptoms. Based on previous literature that linked EDs with a greater focus on exteroceptive bodily information (Mehling et al., 2009; Arciero & Guidano, 2000; Arciero et al., 2004; Mazzola et al., 2014), we expected high ED participants to be more sensitive to tactile stimuli during the SSDT while viewing their body (in the Vision condition). Conversely, in line with previous results found by Mirams and colleagues (2010), we expected low ED participants to report a lower sensitivity to touch and higher false alarms in the Vision condition due to a higher level of somatic interference in this condition.

Supporting our expectations, high ED participants were better able to correctly detect the touch during the SSDT when their hand was visible as compared to when their hand was hidden from sight, having a significantly higher HR in the Vision compared to the No Vision condition. Moreover, in high ED participants there was an effect of the Light on FA only in the

No vision condition but not in the Vision condition. Therefore, the presence of the light was found to induce false reports of touch only when their hand was hidden from sight. Conversely, when the hand was visible, high ED participants were found to be less affected by the influence of the light, ultimately leading to less FA and a more accurate perception of touch.

These results are in line with arguments that body perception in EDs is characterized by a differential processing of exteroceptive bodily information. Indeed, EDs have been described as being characterised by an “outward dispositional affective style”, which means that ED patients tend to anchor their bodily self to a greater extent to external bodily reference points to the detriment of visceral and internal somatic information (Arciero & Guidano, 2000; Arciero et al., 2004; Mazzola et al., 2014). In other words, body perception in EDs has been described as showing an over-investment on sensory information deriving from the interactions with the outer world, such as exteroceptive visual and tactile information. Coherently, vision of the body (as manipulated experimentally) is thought to exacerbate this dispositional perceptive style leading to a greater focus on information, such as touch in the context of the current study. Specifically, we suggest that in participants presenting with ED symptoms, vision of their body increases attention only towards those dimensions of the bodily self that are already invested by a greater focus, that is exteroception. In turn, this shift of focus determines a greater accuracy in exteroception, and therefore also in detecting tactile stimuli. Results of this study (Experiment 2) are in line with the results of Experiment 1 (Sacchetti et al., 2020) in which vision of the face, instead of the hand, was found to increase correct detection of touch during the SSDT in high ED participants. Taken together the two studies suggest a consistent effect of vision of the body (across different body parts; i.e., the face and the hand) in enhancing touch detection in EDs.

Conversely, as the bodily self in EDs is not anchored to interoceptive information, vision of the body may not enhance interoceptive sensibility. Supporting this theory, the high ED group self-reported more confusion and difficulties in recognizing and responding to internal bodily states, as indicated by higher scores in the Interoceptive Deficit scale of the EDI-3.

Furthermore, it should be noted that results in the overall sample showed a positive correlation between HR in Light trials of the Vision condition and the Body Dissatisfaction subscale of the EDI-3. This indicates that participants presenting with a greater dissatisfaction towards their body were also more accurate in perceiving touch when multiple visual information accompanied the stimulation (the presence of the light and the non-informative vision of the hand). These results may suggest that Body Dissatisfaction specifically, among the different subscales of the EDI-3 accounts for the fact that vision of the hand increased HR only in the high ED but not in the low ED group.

For the low ED group non-informative vision of the body was found not to impact participants' ability to correctly detect touch. Replicating previous results by Mirams and colleagues (2010), low ED participants were found to report comparable HR in the Vision and in the No Vision conditions. Moreover, results showed that for the low ED group the presence of the light was more likely to induce false reports of touch only when they performed the task while their hand was visible. Therefore, conversely to the high ED group, for the low ED group, non-informative vision of the hand was found to reduce tactile accuracy by increasing FA. However, conversely to Mirams and colleagues (2010), and against our expectations, there was no overall difference in FA between the Vision and the No Vision condition. Nevertheless, our results partially support the somatic interference hypothesis, according to which non-informative vision of the body may increase somatic interference arising from internal bodily signals that are mistaken for the external touch.

With this regard, we found a positive correlation between scores on the interoceptive deficit subscale of the EDI-3 and FAs, suggesting that difficulties in recognizing interoceptive information are associated with an increased tendency to erroneously report touch. This is also in line with previous findings that FA during the SSDT are associated with lower levels of interoceptive accuracy as assessed using a Heartbeat Perception Task (HPT; Durlik et al., 2014). This explanation is also consistent with Lloyd and colleagues' (2008) attentional account of touch misperception during the SSDT, according to which attention to the body can increase somatic disturbances by raising awareness of subtle bodily sensations that are confused with external tactile stimuli. A similar process has been used to explain somatoform symptoms; that is, physical symptoms experienced in the absence of any apparent physical abnormality (APA, 2013). Different lines of research have linked somatoform symptoms to a heightened and maladaptive awareness of the body that causes an increased salience of benign bodily sensations that are then mistaken for evidence of serious illness (Mehling et al., 2009; Brown et al., 2012). Coherently, previous research on this topic has shown that participants experiencing higher levels of somatoform symptoms are also more inclined to report false sensation of touch during the SSDT (Brown et al., 2010; Brown et al., 2012, see Chapter 2), possibly due to a hypervigilance towards inner body signals.

Overall, in Mirams and colleagues (2010), and in the low ED group of the current study, it might be possible that vision of the body amplified and distorted the focus on interoceptive sensations, which were therefore mistakenly confused for exteroceptive signals. This in turn would lead to greater false reports of touch. This effect was specific for the low ED group, and it was not found for the high ED group, where the perception of interoceptive information has been characterized as blunted in EDs (Mehling et al., 2009).

In conclusion, results of Experiments 1 and 2 indicate that non-informative vision of the body can have different effects on touch perception depending on participants' level of ED symptoms. Previous research has shown that non-informative vision of the body can either enhance or be detrimental to touch perception depending on the type of task that participants are required to performed, and the familiarity of the body part stimulated (Longo & Sadibolova, 2013; Tipper et al., 1998; see Chapter 1). However, our results indicate that top-down mechanisms involving participants' relationship with their body (and specifically body dissatisfaction) can also play a role in determining the effects of non-informative vision of the body on touch perception. Specifically, in Experiment 2, whereas vision of the body was found to increase the correct detection of touch in participants presenting with high ED symptoms; in participants presenting with low ED symptoms, vision of the body was found to diminish tactile accuracy, by increasing the effect of the Light on false alarms, possibly due to a higher somatic interference of internal body sensations.

In the next study of this thesis (Experiment 3), we examined whether top-down mechanisms involving participants' relationship with their body also determine the effects of a different, off line perceptual manipulation (alternative to exposure to the vision of the body), on SSDT performance. Specifically, we investigated the effect of experiencing affective touch on subsequent SSDT performance as compared to a neutral (non-affective) touch manipulation.

Chapter 5

The impact of affective touch on multisensory integration and tactile perceptual accuracy during the somatic signal detection task

In the previous two studies of this thesis, it was found that exposing participants to the vision of their bodies, either the face (Experiment 1) or the hand (Experiment 2), can alter participants' performance during the SSDT. Specifically, in Experiment 1, it was found that vision of one's own face can enhance tactile accuracy in participants presenting with high ED symptoms. Similarly, in Experiment 2, vision of the hand was found to increase the correct detection of touch in participants presenting with high ED symptoms. Conversely, in participants presenting with low ED symptoms, vision of the body was found not to alter (Experiment 1) or to partially diminish (Experiment 2) tactile accuracy during the SSDT. In the current study (Experiment 3), the effects on SSDT performance of an alternative off-line manipulation that can possibly alter multisensory processes was investigated; that is affective touch. Specifically, it was tested whether an affective tactile manipulation could influence participants' subsequent responses to the SSDT as compared to a neutral (non-affective) tactile manipulation.

5.1 Introduction

Affective touch is defined as a tactile processing characterised by a hedonic or emotional component, such as pleasant caress-like tactile interactions (Morrison, 2016). The hedonic and affective value of tactile interactions is thought to be influenced by a number of different factors (i.e., biological, personal and social factors), including higher order personal believes, thoughts and expectations on the quality of such interactions (McGlone et al., 2014; Watkins et al., 2021). However, from a biological/physiological point of view, affective touch is understood to be modulated by specialised, unmyelinated mechanosensitive slow-conducting, peripheral nerves, known as C tactile afferents (CT-afferents; Olausson et al., 2002; McGlone et al., 2014). CT-afferents are mostly found in the hairy skin of the body (Vallbo et al., 1999; Liu et al., 2007; Watkins et al., 2021) and respond optimally to gentle stroking touch (1-10 cm/s stroking velocity; Löken et al., 2009). Specifically, responses of CT-afferents during single unit recordings with microneurography in response to different stroking velocities show that their spike discharge follows an inverted U-shaped pattern, with the greatest response at 3 cm/s, and weaker responses at slower (0.1 cm/s) and faster velocities (30 cm/s; Löken et al., 2009; Ackerley et al., 2014). Importantly, activation of CT-afferents correlates with the subjective rating of pleasantness, indicating that CT-afferents may constitute the peripheral physiological substrate for pleasant tactile information (Löken et al., 2009; Essick et al., 1999; Essick et al., 2010).

Because of their role in contributing to the hedonic value of social physical interactions, CT-afferents have been proposed to play a pivotal part in fostering affiliative behaviours and proximity seeking. Accordingly, different streams of research have recently underlined the importance of CT-afferents in promoting social bonding, as suggested by the 'Social Touch Hypothesis' (Morrison et al., 2010; Krahé et al., 2018). Indeed, it has been shown that CT-afferents respond optimally to touch delivered at skin temperature (Ackerley et al., 2014). Moreover, when asked to stroke babies or their partners, people spontaneously deliver touch at CT optimal velocities (Croy et al., 2016).

CT-afferents ascend via spinothalamic pathways to the posterior insula, a limbic area that is understood to support an early convergence of affective and sensory signals from the body (Olausson et al., 2002; Morrison, 2016; Gazzola et al., 2012). In turn, remapping of information from the posterior to the anterior insula is thought to allow the integration of sensory signals with other bodily information as well as with other cognitive and social factors, ultimately serving body awareness and body self-consciousness (Craig, 2009; Critchley et al., 2004). Indeed, this ascending neural path is hypothesised to be involved in the construction and maintenance of the so called 'bodily self', that is defined as a global, multimodal awareness of one's own body, arising from the integration of information coming from different sensory modalities (Blanke, 2012; Ciaunica & Fotopoulou, 2017).

Following this line of reasoning, researchers have analysed the role of CT-modulated affective touch in tasks assessing the integration of competing multisensory information such as the Rubber Hand Illusion (RHI; Botvinick & Cohen, 1998; Crucianelli et al., 2013; van Stralen et al., 2014; Lloyd et al., 2013). Of relevance here is the finding that the illusion is strongest when the stroking touch is applied at CT-afferent preferred velocities (1-10 cm/s) vs non-affective touch stimuli (i.e., a faster non-CT modulated touch), in terms of a higher embodiment (the misperception of the rubber hand as participants' own hand; Crucianelli et al., 2013; Lloyd et al., 2013) or in terms of a stronger proprioceptive drift (the mis-location of participants' hand as closer to the rubber hand; van Stralen et al., 2014). The authors concluded that CT-modulated affective touch may have a unique contribution to the sense of body ownership as assessed using the RHI.

Similar results were found by Panagiotopoulou and colleagues (2017) who investigated the effects of administering touch at CT optimal vs non-CT optimal velocities during the 'enfacement illusion paradigm'. During this paradigm, participants are stroked on the cheek (a body site densely innervated by CT-afferents) whilst watching a video of another person's face being stroked on the specular cheek. Subsequently, they are shown a video of the other person's face gradually morphing with a photograph of their own face, and they are asked to say at what point the face looks more like them, than the other person. In agreement with previous research using the RHI, results of this study show that CT-modulated affective touch increased participants self-reported experience of the illusion.

Taken together results of these studies suggest that in a multisensory body-awareness context, CT-modulated affective touch is perceived as more meaningful compared to a non-affective touch (McGlone et al., 2014), leading participants to anchor their sense of bodily self to a greater extent to the affective tactile information mediated by CT-afferents, rather than other sensory information. This means that CT-modulated affective touch is potentially more relevant than discriminative touch information in building a global, multimodal perceptive model of one's own body (bodily self). During multisensory integration tasks, such as the RHI, this translates with affective touch enhancing the experience of body ownership (Crucianelli et al., 2013; Crucianelli et al., 2018; Panagiotopoulou et al., 2017).

Further support for the role of CT-afferents in generating the sense of bodily self comes from a positron emission tomography study (PET) which found that when contrasting affective touch on the forearm (CT innervated hairy skin) with affective touch on the palm (non-CT innervated glabrous skin) not only was there the previously reported activations in dorsal posterior insular cortex and mid-anterior orbitofrontal cortex, but there was also activation in the angular gyrus in the parietal cortex (McGlone et al., 2014). The angular gyrus has been shown by Blanke and colleagues (2002) to trigger repeated out-of-body experiences when electrically stimulated in a study with an epilepsy patient. The activation in this area to CT-directed touch during the PET study poses an intriguing question as to the role of this area in coding for the sense of a bodily self.

However, in the studies mentioned above, CT-modulated affective touch was an active component of the tasks that participants were asked to perform, in the sense that affective touch was one of the concomitant and competing sensory information that participants were asked to elaborate and integrate in order to perform the task. Therefore, it was not possible to disentangle whether affective touch induced long-lasting alterations in multisensory integration. In this direction, a previous study by von Mohr and colleagues (2017) indicated that CT-modulated affective touch can induce a subsequent lasting reduction in feelings of social exclusion. However, no studies to date have analysed whether a similar durable effect of CT-modulated affective touch can impact also subsequent multisensory integration. Information on this topic would be crucial in determining the potential for CT-modulated affective touch to be used as an intervention in clinical populations presenting with aberrant body perception and multisensory integration (i.e., people with eating disorders, body dysmorphic disorders, and medically unexplained symptoms).

In the current study, we investigated the effects of CT optimal (affective) vs CT non-optimal (non-affective) touch on subsequent multisensory integration using the Somatic Signal Detection Task (SSDT, see Chapter 2). As explained, in Chapters 1 and 3, the SSDT can be considered a more objective measure of tactile distortion and multisensory integration as compared to other paradigms used for the assessment of multisensory integration such as the RHI.

As opposed to previous research in which CT optimal vs non-CT optimal touch was administered online as part of a multisensory task (Crucianelli et a., 2013; Panagiotopoulou et al., 2017), in the current study, the SSDT was performed offline: before and after receiving the touch. Indeed, previous research using the SSDT paradigm (Mirams et al., 2012) has shown that offline interventions can have a carry-over effect to subsequent performance on the task. Specifically, focusing on interoceptive sensations (during a heart-beat perception task) was found to increase participants reports of touch in the presence and absence of the target tactile pulse; conversely, focusing on external touch (during a grating orientation task) was found to decrease participants reports of touch (Mirams et al., 2012). Building on these results, in the current study, we investigated whether CT-modulated affective touch can also induce an offline carry-over effect on subsequent perceptual processes during multisensory integration measured by the SSDT.

In the current study, the vibrotactile pulse was presented to participants' cheek (as in Experiment 1; Chapter 3), and the SSDT was completed before and after participants received either CT optimal vs non-CT optimal touch to the same cheek. Throughout the experiment, Skin Conductance Levels (SCLs) were also recorded to investigate whether the touch manipulation would induce changes in autonomic physiological arousal, and whether these changes would relate to SSDT responses. Furthermore, before and after receiving the touch manipulation participants were administered with self-report measures of mood (with a focus on Anxiety, Calmness, Happiness, Sadness). Lastly, we administered self-report measures of eating disorder symptoms, body dysmorphic disorder symptoms and body awareness to control for individual differences that might impact participants' performance to the SSDT (Sacchetti et al., 2020; Mehling et al., 2009; Katzer et al., 2012).

Due to the functional role of CT-afferents in multisensory perception and body awareness, we hypothesized CT optimal touch would lead to a more accurate perception during the subsequent SSDT. More precisely, we predicted that CT-modulated affective touch would enhance perceptual awareness on the body site stimulated to a greater extent than non-affective touch. In turn, we expected this enhancement in perceptual awareness to enhance touch perception in that body site, leading participants to be better able to discriminate when, after the manipulation, the tactile pulse was administered and when it was not (higher sensitivity, *d'*). According to previous research that showed a unique link between CT-modulated affective touch and body awareness, we expected this effect to be specific for CT optimal touch as opposed to non-CT optimal touch (Crucianelli et al., 2018; Panagiotopoulou et al., 2017). However, differently from previous research that assessed the effects of CT-modulated affective touch during the RHI, we expect CT optimal touch to enhance perceptual, tactile accuracy rather than amplify perceptual distortions. Indeed, during the RHI tactile information contributes to eliciting the perceptual illusion. Therefore, an enhancement in the salience of the tactile information (i.e., CT-modulated affective touch touch) determined a stronger perceptual distortion (Crucianelli et al., 2013; van Stralen et al., 2014; Lloyd et al., 2013). Conversely, during the SSDT, the presence of the touch (vibrotactile pulse) does not play a role in eliciting the illusion but rather it represents the genuine information required to detect in the absence of the perceptual illusion. Therefore, due to paradigm differences, in the current study we predicted CT-modulated affective touch to enhance perceptual accuracy rather than increase perceptual distortions.

Moreover, in line with previous studies that have investigated the effects of CT optimal touch using implicit measures of emotional valence (e.g., facial electromyography and physiological responses of skin conductance and heart rate variability; Ree et al., 2019; Mayo et al., 2018; Pawling et al., 2017), we also hypothesized that CT optimal touch would increase positive mood (happiness and calmness) and decrease negative mood (anxiety and sadness).

5.2 Method

Participants were tested in a single study session. All participants performed the SSDT at the beginning of the testing session, they then received a touch manipulation, and subsequently performed the SSDT a second time. Participants were randomly assigned to one of two possible touch manipulations: one group received CT optimal touch (3cm/s; n = 32), and the second group received non-CT optimal touch (30cm/s; n = 34). Therefore, the study employed a 2×2×2 mixed designed with group (CT optimal touch vs non-CT optimal touch) as a between subject variable, Light (Light vs No Light) and Time (Pre vs Post-touch) during the SSDT as within-subject variables, and hit rate (HR), false alarm rate (FA), *d*' and c as dependent variables.

5.2.1 Participants

Sixty-six females between 19 and 60 years of age (*M* age = 32.67, *SD* = 15.42) were recruited from the staff and student population at Liverpool John Moores University (LJMU) and from the general population via advertisements placed around the university campus and on social media. The sample size was based on a power analysis using G*Power 3.1.9.7 (Faul et al., 2009), which indicated that overall a minimum sample of n = 56 was needed to detect a medium effect (*f* = .20) with 95% power, using a mixed design ANOVA ("number of groups" = 2 × "number of measurements" = 4) with alpha at .05 (two tailed). The sample size was expanded to 71 participants to increase statistical power. However, 5 participants were excluded from analysis because a consistent tactile threshold level during the SSDT could not be achieved [(HR) > 90% or < 10% during the first repetition of the SSDT and across Light and No Light trials]. We therefore reported the results of 66 participants (CT optimal group: n = 32; non-CT optimal group: n = 34).

Any individual previously clinically diagnosed with, or who had received treatment of any kind for body dysmorphic disorder (BDD) or eating disorders (EDs) were excluded from the study, as well as individuals who had a history of, or currently had any neurological and/or psychiatric disorder. Further exclusion criteria included uncorrectable visual impairments, tactile impairments, skin conditions and pregnancy. To minimize heterogeneity of participants, and consistent with previous studies by our research group, only females were recruited. (Sacchetti et al., 2020; Sacchetti et el., 2021). All participants but two were right-handed as assessed using the Edinburgh Handedness Inventory (EHI; Oldfield, 1971).

According to the Helsinki declaration of ethical standards, the study protocol was approved by the LJMU's University Research Ethics Committee (UREC) 19/NSP/021. All participants gave their informed consent to take part, and they were compensated for their time with a £5 shopping voucher or "participation points" for course credit for BSc Psychology students.

5.2.2 Material and measures

5.2.2.1 The Somatic Signal Detection Task (SSDT) – Face Version (Sacchetti et al., 2020). The study employed the same set-up presented in Chapter 3 with the tactor placed on participants' left cheeks. A mirror-reversed photograph of the participant's face (768 × 583 pixels in size) was presented on the computer screen during all trials of the SSDT. Instructions for participants were presented on the top section of the computer screen in order not to hinder vision of the photograph. As in Chapter 3, during the experimental phase, a LED was fixed to the computer monitor mirroring the location of the tactor on the participant's face (see Figure 5.1). The LED was therefore placed on the right cheek of the face depicted on the monitor.

5.2.2.2 Touch Manipulation. During the touch manipulation, tactile stimulation (brush strokes) were delivered from a female experimenter using a cosmetic brush (No7 cosmetic brush, Boots UK). Prior to testing, the experimenter trained on a high precision scale to deliver strokes at a constant pressure of 220 mN (22gr/cm^2). The CT optimal group received strokes at the velocity of 3cm/s, and the non-CT optimal group at the velocity of 30cm/s. A visual metronome was presented on a computer screen behind the participant to guide the experimenter in delivering the strokes at the correct velocity (3cm/s or 30cm/s; Pawling et al., 2017; Haggarty et al., 2019). The metronome used a custom made PsychoPy script (Peirce, 2007), showing a 3s countdown followed by a 9cm rectangle filling at the required stroking velocity (3s for the 3cm/s touch, and 0.3s for the 30cm/s touch).

The touch manipulation consisted of 4 blocks of 4 trials each, with each trial corresponding to a 6s window during which participants were stroked on a 9cm segment on their left cheek. Therefore, for the CT-optimal group (3cm/s) each trial consisted of 2 consecutive strokes administered, while for the non-CT optimal (30cm/s) each trial consisted of 20 strokes.

After each of the 4 blocks, participants were asked to rate the Pleasantness and Intensity of the stimulation on a 15cm Visual Analogue Scale (VAS) ranging from -10 (unpleasant) to +10 (pleasant), and from 0 (least intense) to 100 (most intense). Pleasantness and Intensity VASs were used as a manipulation check to ensure that CT optimal touch was perceived as more pleasant and less intense compared to non-CT optimal touch in accordance with previous research (Löken et al., 2009; Ackerley et al., 2014; Case et al., 2016).

Moreover, prior to, and after receiving the touch manipulation, participants were asked to report on four 15cm VASs how calm, anxious, happy, and sad they felt from a minimum of

0 (not at all) to a maximum of 100 (very much so). Mood VASs (Calmness, Anxiety, Happiness, Sadness) to analyse the influence of the touch manipulation on participants' emotional state. The experimental set-up is illustrated in Figure 5.1.

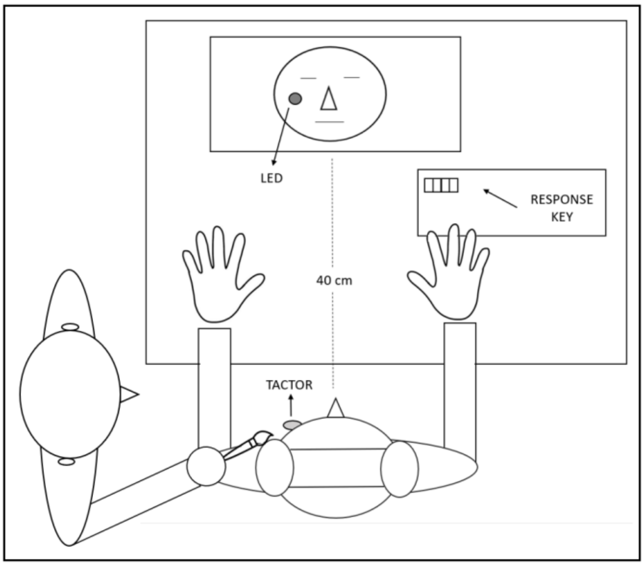


Figure 5.1. Schematic depiction of the experimental set-up during the SSDT. The experimenter (left) delivered the touch manipulation to the participant (right) between the first (Pre) and the second (Post) repetition of the SSDT.

5.2.2.3 Physiological arousal. Electrodermal Activity (EDA) signals (i.e., the electrical activity of the skin resulting from changes in sweating) were recorded using the Biopac MP150 Systems (Version 4.2, Biopac Systems Inc., CA, USA), in three time windows: during the first repetition of the SSDT (Pre), during the touch manipulation, and during the second repetition of the SSDT (Post). The three recordings were interspersed with 90s breaks. Two electrodes were placed on the index and the middle finger of the left hand. The electrodes were connected to the Biopac MP150 Systems and the Biopac Student Lab Pro 3.7 software, which was programmed to filter in real time EDA data with a band-pass of 0–35Hz. The sampling rate for data acquisition was set at 1000Hz.

EDA data were then used for calculating Skin Conductance Levels (SCLs), a measure of the background tonic EDA that is commonly used as an index of psychological arousal. Particularly, SCLs are deemed to reflect slow changes in the autonomic sympathetic nervous system (SNS) in response to stressors or emotional stimuli (Lang et al., 1993; Boucsein , 2012).

Higher SCLs indicate a stronger activation of the SNS and therefore a higher level of arousal (Lang et al., 1993; Reed et al., 2019). In the current study, SCLs were preferred over cardiac measures of physiological arousal, in accordance with previous research that suggested EDA to be a better index for detecting arousal changes when investigating responses that are predominantly of lower arousal (Boucsein, 2012; Ree et al., 2019). However, tactile stimuli have been previously reported to affect also other autonomic and cardiac measures (e.g., Pawling et al., 2017; Triscoli, et al., 2017a; Triscoli et al., 2017b). SCLs were recorded to investigate changes in arousal due to the touch manipulation, and to analyse possible influences of arousal levels on subsequent SSDT responses.

5.2.3 Self-report questionnaires

Self-report measures were used to control the sample for possible confounding variables that have been shown to impact touch perception during the SSDT, that are eating disorder symptoms, body dysmorphic disorder symptoms and body awareness (Sacchetti et al., 2020; Mehling et al., 2009; Katzer et al., 2012). Scores were used to ensure homogeneity of participants and comparability with the general population.

5.2.3.1 Dysmorphic Concerns Questionnaire (DCQ; Oosthuizen, Lambert & Castle, 1998). The DCQ consists of 7 items investigating participants' body image preoccupation and dysmorphic concerns their physical appearance (see Chapter 2, Section 2.5.1).

5.2.3.2 Eating Disorder Inventory-3 (EDI-3; Garner, 2004). The EDI-3 is a 91 items questionnaire for the assessment of ED and ED-related symptoms (see Chapter 2, Section 2.5.2). In the current study, we focused on the ED Risk Composite which constitutes an index of the risk to develop an ED and correspond to the sum of scores on the Drive for Thinness, Bulimia and Body Dissatisfaction subscales.

5.2.3.3 Body Perception Questionnaire-Very Short Form (BPQ-VSF; Porges, 1993). The BPQ is a 12-item self-report questionnaire of body awareness and autonomic reactivity. See Chapter 2, Section 2.5.4.

5.2.4 Design and Procedure

5.2.4.1 General Procedure

At the beginning of each testing session, the experimenter took a photograph of the participant's face using a Nikon D50 digital SLR camera. Participants were standing against a plain-coloured grey background, and they were photographed with a neutral facial expression, without hair covering their face. Each participants' original photograph was centred and cropped to adjust to the computer screen, and it was flipped horizontally as seen in a mirror using Microsoft Picture Manager 2013. The photograph of the participant was presented on the computer monitor during all trials of SSDT as part of the set-up (see above). Subsequently, electrodes were placed on participants' hand as previously explained for recording EDA.

Participants were then asked to complete the first repetition of the SSDT protocol (Pre), which consisted of a thresholding procedure and a testing phase (see below). After completing the SSDT, participants were asked to fill in the mood VASs (Pre), they were administered with the touch manipulation according to their group assignment (CT optimal vs non-CT optimal), and they were then asked to fill in the mood VASs a second time (Post). After the touch manipulation, participants repeated the testing phase of the SSDT a second time (Post). They were then administered each of the self-report questionnaires: the EHI, the EDI-3, the DCQ and the BPQ. Lastly, height and weight were measured with a stadiometer and a scale for calculating the Body Mass Index (BMI; kg/m^2) using the NHS online calculator. The testing procedure lasted approximately 90 minutes. A schematic representation of the general procedure is presented in Figure 5.2.

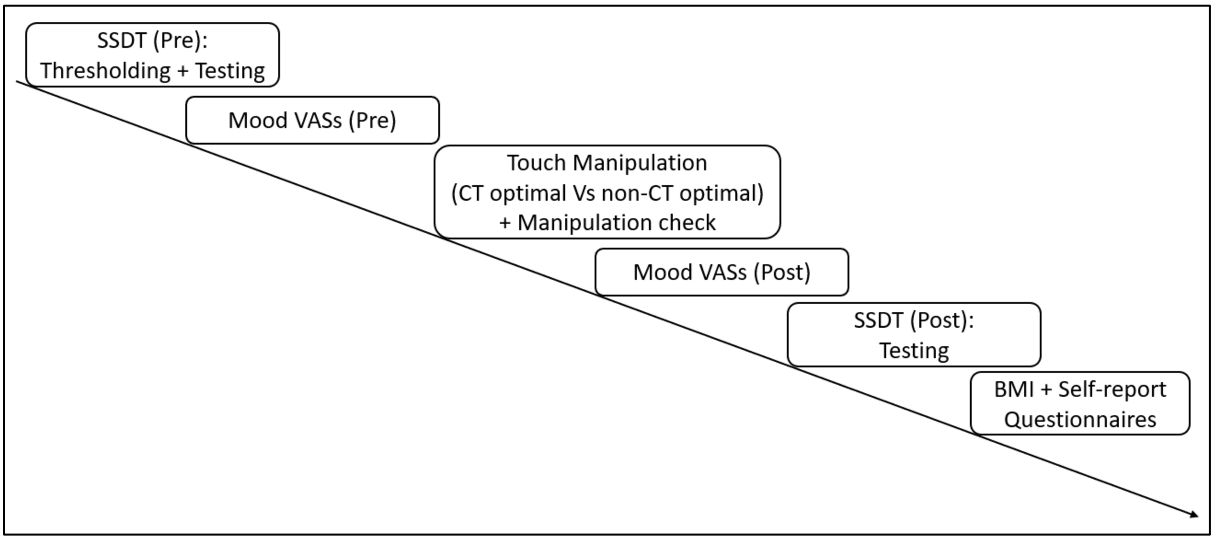


Figure 5.2. Timeline representation of the different steps of the study procedure.

5.2.4.2 SSDT Thresholding Procedure

The intensity of the vibration was determined using a computerized two forced choice thresholding procedure as indicated in Chapter 2. In this study, the beginning of each trial was signalled a 250ms beep sound administered through a pair of earphones. The thresholding procedure was performed only once during the first repetition of the SSDT.

5.2.4.3 SSDT Testing Phase

As in Chapter 3, at the beginning of the testing phase, the experimenter placed the LED on the computer monitor on the right cheek of the photograph presented, therefore mirroring the position of the tactor on participants' face. The experimental phase was then carried out as explained in Chapter 2. As in the thresholding procedure, the beginning of each trial was signalled by an auditory cue (beep sound).

5.3 Results

5.3.1 Data Processing

5.3.1.1 SSDT scores. HR, FA, *d'* and *c* outcomes of the SSDT were calculated as indicated in Chapter 2.

5.3.1.2 SCLs data extrapolation. EDA data were recorded continuously during three time windows: the first repetition of the SSDT (SSDT Pre), the touch manipulation, and the second repetition of the SSDT (SSDT Post), resulting on a total of 3 recordings per participant (each lasting approximately 15 minutes; see Figure 5.2). Each recording was visually inspected for artefacts which were manually removed using Biopac (MP150) Systems. Three SCLs per participant were then extrapolated averaging across the EDA signal in each recording.

5.3.2 Demographics and self-reports analyses

Statistical analyses were performed using SPSS (SPPS Inc., Chicago, IL). All data are reported as Mean (*M*) and Standard Deviation (*SD*). A significance threshold of $p < .05$ was set for all effects, and effect sizes were estimated using Cohen's *d* and partial eta square (η^2).

A series of t-tests was performed to analyse group differences in demographics, baseline mood, and self-report personality traits. As reported in Table 5.1, the two groups (CT vs non-CT) were found not to differ in Age, SSDT threshold levels, or Body Mass Index (BMI). No significant between-groups differences were found in mood prior to the touch manipulation, nor in eating disorder symptoms (EDI), body dysmorphic symptoms (DCQ), or body awareness (BPQ). The two groups were therefore comparable in all measures that were identified as possible confounding variables. Moreover, mean scores for the EDI, DCQ, and BPQ of our two groups were consistent with mean scores of the normative healthy samples, indicating our sample to be representative of the general population (Clausen et al., 2011; Mancuso, Knoesen & Castle, 2010; Cabrera et al., 2018).

Table 5.1

Descriptive statistics for Age, SSDT threshold levels, mood at baseline and questionnaire scores in each group. No significant differences between the two groups were found.

	CT optimal	non-CT optimal				
	M (sd)	M (sd)	t	df	sig	d
Age	32.91 (17.06)	32.44 (13.96)	.12	64	.90	.03
Threshold	-1067.31 (390.86)	-1085 (394.27)	.18	64	.85	.04
BMI	26.37 (5.81)	25.18 (5.56)	.85	64	.40	.21
Calmness_Pre	79.82 (19.66)	72.94 (20.55)	1.39	64	.17	.34
Anxiety_Pre	24.89 (24.09)	25.55 (23.48)	.11	64	.91	.03
Happiness_Pre	70.49 (16.53)	72.62 (16.07)	.53	64	.60	.13
Sadness_Pre	17.23 (19.22)	15.97 (19.47)	.28	64	.78	.06
EDI-3	32.19 (18.25)	29.47 (21.31)	.55	64	.58	.14
DCQ	6.56 (3.93)	6.12 (4.14)	.44	64	.66	.11
BPQ	35.94 (12.35)	36.50 (11.69)	.190	64	.85	.05

5.3.3 Main analyses

Descriptive statistics for HR, FA, *d'* and *c* in each Light and Time condition of the SSDT, in each group are presented in Table 5.2. Before performing the analyses, these SSDT outcomes were tested for normality. HR, *d'* and *c* were normally distributed, therefore parametric analyses were conducted. Three mixed design ANOVAs were performed with Group as the between-subject factor, and Light and Time as within-subject factors, using HR, *d'* and *c* as dependent variables. Paired and independent-sample t tests were performed to follow up significant interactions. Bonferroni correction was used to correct for multiple comparisons.

Conversely, FA in all experimental conditions were not normally distributed, with a significant positive skewness. As FA remained not normal after attempts to transform the data, non-parametric analyses were conducted. As there is no non-parametric test equivalent to a mixed design ANOVA, two Freidman's ANOVAs, for the CT optimal and the non-CT optimal groups, were used to investigate within-subjects effects, with Light and Time as within-subject factors. Wilcoxon tests were used to follow up significant results. Mann-Whitney U tests were used to investigate between-subject effects.

Table 5.2

Descriptive statistics for hit rate, false alarm rate, *d'* and *c* in each Light (Light and No Light) and Time (Pre and Post) condition during the SSDT, in each group (CT and non-CT).

CT optimal		HR (%)	FA (%)	FA (%)	*d'*	*c*
		M (SD)	Mdn (IQR)	M (SD)	M (SD)	M (SD)
Pre	Light	59.53 (25.28)	.07 (.20)	8.43 (7.09)	1.58 (.91)	.45 (.43)
	No Light	47.69 (21.45)	.10 (.23)	10.55 (6.97)	1.41 (.77)	.78 (.43)
Post	Light	53.34 (26.97)	.02 (.19)	6.46 (6.55)	1.66 (1.03)	.73 (.53)
	No Light	44.69 (27.94)	.04 (.21)	7.74 (7.45)	1.41 (1.03)	.92 (.50)
Non-CT optimal		HR (%)	FA (%)	FA (%)	*d'*	*c*

		M (SD)	Mdn (IQR)	M (SD)	M (SD)	M (SD)
Pre	Light	46.91 (25.24)	.04 (.20)	7.74 (6.93)	1.30 (.82)	.77 (.48)
	No Light	44.30 (26.68)	.07 (.25)	9.44 (7.10)	1.35 (.90)	.89 (.52)
Post	Light	45.82 (30.14)	.07 (.21)	8.59 (6.44)	1.19 (.93)	.83 (.57)
	No Light	33.50 (23.14)	.07 (.22)	9.21 (7.21)	.91 (.69)	.97 (.56)

5.3.3.1 Hit Rate (HR)

There was a significant main effect of the Light ($F(1,64) = 33.48$, $p = .000$, $\eta^2 = .34$) and a significant three way interaction Time × Light × Group ($F(1,64) = 5.73$, $p = .020$, $\eta^2 = .08$). Follow-up analyses showed higher HR in Light compared to No Light trials in the CT optimal group ($F(1,31) = 19.98$, $p = .000$, $\eta^2 = .39$; Light: $M = 56.44$, $SD = 21.90$; No Light: $M = 46.19$, $SD = 21.80$). Conversely, in the non-CT optimal group there was no effect of the Light before the touch manipulation (Pre; $t(33) = |1.05|$, $p = .303$, $d = .18$). This indicates that during the first repetition of the SSDT (Pre), for the non-CT optimal group, HRs were less influenced by the presence of the Light than the CT optimal group . Accordingly, there were significant between-groups differences during the first repetition of the SSDT (Pre), with the non-CT optimal group showing lower HR in Light trials ($M = 46.91$, $SD = 25.23$) compared to the CT optimal group ($M = 59.53$, $SD = 25.28$; $t(64) = |2.03|$, $p = .047$, $d = .50$), and a lower change score from No Light to Light trials ($t(64) = |2.86|$, $p = .006$, $d = .71$; non-CT optimal: $M = 2.61$, $SD = .14.53$; CT optimal: $M = 11.84$, $SD = 11.43$).

In the non-CT optimal group the effect of the Light was present only after the touch manipulation (Post; $t(33) = |3.89|$, $p = .000$, $d = .67$) showing higher HR in Light ($M = 45.82$, $SD = 30.14$) compared to No Light ($M = 33.50$, $SD = 23.14$) trials. However, this effect seemed to be driven by the fact that HR dropped down significantly in No Light trials from before (Pre: $M = 44.30$, $SD = 26.68$) to after the touch manipulation (Post: $M = 33.50$, $SD = 23.14$; $t(33) = |2.89|$, $p = .007$, $d = .50$), indicating that participants in the non-CT optimal group were less able to perceive the touch after the touch manipulation without the prompt of the Light.

No main effect of Time and Group, and no interactions were found to be significant (all $Fs \leq 1.98$; all $ps \geq .16$).

5.3.3.2 False Alarm Rate (FA)

A Friedman's test showed that there was a significant difference in FA in at least one of the four experimental conditions (Light × Time) in the CT optimal group ($X^2(3) = 19.32$, p = .000, W = .20). Post-hoc tests using Wilcoxon signed-rank test showed that in the CT optimal group there was a significant effect of Time with lower FA after the touch manipulation (Post; *Mdn* = 4.50) as compared to before it (Pre; *Mdn* = 8.90; z = -2.52, p = .012, r = .45), indicating that receiving CT optimal touch decreased subsequent false reports of the tactile pulse during the SSDT. No other significant within-subjects effects were found in the CT optimal group (all $zs \leq$ -1.85, all $ps \geq$ .064). In regard to the non-CT optimal group, a Friedman's test showed that there was a tendency towards significance in FA in the difference between the four experimental conditions (Light × Time; $X^2(3) = 7.58$, p = .056, W = .07). However, follow up analyses showed no within-subjects effects to be significant (all zs ≤ -1.86, all $ps \geq$ .083).

Mann-Whitney tests revealed a significant between-groups difference in FA in the change score between Pre and Post FA (before and after the touch manipulation; U = 376.50, z = -2.18, p = .029, η^2 = .07), with a stronger decrease in FA from Pre to Post in the CT optimal group (*Mdn* = -2.50) as compared to the non-CT optimal group (*Mdn* = .00). No other significant differences between the two groups were found ($U \leq 406$; $p \geq .062$).

5.3.3.3 Sensitivity (d')

There was a main effect of Light with higher *d'* in Light (M = 1.43, SD = .80) compared to No Light (M = 1.27, SD = .74) trials. Moreover, there was a tendency towards a main effect of Group (F(1,63) = 2.97, p = .071 η^2 = .04) due to a higher d' in the CT optimal (M = 1.51, SD = .73) compared to the non-CT optimal group (M = 1.19, SD = .71). Further exploratory analyses were run to test whether the difference in *d'* between the two groups was present only after the touch manipulation (Post) or also before it (Pre). Results showed a significantly higher *d'* in the CT optimal vs the non-CT optimal group only after the touch manipulation (Post; t(64) = |2.36|, p = .022, d = .57; CT optimal: M = 1.54, SD = .90; non-CT optimal: M = 1.50, SD = .77). This difference may reflect the fact that a decrease in FA after the touch manipulation was found in the CT optimal group only. Conversely, there was no between-groups difference in *d'* before the touch manipulation (Pre; t(64) = |.84|, p = .403, d = .21).

There was no significant main effect of Time, and no two or three way interactions were significant (all $Fs \leq 1.98$; all $ps \geq .16$).

5.3.3.4 Response criterion (c)

There was a significant main effect of Time ($F(1,64) = 7.71$, $p = .007$, $\eta^2 = .10$) with higher *c* during the second repetition of the SSDT (Post; $M = .87$, $SD = .50$) compared to the first repetition of the SSDT (Pre; $M = .73$, $SD = .46$), indicating that participants were overall more inclined to report feeling the tactile pulse, regardless whether it was administered or not, before (Pre) rather than after (Post) the touch manipulation,

There was also a main effect of the Light ($F(1,64) = 37.75$, $p = .000$, $\eta^2 = .37$) and a significant Light × Group interaction ($F(1,64) = 4.65$, $p = .035$, $\eta^2 = .07$). Follow-up analyses showed a lower *c* in Light compared to No Light trials in both the CT optimal ($t(31) = |6.88|$, $p = .000$, $d = 1.21$; Light: $M = .59$, $SD = .41$; No Light: $M = .85$, $SD = .42$) and the non-CT optimal group ($t(33) = |2.53|$, $p = .016$, $d = .43$; Light: $M = .80$, $SD = .46$; No Light: $M = .93$, $SD = .47$). Further follow up analyses showed no significant between-groups differences in *c*. However, when looking at change scores between Light and No Light trials, the CT optimal group showed a stronger decrease in *c* from No Light to Light trials ($M = -.26$, $SD = .22$) compared to the non-CT optimal group ($M = -.13$, $SD = .29$; $t(64) = |2.16|$, $p = .035$, $d = .53$). Overall, these results indicate that all participants had a higher tendency to report perceiving the tactile pulse when the Light was present; however, this tendency was slightly stronger in the CT optimal group.

There was no significant main effect of Group, and no other two or three way interactions were significant (all $Fs \leq 1.98$; all $ps \geq .16$).

5.3.3.5 SSDT Results summary

Overall SSDT outcomes showed that in the CT optimal group, according to previous literature, the presence of the light induced an increase in HR as compared to trials in which the light was absent (Sacchetti et al., 2020; Sacchetti et al., 2021). Conversely, in the non-CT optimal group the presence of the light was found to induce higher HR only after receiving the touch manipulation. However, this effect was driven by the fact that after receiving the non-affective touch, there was a decrease in HR in trials during which the light was absent. This suggests that participants in the non-CT optimal group were less able to perceive the touch after the touch manipulation when there was not the prompt of the light.

Conversely, receiving CT-modulated affective touch was found to decrease FA, with participants in the CT optimal group reporting less FA after the touch manipulation. Accordingly, the change score in FA from before to after the touch manipulation was significantly greater in the CT optimal group as compared to the non-CT optimal group. Results in FA were partially mirrored by results in *d'*. Indeed, the CT optimal group showed a higher *d'* after the touch manipulation when compared to the non-CT optimal group. Taken together, results in FA and *d`* suggest that CT-modulated affective touch induced an increase in tactile accuracy. However, analyses in *d'* were exploratory and followed-up a main effect of Group that was only approaching significance.

Moreover, there were significant effects of the Light on *d'* and c indicating that the presence of the light induced participants to correctly report perceiving the tactile pulse more often. This effect of the Light on c was slightly stronger in the CT optimal group, which exhibited a higher change score between Light and No Light trials compared to the non-CT optimal group. However, this difference in c between the two groups seemed to be driven by previously shown results in HR, where the presence of the light was found to induce an increase in HR in the CT optimal group only. In contrast to some previous studies, there was no effect of the Light on FAs (Lloyd et al., 2008; Mirams et al., 2010).

5.3.4 CT vs non CT touch manipulation check

Two Independent sample t-tests were performed with Intensity and Pleasantness as dependent variables and Group as a between-subjects factor. According to our expectations and in accordance with previous literature, the CT optimal group rated the touch manipulation as significantly more pleasant (M = 6.72, SD = 3.09; $t(64) = |5.73|$, p = .000, d = 1.42) and less intense (M = 33.44, SD = 23.16; $t(64) = |3.46|$, p = .001, d = .85) compared to the non-CT optimal group (Pleasantness: M = 1.70, SD = 3.94; Intensity: M = 51.09, SD = 18.05; Löken et al., 2009; Ackerley et al., 2014; Case et al., 2016).

5.3.5 Mood VASs

Four mixed design ANOVAs were performed with Time as within-subject factor and Group as a between-subjects factor to assess how the touch manipulation effected mood (Pre vs Post the touch manipulation) in the CT optimal vs non-CT optimal group. The touch manipulation increased participants' self-reported Calmness ($F(1,64) = 4.36$, p = .041, η^2 = .06; Pre: M = 76.28, SD = 20.27; Post: M = 81.01, SD = 17.76) and Happiness ($F(1,64) = 7.65$, p = .007, η^2 = .11; Pre: M = 71.59, SD = 16.20; Post: M = 76.17, SD = 16.19), and decreased participants' self-reported Anxiety ($F(1,64) = 12.56$, p = .001, η^2 = .16; Pre: M = 25.23, SD

=23.60; Post: M = 16.74, SD = 20.06) and Sadness (F(1,63) = 5.36, p = .018, η^2 = .09; Pre: M = 16.59, SD =19.21; Post: M = 12.96, SD = 17.05). However, contrary to our expectations, these effects were not specific for the CT optimal group. Indeed, there were no significant main effects of Group and no Time × Group interactions were significant (all $Fs \leq 1.91$; all $ps \geq .17$).

5.3.6 Physiological arousal

A mixed ANOVA was performed with Time as a within-subjects factor, Group as a between-subjects factor and SCLs as the dependent variable, to analyse changes in physiological arousal during testing. For this analysis three temporal windows were considered: the first repetition of the SSDT (SSDT Pre), the touch manipulation (Touch) and the second repetition of the SSDT (SSDT Post). Results showed a significant main effect of Time (F(2,64) = 59.67, p = .000, η^2 = .48) and a significant Time × Group interaction (F(2,64) = 3.13, p = .047, η^2 = .05). Follow-up analyses indicated that SCLs during Touch (M = 8.87, SD = 4.79) were significantly higher compared to both the SSDT Pre (M = 6.04, SD = 4.46; t(65) = |10.69|, p = .000, d = .61) and the SSDT Post time window (M = 7.53, SD = 5; t(65) = |5.30|, p = .000, d = .27). Moreover, SCLs during the SSDT Post time window were found to be significantly higher than SCLs during the SSDT Pre time window (t(65) = |10.69|, p = .000, d = .61). Further Independent sample t-tests indicated that the CT optimal group had a significantly higher change score in SCLs from SSDT Pre to Touch (M = 3.47, SD = 2.32) as compared to the non-CT optimal group (M = 2.22, SD = 1.80; t(64) = |2.45|, p = .017, d = .60). No other between-groups comparisons were found to be significant (all $ts \leq 1.40$; all $ps \geq .17$). Overall results indicated that the touch manipulation induced an increase in arousal that was slightly higher in the CT optimal group as compared to the non-CT optimal group. After the touch manipulation, during the second repetition of the SSDT, the level of arousal decreased. However, it remained significantly higher than during the first repetition of the SSDT. SCLs data are presented in Figure 5.3.

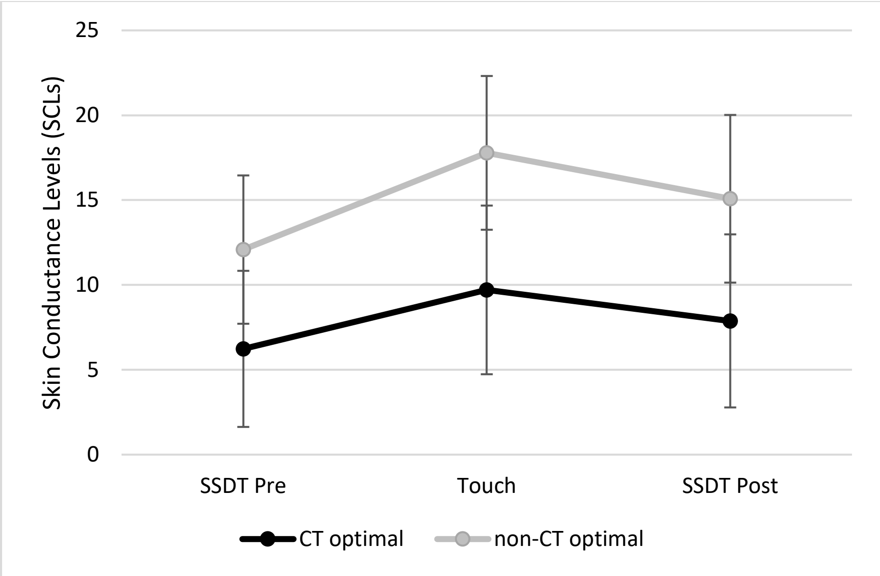


Figure 5.3. Mean SCLs in the CT optimal and in the non-CT optimal groups during the first repetition of the SSDT (SSDT Pre), the touch manipulation (Touch), and the second repetition of the SSDT (SSDT Post). Error bars show the standard deviation. SCLs increased during the touch manipulation, especially for the CT optimal group.

5.3.7 Exploratory correlational analyses

5.3.7.1 SSDT outcomes, mood and arousal

Exploratory Pearson's and Spearman's correlations were run to test whether participants' emotional states (Mood VASs), levels of arousal (SCLs), and perceived quality of touch (Intensity and Pleasantness) were related to performance during the SSDT (HR, FA, d', c). There was a relationship between the HR and d' indices and levels of arousal (SCLs). Particularly, there was a significant positive correlation between overall HR and SCLs during the touch manipulation ($r = .34$; $p = .005$) and SCLs during the second repetition of the SSDT (Post; $r = .28$; $p = .023$). Alongside d' was positively correlated to SCLs in all three temporal windows: during the first repetition of the SSDT ($r = .27$; $p = .027$), the touch manipulation ($r = .38$; $p = .002$) and the second repetition of the SSDT ($r = .32$; $p = .009$). Overall, these results suggest that participants exhibiting higher levels of arousal were also more accurate in correctly reporting the tactile pulse during the SSDT as indicated by HR and d'. Conversely, SSDT responses were not related to participants' emotional states (as measured by the Mood VASs), or perceived quality of touch (ratings of Intensity and Pleasantness; all $rs \leq .17$; all $ps \geq .18$).

5.3.7.2 Manipulation check, mood and arousal

Further correlational analyses were run to analyse the relationship between participants' perceived quality of touch during the touch manipulation (Intensity and Pleasantness; i.e., manipulation check), and subsequent emotional states (Mood VASs_Post) and levels of arousal. Perceived Pleasantness of touch was found to be positively correlated with subsequent Calmness (r = .35; p = .004) and negatively correlated with subsequent Anxiety (r = .34; p = .005). Therefore, the more pleasant the touch manipulation was perceived the calmer and less anxious participants felt after it. Moreover, Intensity of touch was found to be positively correlated with subsequent Sadness (r = .28; p = .020), suggesting that the more intense the touch was perceived the sadder participants were after the touch. There were no other significant correlations (all $rs \leq$ -.17; all $ps \geq$ .16).

5.3.7.3 ED-related symptoms and SSDT outcomes

As in the previous two experiments of this thesis, it was found that ED symptoms were related to differential responses during the SSDT, further correlations were used to investigate the relationships between ED-related symptoms (ED Risk Composite, DCQ and BPQ scores) and SSDT responses. Separate analyses were run considering SSDT responses before (Pre) and after (Post) receiving the touch manipulation, as well as in their change scores from before to after the touch manipulation (Post-Pre). Analyses on SSDT responses before the touch manipulation were performed pooling together the two experimental groups (CT optimal and non-CT optimal). Analyses on after the touch manipulation and on Post-Pre changes scores were performed separately for the two experimental groups to take into account the differences in experimental manipulation. Therefore, in these last analyses, sample sizes were particularly scarse (CT optimal: n = 32; non-CT optimal: n = 34) and results should be interpreted with caution.

No significant correlations were found before the touch manipulation (all $rs \leq$ .17; all $ps \geq$ .18). In the CT optimal group only there were significant positive correlations between the ED Risk Composite and Post-Pre change scores in HR (r = .40; p = .023) and d\` (r = .43; p = .014). Coherently, there was a significant negative correlation between the ED Risk Composite and the Post-Pre change score in c (r = -.38; p = .031) which was driven by the increase in HR reported above. Overall, these results indicated that participants presenting with higher ED symptoms showed a stronger improvement in their ability to correctly detect the touch after having received CT-modulated affective touch. No other significant correlations were found (all $rs \leq .24$; all $ps \geq .17$).

5.4 Discussion

The aim of the current study was to investigate the effects of CT optimal (affective) vs non-CT optimal (non-affective) touch on subsequent visuo-tactile multisensory integration using the Somatic Signal Detection Task (SSDT). According to previous literature, linking CT optimal affective touch to body awareness and multisensory perception, we predicted CT-modulated affective touch to enhance perceptual accuracy during the subsequent SSDT as compared to non-affective touch.

Results of the study showed that CT-modulated affective touch led to a decrease in false reports of feeling the tactile pulse (FA) during the SSDT. Results in FA were partially mirrored by results in *d`*. There was a tendency towards a main effect of group on *d'*, and exploratory analyses showed that sensitivity in detecting the tactile pulse (*d`*) was significantly higher after receiving affective touch (CT optimal group) in comparison to after receiving non-affective touch (non-CT optimal group). It should be noted, however that there was no significant group × time interaction for *d'*. Nevertheless, these results suggest that participants receiving CT-modulated affective touch were then less inclined to erroneously report the tactile pulse when absent (FA), and were better able to discriminate when the tactile pulse was administered from when it was not (*d`*). Therefore, in line with our expectations, CT-modulated affective touch was shown to induce an increase in tactile accuracy.

To date, this is the first study demonstrating a lasting effect of CT-modulated affective touch on perceptual accuracy and multisensory (visuo-tactile) integration. Prior studies have indicated that in a multisensory context (i.e., during multisensory integration tasks) CT-modulated affective touch was perceived as more meaningful when compared to non-affective discriminative touch (Gentsch et al., 2016; Ciaunica & Fotopoulou, 2017). During the Rubber Hand Illusion (RHI) or the Enfacement Illusion, for example, CT-modulated affective touch has been linked to a stronger experience of the illusion and an enhancement of body ownership in participants (Crucianelli et al., 2013; Lloyd et al., 2013; van Stralen et al., 2014; Panagiotopoulou et al., 2017). According to these results, it has been argued that CT-afferents may play a unique role in the construction of the bodily self, that is the multimodal perceptually integrated model of one's own body (Blanke, 2012; Crucianelli et al., 2013; Ciaunica &

Fotopoulou, 2017). However, it remained unclear whether CT-modulated affective touch could induce long-lasting alterations in multisensory integration and body perception. This study aimed to build upon this gap in the current literature. Results showed that CT-modulated affective touch can indeed induce long lasting effect on a multisensory integration task that is the SSDT by increasing participants tactile accuracy.

This effect was specific for CT-modulated affective touch. In fact, non-affective touch was found not to impact on FA and *d`*. Conversely, non-affective touch induced a partial decrease in the correct detection of touch (HR) during the SSDT. Indeed, the non-CT optimal group showed a significant effect of the Light on HR only after receiving the touch manipulation, with higher HR in trials during which the light was present as compared to trials during which the light was absent. However, this effect was driven by the fact that after the touch manipulation, in the non-CT optimal group there was a decrease in HR in trials during which the light was absent, suggesting that participants receiving non-affective touch were then less able to perceive the tactile pulse without the prompt of the light.

It is possible that the fast touch (30 cm/s) administered in the non-CT optimal group desensitized the same tactile channels required to detect the vibrotactile stimulation administered during the SSDT. In this respect, a previous psychophysiological study indicated that adaptation to prolonged fast/vibrating tactile stimuli induced a desensitization of skin mechanoreceptors that were then less sensitive in discriminating different textures (Gescheider et al, 1985; Hollins et al., 2001). It could be therefore hypothesised that a similar mechanism influenced participants responses in this study, so that after receiving non-affective fast touch, mechanoreceptors were desensitized to the perception of the tactile pulse during the SSDT. According to this explanation, in a previous study by Mirams and colleagues (2012) participants showed decreased touch reports during the SSDT after performing a grating orientation task which involved focusing on external touch. Coherently to our reasoning, it could be the case that also in this study, the tactile stimulation involved in discriminating grating orientations fatigued and desensitized skin mechanoreceptors, leading to a decrease in touch reports during the subsequent SSDT.

Further SSDT results showed that, in line with previous literature, the presence of the light facilitated participants perception of the tactile pulse during the task. This was reflected by overall higher HR and *d`,* and lower *c* in trials during which the light was present. The touch manipulation, in both the conditions of affective and non-affective touch, was found not to alter this effect of the light on touch detection during the SSDT. Although the non-CT optimal group showed an effect of the light (higher HR in light-present vs light-absent trials) only after receiving non-affective touch, as previously discussed, this effect seemed to be driven by a decrease in HR in trials during which the light was absent, which can be linked to a desensitization of mechanoreceptors after receiving a fast touch.

In contrast with some previous studies using the SSDT, the presence of the light did not increase false reports of touch (Llyod et 2008; Mirams et al., 2010). However, this is consistent with other studies in the previous literature. Indeed, some of previous studies assessing SSDT responses did not find a significant effect of the light on FA (Sacchetti et al., 2020; Sacchetti et al., 2021; Lloyd et al., 2011; Mirams et al., 2017). In one of these studies, FA were even found to be higher when the light was absent as compared to when it was present (Lloyd et al., 2011). Moreover other studies in the previous literature did not report FA results, and it is therefore not possible to compare them with results of this study (Mirams et al., 2012; Mirams et al., 2013). Taken together these results suggest that the presence of the light during the SSDT can influence both correct and incorrect reports of touch. Further research should focus on whether participants' emotional/attentional states or personality traits play a role in determining whether the presence of the light influence more correct or incorrect report of touch during the SSDT.

Throughout the experiment, Skin Conductance Levels (SCLs) were also recorded to analyse whether the touch manipulation induced changes in autonomic physiological arousal. Results indicated that the touch manipulation induced an increase in arousal that was slightly higher for affective vs non-affective touch. After the touch manipulation, during the second repetition of the SSDT, the level of arousal slowly decreased. However, SCLs remained significantly higher compared to baseline levels (during the first repetition of the SSDT). A single study only previously analysed the relationship between CT-modulated affective touch and SCLs with results similar to the results of this study (Ree et al., 2019). Indeed, Ree and colleagues (2019) showed SCLs to increase after receiving tactile stimulation, with a greater increase for CT optimal vs non-CT optimal touch, although this difference did not reach significance. However, it should be noted that other studies using different indexes of arousal, such as the heart rate, the heart rate variability, and the amplitude in skin conductance response, all suggested CT-modulated affective touch to be associated with a decrease, rather than an increase in arousal (Pawling 2017b, Triscoli 2017, Fairhurst 2014). Therefore, a comprehensive picture of how different sympathetic and parasympathetic indexes of arousal vary due to CT-modulated affective touch is still to be drawn by future research.

Interestingly, SCLs were positively correlated with participants' ability to correctly detect the tactile pulse during the SSDT (HR), and to accurately discriminate when the tactile pulse was administered and when it was not (*d`*). These results are in agreement with those from Experiment 1, in which the change scores in SCLs between experimental conditions was found to be associated with a parallel increment in participants ability to discriminate touch (*d`*) in light-present trials of the SSDT (Sacchetti et al., 2020). Taken together, these results suggest that participants' responses during the SSDT can be influenced by their arousal levels, with higher SCLs predicting a more accurate tactile perception. Moreover, as SCLs were found to increase more steeply during CT-modulated affective touch as compared to non-affective touch, it could be hypothesized that SCLs may mediate the relationship between CT-modulated affective touch and increased tactile accuracy. Future research should further investigate this hypothesis.

In line with our expectations, CT-modulated affective touch was found to induce an increase in positive mood (Happiness and Calmness) and a decrease in negative mood (Anxiety and Sadness). However, and in contrast to our expectation, this effect was not specific for CT-modulated affective touch, but was also present after receiving non-affective touch. Mood was partially influenced by participants' perceived quality of touch during the touch manipulation (Intensity and Pleasantness). Indeed, participants reported feeling calmer and less anxious the more pleasant they had rated the touch manipulation, and reported feeling sadder the more intense the touch manipulation was perceived to feel. However, mood and perceived quality of touch were found not to influence SCLs.

It was also found that participants presenting with higher ED symptoms after receiving CT-modulated affective touch showed a greater improvement in their ability to correctly detect the touch (HR) and to discriminate when the touch was administered from when it was not (*d`*) during the subsequent SSDT. These results are important to inform a possible use of CT-modulated affective touch as an intervention to increase perceptual accuracy and awareness in EDs (see Chapter 1, Section 1.6; see Chapter 7, Section 7.3.3). However, it should be noted that the sample analysed here was made of only 32 participants, and therefore did not reach statistical power for correlational analyses (Field et al., 2013). Results should be therefore discussed with caution.

To summarize, results of this study showed for the first time a long-lasting effect of CT-modulated affective touch on multisensory integration and perceptual awareness. In the context of the SSDT, where participants are required to detect a tactile pulse independently from the presence/absence of a concomitant light flashing, this effect translated in a greater tactile accuracy. Moreover, results of the study suggested SCLs to be a possible mediating mechanism linking CT-modulated affective touch to a greater tactile accuracy during the SSDT. It is worth noticing that from a neurophysiological point of view, CT-afferents have been linked to the activation of brain areas that are involved in the elaboration and integration of multisensory information (e.g., the posterior insula; Morrison, 2016; Gazzola et al., 2012), and in the codification of the sense of a bodily self (e.g., the angular gyrus; McGlone et al., 2014). Therefore, it could be the case that an activation of this brain network after receiving CT-modulated affective touch alters the way subsequent sensory information are coded and integrated in the building of the bodily self. Specifically, results of this study might suggest that by enhancing the sense of a bodily self through CT-modulated affective touch, body perception may benefit from a greater accuracy and awareness.

These results are particularly important to inform available treatments for those pathological conditions in which perception of the body is altered such as eating disorders (EDs). Previous research has shown EDs to be characterized by profound alterations in body perception, that also encompass disruptions in the elaboration and integration of multisensory information (Eshkevari et al., 2012; Case et al., 2012). Coherently, in the previous studies of this thesis we found participants presenting with higher level of ED symptoms to be differently affected by bodily-related visual information while performing the SSDT. These results confirmed the hypothesis that EDs are associated with alterations in the integration of multisensory information. Specifically, in these studies, high ED participants showed altered responses to bodily-related visual information when integrated to visuo-tactile information. Conclusions of Experiment 3 promote a possible use of CT-modulated affective touch as an intervention for increasing perceptual body accuracy and awareness in EDs. Previous studies have shown affective touch to increase the sense of body ownership in neuropsychological conditions such as asomatognosia and somatoparaphrenia (van Stralen et al., 2011; Gentsch et al., 2016; Jenkinson et al., 2020). A future stream of research should investigate whether the use of affective touch as an intervention can be expanded also to EDs.

Chapter 6

Do arousal levels and personality traits influence perceptual processes during the somatic signal detection task?

Based on the results of the previous studies of this thesis it was hypothesized that participants' level of arousal, as assessed using skin conductance levels (SCLs), may be linearly associated with a more accurate perception of touch during the SSDT (see Chapters 3 and 5). However, due to the lack of statistical power, it was not possible to thoroughly test this hypothesis in those single studies. In the current Chapter, the data sets from Experiments 1 and 3 were pooled to take advantage of the use of an enlarged dataset to test this hypothesis. Pooling the data from Experiments 1 and 3 also allowed us to better investigate the relationship between ED symptoms and SSDT responses with increased statistical power.

6.1 Introduction

6.1.1 The relationship between arousal levels and SSDT performance

The experiments reported in Chapters 3 and 5 suggested that participants' physiological state may influence their responses during the SSDT. Physiological arousal was measured in terms of Skin Conductance Levels (SCLs). As explained in Chapter 3, SCLs correspond to the background electrodermal activity of the skin, and represent an index of the activity of the sympathetic nervous system (SNS; Sztajzel, 2004; Mendes, 2009). In turn, the SNS is activated in response to emotional stimuli and/or stress. Therefore, higher SCLs indicate an increase in the activity of the SNS in response to emotional stimuli.

Specifically, in Experiment 1, higher arousal was found to be associated with a greater accuracy (d') in detecting tactile information, and especially in trials where there was a simultaneous LED flashing (Sacchetti et al., 2020). Accordingly, exploratory correlational analyses indicated that increases in SCLs between experimental conditions (self-focused attention vs. neutral) were associated with a parallel increment in the accuracy to detect touch (d').

In Experiment 3, in which we investigated the effects of a tactile manipulation on physiological arousal and SSDT performances, we found similar results. Overall SCLs were positively correlated with participants' ability to correctly detect the tactile pulse during the

SSDT (HR), and with participants' ability to accurately discriminate when the tactile pulse was administered and when it was not (*d'*; Sacchetti et al., under review).

In this regard, it is worth mentioning that previous research has linked arousal to perceptual accuracy. Specifically, it was proposed that higher arousal (regardless of the emotional valence associated) can lead to participants to experiencing their body as more perceptually salient, in terms of increasing participants' attention towards incoming perceptual information. This in turn, would lead to a subsequent increase in perceptual accuracy (Wegner & Giuliano, 1980; Salovey, 1992; Liao & Masters, 2002).

It could be hypothesized that, regardless of experimental manipulations, higher arousal levels (as measured by SCLs) may be linearly associated with a more accurate tactile perception (higher HR and *d'*) during the SSDT. However, it was not possible to determine whether this hypothesis was true in the individual studies before mentioned (Experiment 1 and 3) due to the lack of statistical power. Alternatively, it was proposed that arousal levels may be better conceptualized as mediators of the link between increased self-awareness (as experimentally manipulated: through the manipulation of self-focused attention in Chapter 3; and due to receiving an affective touch manipulation in Chapter 5) and tactile accuracy.

The first aim of the current study was to test whether higher arousal levels were linearly associated with a more accurate tactile perception during the SSDT on large sample of participants (n = 119). To this aim we selected and merged the data from Experiments 1 and 3 that were equivalent for set-up and experimental condition (Sacchetti et al., 2020; Sacchetti et al., under review). Specifically, in both experiments, participants performed the face-version of the SSDT (explained in Chapter 2) while looking at a picture of their own face (see the procedure section for more information). Meanwhile, SCLs were measured.

6.1.2 The relationship between ED symptoms and SSDT performance

Previous research has shown that differences in personality traits and the presence of psychopathological symptoms (although not of clinical relevance; i.e., subclinical) can impact the way participants encode and process incoming stimuli (Costantini, 2014). This manifests both in differences in lower-level information processing (i.e., the encoding of primary perceptual information) such as the initial detection of threat in visual stimuli (Öhman, Lundqvist, & Esteves, 2001), and in higher-level information processing (i.e., the integration and elaboration of primary perceptual information) such as broad schemata of the self and of the world (Mineka, Rafaeli, & Yovel, 2003; Yovel, Revelle & Mineka, 2005).

For example, Yovel and colleagues (2005) demonstrated that participants with obsessive-compulsive personalities, clinically described as rigid and attentive to details in their everyday life (Shapiro, 1965), tended to focus more often on small local details also in a perceptual task. In fact, when asked to perform the global-local hierarchical-letters paradigm, during which participants are asked to focus alternatively on the local/global aspects of an image, participants with obsessive-compulsive personalities were found to be more detail-oriented as compared to controls. Indeed, obsessive-compulsive participants were particularly distracted by the to-be-ignored local aspects of the image when asked to identify their global aspects.

Similarly to obsessive compulsive personalities, anorexic (AN) patients, that are clinically described as preoccupied with details about their body, have been found to have a preferential detail-oriented perceptual style in a perceptual task. Indeed, when tested using an inversion effect paradigm, which requires participants to visually discriminate upright and inverted images of whole bodies, faces and objects, AN patients presented selective deficits in the discrimination of upright body stimuli, which requires a global processing. Conversely, they were comparable to healthy controls in their ability to discriminate inverted bodies, which requires a detail-oriented processing of the image (Urgesi et al., 2014)[4].

Participants' differences in personality traits and psychopathological symptoms have also been found to influence their performance in tasks assessing multisensory integration (Ferri et al., 2014; Peled et al, 2000; Eshkevari et al., 2012).

For example, clinical samples of eating disorder (ED) patients and in people presenting with subclinical ED symptoms were found to be more sensitive to the RHI (see Chapter 1) both in terms of proprioceptive drift and in terms of subjective body ownership (Mussap & Salton, 2006; Eshkevari et al., 2012; Caglar-Nazali et al., 2014). Similar results were found in samples of schizophrenic patients and people presenting with schizotypal personality traits, who like ED patients, were more inclined to perceive the illusion (Peled et al., 2000; Peled et al., 2003; Thakkar et al., 2011; Asai et al., 2011).

Taken together, these results suggest that schizophrenic and ED symptoms modulate the way participants encode and integrate tactile and visual information during the RHI, resulting in a more malleable sense of the bodily self that is more easily inclined to incorporate an external object (the rubber hand) in the representation of the body (Ferri et al., 2014;

[4] These results are coherent with a broader literature that has linked EDs to a deficit in central coherence, that is the ability to determine meaning (i.e., a global picture) from a collection of details (see for example, Lopez et al., 2008; Lang et al., 2016). This deficit in central coherence manifest with an overall greater focus on details, and therefore with a superior local processing of information, that however hinders a correct global processing, that is therefore poorer compared to healthy controls (Lopez et al., 2009; Lang et al., 2016).

Eshkevari et al., 2012). Conversely, participants reporting a high propensity to out-of-body experiences, autistic or body dysmorphic disorder (BDD) symptoms were found to be normally or less inclined to perceive the RHI (Paton eta la., 2012; Braithwaite et al., 2017; Kaplan et al., 2014).

Psychopathological symptoms have been found to modulate multisensory integration also during the SSDT. Specifically, previous research has shown that participants reporting higher levels of somatoform dissociation and physical symptoms tended to erroneously report perceiving a touch more often as compared to controls (Brown et al., 2010; Brown et al., 2012; see Chapter 2).

Following the previous studies of this thesis, in the current study (Experiment 4) we intended to further investigate whether ED and ED-related symptoms can explain differences in individual SSDT performance. Although ED symptoms did not relate to difference in SSDT performance per se in Experiments 1 and 2, participants presenting with high vs. low ED symptoms were found to be differently affected by vision of the body and self-focused attention when performing the task (Sacchetti et al., 2020; Sacchetti et al., 2021). Indeed, participants with high ED symptoms were found to be better able to correctly detect the touch during the SSDT when they were exposed to the vision of their face (Experiment 1) or their hand (Experiment 2) while performing the task. It was concluded that participants presenting with higher ED symptoms may be more strongly influenced by bodily related visual information in a multisensory context due to their "predisposition" to place a greater focus on visual aspects of the body (Arciero & Guidano, 2000; Arciero et al., 2004; Mazzola et al., 2014; see Chapters 3 and 4).

However, in these previous studies the samples sizes were fairly small for systematic correlational analyses between the SSDT outcome variables and self-report measures. Correlational analyses were therefore limited to the testing of specific hypotheses and were carried out as exploratory. In the current study (Experiment 4), we carried out a systematic correlational investigation between ED and ED-related symptoms and SSDT outcomes. Coherently with the observation that EDs are characterized by a greater reliance on visual information over other sensory modalities (Arciero & Guidano, 2000; Arciero et al., 2004; see Chapters 3 and 4), we expected participants presenting with higher ED symptoms to be more strongly influenced by the visual input of the light during the SSDT. In this respect, it should be noted that in previous studies of this thesis exposure to bodily-related visual information (i.e., vision of the body) was found to be associated overall with a better perception of touch during the SSDT (as indicated by results in HR and *d*') for high ED participants (see Chapters

3 and 4). Coherently, in the current investigation, we expected the presence of the light to induce a greater tactile accuracy (*d*') especially in those participants presenting with higher ED and ED-related symptoms.

6.2 Methods

6.2.1 Participants

Data from the one hundred and nineteen female participants, who were recruited for Experiments 1 and 3 (from the staff and student population at Liverpool John Moores University (LJMU) and from the general population), was used in the current study. Therefore, the study population consisted of two samples (Sample 1 from Chapter 3: n = 53; Sample 2 from Chapter 5: n = 66) recruited in the context of the two previous studies which were equivalent for inclusion and exclusion criteria.

Any individual previously clinically diagnosed with, or who had received treatment of any kind for body dysmorphic disorder (BDD) or eating disorders (EDs) were excluded from the study, as well as individuals who had a history of, or currently had any neurological and/or psychiatric disorder. Further exclusion criteria included un-correctable visual impairments, tactile impairments, skin conditions and pregnancy. To minimize heterogeneity of participants, and consistent with previous research on EDs, only females were recruited. All participants but two were right-handed as assessed using the Edinburgh Handedness Inventory (EHI; Oldfield, 1971).All participants were between 18 and 60 years of age (*M* = 28.34; *SD* = 11.30). An a-priory power analysis using G*Power 3.1.9.7 (Faul et al., 2009), indicated that overall a minimum sample of n = 92 was needed to detect a medium effect (f = .30) with 90% power, using Correlation point biserial model with alpha at .05 (two tailed). The sample size was expanded to 119 participants to increase statistical power.

According to the Helsinki declaration of ethical standards, the study was approved by the LJMU's Research Ethics Committee. All participants gave their informed consent to take part, and they were compensated for their time with a £5 shopping voucher or "participation points" for course credit for BSc Psychology students.

6.2.2 Material and measures

6.2.2.1 The Somatic Signal Detection Task (SSDT) – Face Version (Sacchetti et al., 2020). The face version of the SSDT was employed as described in Chapter 3 and Chapter 5. The experimental set-up is illustrated in Figure 6.1.

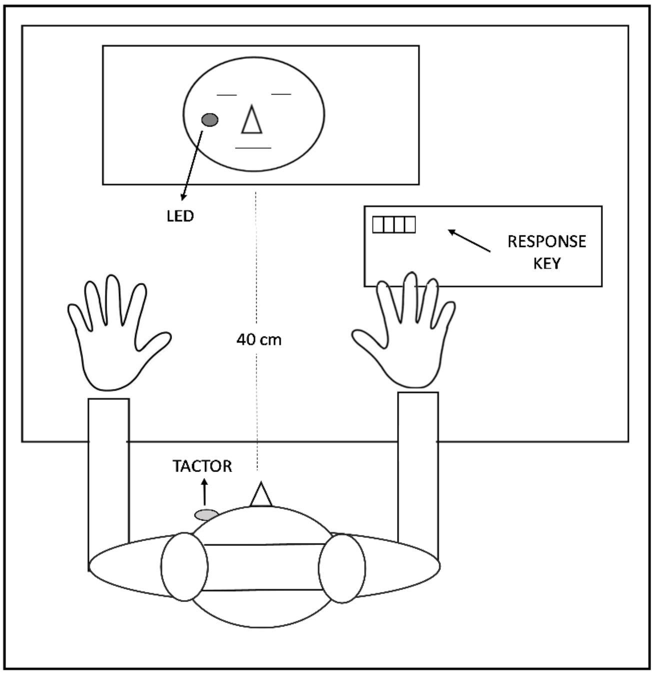


Figure 6.1. Schematic depiction of the experimental set-up during the SSDT (Self condition in Experiment 1, Pre condition in Experiment 5).

6.2.2.2 Physiological arousal. Electrodermal Activity (EDA) signals (i.e., the electrical activity of the skin resulting from changes in sweating) were recorded using the Biopac MP150 Systems (Version 4.2, Biopac Systems Inc., CA, USA), in two time windows: at baseline, prior to performing the SSDT, and during the SSDT. Two electrodes were placed on the index and the middle finger of the left hand. The electrodes were connected to the Biopac MP150 Systems and the Biopac Student Lab Pro 3.7 software, which was programmed to filter in real time EDA data with a band-pass of 0–35Hz. The sampling rate for data acquisition was set at 1000Hz.

EDA data were then used for calculating Skin Conductance Levels (SCLs), a measure of the background tonic EDA that is commonly used as an index of psychological arousal. Particularly, SCLs are deemed to reflect slow changes in the autonomic sympathetic nervous system (SNS) in response to stressors or emotional stimuli (Lang et al., 1993; Boucsein , 2012). Higher SCLs indicate a stronger activation of the SNS and therefore a higher level of arousal (Lang et al., 1993; Reed et al., 2019).

6.2.3 Self-report questionnaires

6.2.3.1 Dysmorphic Concerns Questionnaire (DCQ; Oosthuizen, Lambert & Castle, 1998). The DCQ is a 7-item self-report scale investigating body image preoccupation and dysmorphic concerns (see Chapter 2, Section 2.5.1)

6.2.3.2 Eating Disorder Inventory-3 (EDI-3; Garner, 2004). The EDI-3 is 91-item self-report questionnaire used to assess disordered eating symptomatology (see Chapter 2, Section 2.5.2).

6.2.4 Design and Procedure

6.2.4.1 General Procedure

At the beginning of each testing session, the experimenter took a photograph of the participant's face that was then presented on the computer monitor during all trials of SSDT as described in Chapter 3 and Chapter 5. Subsequently, electrodes were placed on participants' hand as previously explained for recording EDA.

Participants were then asked to complete the SSDT protocol (see below). After completing the SSDT, they were then administered each of the self-report questionnaires of the EHI and the DCQ. Sixty-six participants completed the EDI-3 together with the other two questionnaires (Experiment 3, Chapter 5), while fifty-three participants completed the EDI-3 prior to the testing session (Experiment 1, Chapter 3), due to differences in the experimental design of the two studies.

Height and weight were measured with a stadiometer and a scale for calculating the Body Mass Index (BMI; kg/m^2) using the NHS online calculator. The procedure lasted approximately 20-30 minutes.

6.2.4.2 SSDT Thresholding Procedure

The two studies employed two different thresholding procedures. For the first sample (n = 53) the intensity of the tactile pulse was calibrated manually using a staircase procedure (Cornsweet, 1962, see Chapter 2). Whereas for the second sample (n = 66) the threshold was found using the Parameter Estimation by Sequential Testing (PEST; Taylor & Creelman, 1967, see Chapter 2). For both samples the thresholding procedure took approximately 15 minutes.

Immediately after completing the thresholding procedure, participants started the experimental phase of the SSDT.

6.2.4.3 SSDT Experimental Phase

After completing the thresholding, participants performed the experimental phase of the SSDT as indicated in Chapter 3 and Chapter 5. Specifically, in Chapter 3 (Experiment 1) participants repeated the SSDT in three experimental conditions: while watching a photograph of their face (Self condition), a photograph of another person's face (Other condition) and a Scrambled face (Scrambled condition). The order of the three conditions was randomized between participants. For the current analyses, we selected only responses of participants during the Self condition. In Chapter 5 (Experiment 3) participants performed the SSDT while watching a photograph of their face twice: before (Pre) and after (Post) receiving a touch manipulation. For the current analyses, we selected only responses of participants before receiving the touch manipulation (Pre) to allow comparability between the two studies.

6.2.5 Statistical Analysis and Statistical Software

All Statistical analysis were performed using Statistica 8.0 (StatSoft Inc, Tulsa, Oklahoma software). All data are reported as Mean (M) and Standard Deviation (SD). A significance threshold of $p < .05$ was set for all effects. Effect sizes were estimated using Cohen's *d*.

A series of t tests were conducted to investigate whether there were differences in age, BMI, DCQ, SCLs EDI-3 subscales, between the Sample 1 and Sample 2 of the study population.

Pearson's and Spearman's correlations were run to explore the relationship between SSDT outcomes (HR, FA, *d'*, *c*), levels of physiological arousal (SCLs) and self-report personality characteristics (DCQ and EDI-3 subscales). No correction for multiple comparisons were carried out given the exploratory nature of these analyses.

6.3 Results

6.3.1 Data Processing

6.3.1.1 SSDT scores. HR, FA, *d'* and *c* outcomes of the SSDT were calculated as indicated in Chapter 2.

6.3.1.2 SCLs data extrapolation. EDA data were recorded continuously at baseline and while performing the SSDT. Baseline recordings lasted 1 to 5 minutes, while recordings during the SSDT lasted approximately 15 minutes. Each recording was visually inspected using Biopac (MP150) Systems, and artefacts were manually removed. SCLs were then extrapolated averaging across the EDA signal in each recording, giving two measures of SCLs per participant (baseline and SSDT SCLs). Baseline-corrected SCLs were then calculated (SSDT SC:s – baseline SCLs) and used for analyses.

6.3.2 Preliminary analyses

Demographics of the study population and scores in self-report questionnaires are presented in Table 6.1. Overall participants presented with scores in DCQ and EDI-3 subscales that were comparable to normative values in the general population (Clausen et al., 2011; Mancuso, Knoesen & Castle, 2010). The mean BMI was slightly higher than the upper cut-off for normal weight (>25) indicating that overall the study population was slightly overweight.

Preliminary analyses were performed to compare the two samples forming the study population in demographics, SCLs and self-report questionnaires (see Table 6.2). Results showed the two samples to be comparable in all measures with the exclusion of Age. Sample 1 was found to have a mean age significantly lower than Sample 2. However, we considered this difference not to hinder the possibility to merge the two samples as both samples had a mean age within the early adulthood age range (Peterson, 2013).

Table 6.1

Descriptive statistics for age, BMI, DCQ, and EDI-3 subscales

	Minimum	Maximum	M (SD)
Age	18	60	28.34 (11.30)
BMI	17	54	25.24 (6.11)
DCQ	0	17	6.14 (3.84)
Drive for Thinness	0	28	8.99 (7.98)
Body Dissatisfaction	0	38	14.59 (10.21)
Bulimia	0	29	5.79 (5.69)
Low Self-esteem	0	22	5.50 (5.24)
Personal Alienation	0	19	4.67 (4.22)
Interpers. Insecurity	0	21	7.27 (5.51)
Interpers. Alienation	0	21	5.93 (4.48)
Interoceptive Deficit	0	24	6.01 (5.55)
Emotional Dysreg.	0	19	4.71 (4.55)
Perfectionism	0	22	8.61 (5.13)
Ascetism	0	18	4.83 (4.34)
Maturity Fear	0	21	8.48 (4.57)
ED Risk	0	84	29.29 (20.19)

Table 6.2

Descriptive statistics for age, BMI, DCQ, SCLs, and EDI-3 subscales in each group, together with t-test statistics

	Sample1 (n = 53)	Sample2 (n = 66)				
	M (SD)	M (SD)	t	df	p	d
Age	23.94 (4.90)	31.88 (13.57)	4.40	117	.001	.77
BMI	25.60 (6.61)	25.76 (5.67)	1.03	117	.30	.03
DCQ	5.91 (3.62)	6.33 (4.02)	.60	117	.55	.11
SCLs	.64 (2.93)	.10 (2.29)	1.11	117	.27	.20
Drive for Thinness	8.43 (7.97)	8.02 (.99)	.68	117	.50	.07
Body Dissatisfaction	13.79 (10.67)	9.86 (1.21)	.76	117	.45	.52
Bulimia	5.21 (4.93)	6.26 (6.24)	-1	117	.32	.19
Low Self-esteem	5.23 (5.21)	5.71 (5.30)	.50	117	.62	.09
Personal Alienation	4.55 (4.75)	4.77 (3.79)	.29	117	.77	.05
Interpers. Insecurity	6.25 (5.02)	8.08 (5.79)	1.80	117	.07	.34
Interpers. Alienation	5.87 (4.83)	5.98 (4.22)	.14	117	.89	.02
Interoceptive Deficit	6.38 (4.89)	5.71 (5.91)	.65	117	.52	.12
Emotional Dysreg.	4.38 (4.44)	4.98 (4.65)	.72	117	.47	.14
Perfectionism	8.04 (4.84)	9.06 (5.35)	1.08	117	.28	.20
Ascetism	4.25 (4.04)	5.30 (4.53)	1.33	117	.19	.24
Maturity Fear	8.34 (4.47)	8.59 (4.69)	.30	117	.77	.05
ED Risk	27.43 (20.73)	30.79 (19.78)	.90	117	.37	.46

6.3.3 Correlational analyses: SSDT outcomes and arousal

No significant correlations were found between SCLs and mean scores in SSDT outcomes (HR, FA, *d'*, *c*) ($r \leq .13$; $p \geq .16$). Alongside, no significant correlations were found between SCLs and SSDT outcomes as assessed separately in light-present and in light-absent trials ($r \leq .16$; $p \geq .08$). However, *d'* showed a positive correlation with SCLs in light-present trials that was found to approach significance ($r = .16$; $p = .08$), suggesting that participants reporting higher SCLs were also more accurate in discriminating when the tactile pulse was administered from when it was not, and especially in light-present trials. Interestingly, although with no statistical significance, *d'* consistently showed positive correlation coefficients with SCLs (*d'*: $r = .13$; $p = .16$; *d'* Light: $r = .16$; $p = .08$; *d'* No Light: $r = .08$; $p = .40$), while FA showed consistently negative correlation coefficients with SCLs (FA*:* r = -.12; p = .18; FA Light*:* r = -.10; p = .27; FA No Light*:* r = -.10; p = .26). Therefore, participants reporting higher SCLs showed also a trend towards a more accurate perception of the tactile pulse (higher *d'*) and a weaker inclination to misperceive the tactile pulse when not administered (lower FA).

Lastly, no significant correlations were found between SCLs and change scores in SSDT outcomes between light-presents and light-absent trials ($r \leq .15$; $p \geq .13$), suggesting that SCLs were not related to the effects of the light on SSDT responses.

6.3.4 Correlational analyses: SSDT outcomes and self-report questionnaires

There was a significant correlation between the Interpersonal Alienation EDI-3 subscale and HR (r = .23; p = .012) as well as *d'*(r = .25; p = .006). The Interpersonal Alienation subscale of the EDI-3 represents an index of participants' propensity to engage in intimate relationships. Higher scores indicate participants' tendency to feel trapped and/or misunderstood in relationships. Therefore, overall results showed that participants with a lower propensity to engage in intimate relationships, were also better able to correctly detect the tactile pulse during the SSDT (HR) and to discriminate when the tactile pulse was administered from when it was not (*d'*). This was the case both in light-present trials (HR Light: r = .22; p = .017; *d'* Light: r = .24; p = .009) and in light-absent trials (HR No Light: r = .21; p = .018; *d'* No Light: r = .23; p = .011).

Moreover, there were significant negative correlations between the change score in c from light-absent to light-present trials and the Body Dissatisfaction EDI-3 subscale (r = -.25; p = .007) as well as the ED Risk Composite (r = -.18; p = .046) which encompasses also Body Dissatisfaction.

These results indicate that participants reporting higher levels of ED symptoms and specifically a greater dissatisfaction towards their body were also more strongly influenced by the presence of the light during the SSDT, and in particular tended to report more often perceiving the tactile pulse when the light was present regardless whether the tactile pulse was actually administered or not (i.e., a more liberal response criterion).

No other significant correlations were found between SSDT outcomes and EDI-3 and DCQ scores ($r \leq .13$; $p \geq .15$). Further correlational analyses were run to test whether participants' BMI may have influenced their responses during the SSDT. No significant correlations were found between SSDT outcomes and BMI ($r \leq -.04$; $p \geq .65$).

6.4 Discussion

The aim of the current study was twofold. On the one hand, we wanted to investigate, with increased statistical power, whether participants' physiological state, and specifically the level of arousal (i.e., SCLs) are related to responses during the SSDT. Specifically, we investigated whether increased SCLs were linearily associated with a more accurate perception of touch during the SSDT. On the other hand, we wanted to investigate the relationship between ED and ED-related symptoms (EDI-3 subscales) and SSDT performance. Specifically, we tested whether participants presenting with higher ED symptoms were more strongly influenced by the visual input of the light during the SSDT as indicated by increased HR and *d'* in Light trials.

In accordance with the results from Experiments 1 and 3, it was hypothesized that higher SCLs may be linearly associated with a more accurate tactile perception (higher HR and *d*') during the SSDT. Results of correlational analysis carried out in this study only partially confirmed this hypothesis. Specifically, participants reporting higher SCLs also had more accurate perception of touch (*d*') in trials during which the light was administered. Although, this effect was found only to approach significance. Alongside, in both light-present and light-absent trials, SCLs tended to be associated with a more accurate perception of touch (*d*') and with a lower tendency to falsely report touch when not administered (FA). However, these correlations showed only a trend in participants which did not reach significance.

Therefore, our hypothesis was only partially confirmed by the data. There seems to be a trend between the level of SCLs and SSDT performance, overall suggesting that higher SCLs are partially associated with a more accurate perception of touch during the SSDT. However, this association was stronger in the single studies of this thesis, in which the experimental manipulation was taken into account (see Chapters 3 and 5). In other words, changes in in SCLs secondary to experimental manipulations have been found to be explanatory of subsequent individual differences in SSDT responses. However, when considering SCLs regardless of the experimental manipulation (such as within the same experimental condition as we did in the present analysis) this association weakens. Therefore, the current results suggest that higher SCLs may be better conceptualized as mediators of the link between the experimental manipulation and SSDT responses, rather than being associated to SSDT responses in a linear fashion. However, in the single studies of Experiment 1 and 3 it was not possible to test mediational models due to insufficient sample sizes. Further research will be therefore needed to validate this interpretation of results.

This is however partially in agreement with previous research that has linked higher arousal levels to a greater perceptual accuracy. Specifically, it was proposed that higher arousal can induce a stronger focus towards once's own body and therefore enhance perceptual accuracy (Wegner & Giuliano, 1980; Salovey, 1992; Liao & Masters, 2002).

The second aim of this study was to systematically investigate the relationship between ED and ED-related symptoms and SSDT performance. In accordance with previous literature that linked EDs with a stronger focus on visual information (Arciero & Guidano, 2000; Arciero et al., 2004; see Chapters 3 and 4), we expected ED and ED-related symptoms to be associated with a stronger effect of the light on SSDT responses. Specifically, given the findings of previous studies of this thesis (see Chapters 3 and 4) in which participants presenting with higher level of ED symptoms were more accurate in perceiving the touch during the SSDT (*d'*) when bodily-related visual information were administered, in the current analysis we expected the visual input of the light to induce a greater increase in tactile accuracy (*d'*) especially in those participants presenting with higher levels of ED and ED-related symptoms. .

Partially confirming our hypothesis, it was found that participants reporting higher level of ED symptoms and specifically a greater body dissatisfaction tended also to report more often perceiving the touch during the SSDT when the light was present. However, this effect was found regardless of whether the tactile pulse was administered or not. In other terms, the presence of the light induced high symptomatic individuals to report touch more often not only in terms of correct reports of touch (HR) but also false reports of touch (FA). Therefore, the presence of the light did not affect tactile accuracy (*d'*) in high symptomatic participants, as hypothesized. Conversely, the presence of the light was found to shift high symptomatic participants' response criterion towards are more liberal criterion. In other words, in the presence of the light, high symptomatic participants were more likely to report a tactile signal as present in an ambiguous situation, such as the SSDT, across touch-present and touch-absent trials, therefore indicating a disinhibition in perceptual decision-making.

Overall these results support the claim that EDs are characterised by a greater focus on visual information over other sensory information. This claim has been primarily formulated on the basis of clinical observation underlying how ED patients manifest an excessive focus on the visual aspects and physical appearance of their bodies (Arciero & Guidano, 2000; Arciero et al., 2004). Further research in experimental psychology expanded this observation also to the context of primary perceptual processes and multisensory integration. For example, it has been suggested that ED patients place a greater focus on visual information when performing the RHI, leading them to a stronger experience of the illusion when compared to healthy controls (Mussap & Salton, 2006; Eshkevari et al., 2012; Caglar-Nazali et al., 2014;

See Chapter 1).

However, together with the results of previous studies of this thesis, we have found a discrepancy between bodily-related and non-bodily related visual information in influencing multisensory integration during the SSDT. Indeed, vision of the body was found to lead to a better perception of touch during the SSDT in high symptomatic participants (as indicated by results in HR and *d'* in Experiments 1 and 2). Conversely, in the current examination, the visual input of the light (a non-bodily related visual information) was found to induce greater reports of touch in high symptomatic participants both in correct and in incorrect trials. It is therefore possible that bodily-related and non-bodily-related information lead to different effects on touch perception and multisensory integration in high symptomatic participants. Specifically, bodily related information may increase correct report of touch, and therefore perceptual accuracy, and non-bodily related information may induce a non-specific increase in touch reports, and therefore a disinhibition in perceptual decision-making.

Interestingly, results showed also that participants with a lower propensity to engage in intimate relationships, were also better able to correctly detect the tactile pulse during the SSDT (HR) and to discriminate when the tactile pulse was administered from when it was not (*d'*). scores on the Interpersonal Alienation subscale of the EDI-3, which is an index of participants' propensity to engage in intimate relationships, was found to be positively correlated with HR and *d'*. Although no specific hypotheses were formulated for this subscale, results of this study can inform future analysis on the effects of personality traits on SSDT performance. In this respect, we can hypothesise that participants that are less inclined to be intimate with other people define stronger perceptual boundaries between the self and the environment (non-self). In turn, this may induce these individuals to sharpen the senses that are responsible for detecting non-self, external information (i.e., exteroceptive information), that may be perceived as a threat to the solidity of the self. However, this is merely a speculative interpretation of the results, as to our knowledge, no prior studies have investigated the link between individuals' propensity to engage in intimate relationships and multisensory integration/primary perceptual processes. It will be therefore the scope of future studies to further investigate this new direction of research.

Results of this study are not without limitations. In this respect, it should be noted that the study population here analysed comprised two different samples of participants that were tested in different context depending on the respective experimental design. Accordingly, the two sample were heterogenous in terms of the thresholding procedure they underwent to before performing the testing phase of the SSDT. Moreover, it should be noted that while data extracted from Experiment 3 (Chapter 5) corresponded to the first experimental condition for all participants, in Experiment 1 (Chapter 3) the order of the experimental conditions was randomised across participants. Therefore, in the data extracted from Experiment 1 some participants performed the condition here analysed at the beginning of the testing session, while others at the end. Although, a prior study by McKenzie and colleagues (2010) demonstrated participants' SSDT responses to be constant over time and not to be influenced by learning processes. Therefore, the order according to which participants performed the different experimental conditions in Experiment 1 should not have influenced the results of this examination. Lastly, it should be noted that the correlational coefficients found in the current analyses were often small, and therefore their interpretation should be done cautiously, and further research should be carried out to expand on these research questions.

In conclusion, overall results of this study suggested that SCLs may mediate the relationship between experimental manipulations and changes in SSDT responses. Coherently, future research involving the SSDT should consider measuring SCLs as possible explanatory variable of results. Findings of this investigation also expanded on the results of previous studies investigating the relationship between ED symptoms and SSDT outcomes. Specifically, it was found that the presence of the light induced an increase in participants' reports of touch from light-absent to light-present trials, that was stronger for those participants reporting higher ED symptoms. This is in line with the prior observation that ED patients tend to place a greater focus to visual information over other sensory information. This is also partially in line with previous results presented in this thesis, indicating vision of the body to induce an increase in participants reports of touch in high ED participants. However while vision of the body, and therefore exposure to bodily-related visual information, was found to increase selectively correct reports of touch; the input of the light, and therefore exposure to a non-bodily related visual information, was found to induce an increase in the overall reports of touch (correct and incorrect). Therefore, we can hypothesize the existence of a differential effect of bodily related and non-bodily related visual information on multisensory processes in the context of EDs, with the former influencing perceptual accuracy and the latter influencing the response criterion used by participants to detect the touch.

Overall conclusions about the results found in the different studies of this thesis are presented in Chapter 7.

Chapter 7

General Discussion

7.1 Introduction

The main aim of the present thesis was to investigate perceptual processes and multisensory integration in the context of EDs. In order to do so, experimental behavioural methodologies were used. Specifically, as outlined in Chapter 2, the main paradigm used across the different studies of this thesis is the SSDT (Lloyd et al., 2008) combined with physiological measures of arousal (including SCLs and HRV).

Re-cap of aims:

(i) The first aim was to investigate whether body misperception in EDs encompasses also alterations in the multisensory integration of exteroceptive visuo-tactile information. Previous research on multisensory integration in EDs has shown this clinical population to be characterised by impairments in the integration of visuo-tactile-proprioceptive and visuo-haptic-proprioceptive information (Case et al., 2012; Eshkevari et al., 2012; Keizer et al., 2014). Here, the relationship between ED symptoms and exteroceptive visuo-tactile multisensory integration, as assessed using the SSDT, were investigated (Chapter 3, 4 and 6).

(ii) The second aim was to investigate whether exposing participants to the vision of their body would alter multisensory integration processes during the SSDT, and whether this effect would differ in high versus low ED symptomatic participants. Participants with different levels of ED symptoms performed the SSDT while exposed to the vision of their face (Chapter 3) or their hand (Chapter 4) in comparison to control conditions.

(iii) A third aim was to test whether: a) interoceptive affective stimuli (i.e., affective touch) altered the integration of exteroceptive visuo-tactile information as measured by the SSDT; b) whether the effects of affective touch on SSDT performance can be informative for the development of treatments targeting body misperception and abnormal multisensory integration in EDs (Chapter 5).

(iv) A fourth aim of was to investigate whether physiological arousal, as assessed using SCLs, explained individual differences in SSDT performance (Chapters 3, 4 and 6).

In this final Chapter, results of the studies are summarized and discussed in the framework of the previous literature outlined in Chapter 1. Specifically, the main findings are reviewed in order to highlight their contribution to the general understanding of body misperception in EDs and related clinical implications. Methodological limitations and future directions are also discussed.

7.2 Overview of the findings

In Chapter 3 (Experiment 1), differences in SSDT performance between participants presenting with low vs. high ED symptoms were tested. Moreover, it was investigated whether exposure to the vision of one's own face would alter SSDT performance differently for participants presenting with low vs. high ED symptoms. To this aim, participants performed the SSDT in three conditions: while looking at a picture of their own face, another female face, and a scrambled face. Throughout the testing physiological arousal was measured as assessed by heart rate variability (HRV) and skin conductance levels (SCLs). The experimental manipulation was found to differentially affect high vs. low ED participants. Indeed, in high ED participants vision of their own face was associated with an increase in SCLs accompanied by an increase in tactile accuracy during the SSDT. Conversely, for the low ED group, SCLs and tactile accuracy during the SSDT were higher in the control conditions (vision of another female face and the scrambled face). Therefore, vision of once' own face was found to enhance tactile accuracy during the SSDT selectively in high ED symptomatic participants. This suggested that in those with high ED symptoms, attention to the bodily self may exacerbate a predisposition to focusing on external rather than internal bodily information. Higher SCLs were hypothesized to be a possible mediator linking the experimental manipulation to a greater tactile accuracy.

In Chapter 4 (Experiment 2), replicability of the results of the previous study was tested by targeting a different body part alternative to the face. Specifically, it was investigated whether exposure to the vision of one's own hand would alter SSDT performance differently in participants presenting with low vs. high ED symptoms. To this aim, participants performed the SSDT while their hand was visible (non-informative vision), and again while their hand was hidden from sight (no vision). In agreement with the results of Experiment 1, vision of the hand had a different effect on SSDT performance according to participants' levels of ED symptoms. Specifically, high symptomatic participants were found to be better able to correctly detect the touch during the SSDT when their hand was visible. Conversely, for low ED participants, vision of the body was linked to a greater effect of the light in inducing false reports of touch. These results were consistent with results of Experiment 1, supporting the hypothesis that in those with high ED symptoms, vision of the body (either the face or the hand) may exacerbate a predisposition to focusing on external bodily information, such as touch.

In Chapter 5 (Experiment 3), the effects of an off-line manipulation alternative to vision of the body on SSDT performance was investigated. In particular, the experiment aimed to test the effects of receiving an affective touch manipulation targeted to preferentially stimulate CTs, as compared to a neutral (non-affective) touch manipulation on subsequent SSDT performance. Participants performed the SSDT twice before and after receiving the touch manipulation. Throughout the testing, SCLs were measured as an index of physiological arousal. Participants also self-reported their mood before and after receiving the touch manipulation. Self-reported ED symptoms, and dysmorphic disorder symptoms were also measured. Affective touch led to an increase in tactile accuracy, as indicated by less false reports of touch and a trend towards a higher tactile sensitivity during the subsequent SSDT. Conversely, non-affective touch was found to induce a partial decrease in the correct detection of a vibrotactile stimulus, possibly due to a desensitization of skin mechanoreceptors. Both affective and non-affective touch induced a more positive mood and higher SCLs in participants. However, the increase in SCLs was greater after affective touch. It was concluded that receiving affective touch may increase perceptual accuracy and awareness by enhancing the sense of a bodily self. Similar to the results of Experiment 1, higher SCLs are suggested to be a possible mediator linking affective touch to a greater tactile accuracy. Moreover, participants reporting higher ED symptoms were found to be more strongly influenced by the affective touch manipulation, as indicated by a greater tactile accuracy during the subsequent SSDT.

In Chapter 6 (Experiment 4), some of the data from Experiment 1 and 3 was pooled to further assess the relationship between SCLs, ED and ED-related symptoms, and tactile accuracy during the SSDT. Linear correlational analyses were performed. Results showed a trend for SCLs to be partially associated with a more accurate perception of a vibrotactile stimulus during the SSDT. However, these results were found only to approach significance. Overall, it was suggested that SCLs may be not linearly associated with tactile accuracy during the SSDT, but may be better conceptualized as a possible mediator between experimental manipulations and SSDT outcomes. Moreover, it was found that the presence of the light during the SSDT induced an increase in participants' reports of touch (from light-absent to light-present trials), that was stronger for those participants reporting higher ED symptoms. This is in line with the prior observation that ED patients tend to place a greater focus to visual information over other sensory information. This is also partially in line with previous results presented in this thesis, indicating vision of the body to induce an increase in reports of touch in high ED participants.

7.3 Interpretation of results and future directions

7.3.1 Understanding the effects of ED symptoms on multisensory integration

As reported in Chapter 1, EDs have been linked to profound alterations in body perception that manifest in different sensory modalities (Gaudio et al., 2014; Cuzzolaro & Fassino, 201). Coherently, body misperception in EDs has been found to encompass disruptions in the integration of multisensory information. Specifically, EDs have been linked to alteration in the integration of visuo-tactile-proprioceptive information as indicated by results in research using the RHI. Indeed, ED patients have been found to be more inclined to perceive this bodily illusion as compared to healthy controls both in terms of a stronger subjective experience of ownership of the fake hand (Eshkevari et al., 2012; Keizer et al., 2014; Zopt et al., 2016) and in terms of a more pronounced proprioceptive drift (Eshkevari et al., 2012; Keizer et al., 2014).

The authors interpreted these results suggesting that ED patients may have an increased sensitivity to the visual aspects of body perception and a decreased sensitivity to proprioceptive information, which in turn determines alterations in visuo-tactile-proprioceptive multisensory integration, and ultimately a stronger illusion in the context of the RHI (Eshkevari et al., 2012; Caglar-Nazali et al., 2014). These results were partially replicated using the Full body Illusion (FBI; Slater et al., 2010; Keizer et al., 2016), a paradigm similar to the RHI that targets the whole body of participants, rather than only their hand, thanks to the use of virtual reality (see Chapter 1, Section 1.4 for more information). Thus, these results indicated alterations in visuo-tactile-proprioceptive multisensory integration in EDs are not specific to the hand, but generalizable to the whole body (Keizer et al., 2016).

ED patients have been found also to have alterations in the integration of visuo-haptic-proprioceptive information as indicated by results in research using the Size-Weight Illusion (SWI; Case et al., 2012). Indeed, in Case and colleagues' study (2012) patients with AN were significantly less susceptible to the illusion than healthy controls (see Chapter 1, Section 1.4 for details). In accordance with the interpretation of results in research using the RHI, the SWI results suggested that in a multisensory context AN patients placed a greater focus on visual signals rather than on somatosensory ones (Risso et al., 2020).

The first aim of this thesis was to assess whether body misperception in EDs also encompasses also alterations in the multisensory integration of exteroceptive visuo-tactile information as assessed using the SSDT. Participants presenting with low vs. high ED symptoms were found not to show between groups differences in their SSDT performance. However, when using correlational analysis it was found that the presence of the light during the SSDT induced an increase in participants' reports of touch from light-absent to light-present trials that was stronger for those participants reporting higher ED symptoms.

This is in line with the prior observation that ED patients tend to place a greater focus to visual information over other sensory information (i.e., visual capture; Risso et al., 2020; Eshkevari et al., 2012; Case et la., 2012). In the context of the SSDT, this tendency manifested with participants presenting with higher levels of ED symptoms placing a greater focus on the presence of the light flashing. This, in turn, lead high ED participants to rely more strongly on visual information (i.e., the light) in their decision making about the detection of tactile stimuli. As during the SSDT the presence of the light is not indicative of the presence of a tactile stimulation (i.e., the light is equally administered in touch-present and touch-absent trials), visual capture in high symptomatic participants resulted in a more liberal response criterion rather than in an increase in tactile accuracy. In other terms, the presence of the light led high symptomatic participants to report more often the tactile pulse both in touch-present and in touch-absent trials, therefore increasing both correct and incorrect reports of feeling the touch.

However, it should be noted that this relationship between ED symptoms and the effects of the light on touch reports during the SSDT was fairly weak. Indeed, as previously mentioned, while there was a significant correlation between ED symptoms and change scores (between light-absent and light-present trials) in response criterion, this relationship was found not to be strong enough to result in between groups differences in the single studies of this thesis (Experiments 1 and 2). In this regard it should be noted that the SSDT assesses the integration of sensory information that are exclusively exteroceptive: visual and tactile. Conversely, other paradigms used in previous research to assess multisensory integration in EDs (i.e., the RHI and the SWI) implicate integrating exteroceptive (visual and tactile) and interoceptive information. As mentioned in Chapter 1 (Section 1.4), body misperception in EDs has been linked also to an impairment in the elaboration of interoceptive information, with ED patients presenting with a decreased focus on interoceptive signals (Fassino et al., 2004; Mehling et al., 2009; Arciero et al., 2004; Mazzola et al., 2014). Therefore, it could be the case that body misperception in EDs manifests in aberrant multisensory integration processes more strongly when both the exteroceptive and the interoceptive modalities are implicated. Conversely, multisensory integration would remain more intact when exteroceptive information only are to be integrated.

In accordance with this hypothesis are the results of a recent study conducted by Risso and colleagues (2020) with the aim to analyze multisensory integration processes in EDs. Specifically, they investigated visual, tactile and bimodal perception of elliptical shapes in a group of patients with AN and healthy controls, finding that AN patients did not differ significantly from healthy controls in the way they integrated visuo-tactile exteroceptive information during the task. Importantly, also in this case the task used did not involve the elaboration of interoceptive information, but only the integration of exteroceptive information, which, according to our hypothesis, may remain fairly intact in EDs. However, future research should test this hypothesis by assessing multisensory integration in EDs using different tasks involving different sensory modalities (including interoceptive and exteroceptive modalities), and comparing participants performance across these different tasks. For example, exteroceptive processes could be assessed using the two-point discrimination task, during which participants are asked to judge the distance between two tactile stimuli (e.g., Keizer et al., 2011; 2012), and the grating orientation task, during which participants are asked to estimate the orientation of fine grating patterns (e.g., Taylor-Clarke et al., 2004). Whereas interoceptive abilities could be assessed using a heartbeat perception task (Schandry, 1981) and a respiratory perception task (Murphy et al, 2017), which require participants to focus on their heartbeat and breathing sensations. Additionally, the assessment of interoception could include the evaluation of participants' responses to CT-modulated affective touch (i.e., the perception of pleasantness; Crucianelli et al, 2013).

Results of this thesis can be compared with previous research using the SSDT in patients reporting somatoform symptoms (see Chapter 2). Previous studies have shown that participants experiencing higher levels of somatoform symptoms are also more inclined to report false sensations of touch during the SSDT (Brown et al., 2010; Brown et al., 2012, see Chapter 2). According to the somatic interference hypothesis, this higher tendency to misperceive the touch was interpreted as stemming from the fact that patients with Somatoform symptoms show a hypervigilance towards inner body signals, that were therefore mistaken for external touch during the SSDT. Coherently, patients with somatoform symptoms have been described as presenting with a heightened awareness of the body that causes an increased salience of benign bodily sensations that are then mistaken for evidence of serious illness (Mehling et al., 2009; Brown et al., 2012). Conversely, ED patients have been characterized as having an attenuated focus on interoceptive signals that are usually overridden by other sensory information (Fassino et al., 2004; Mehling et al., 2009). Therefore, in the context of EDs the results of the studies may be interpreted as not driven by a confusion of internal signals as external (as in the somatic interference hypothesis) but rather to be driven by visual capture.

7.3.2 The effect of vision of the body on body misperception in EDs

The second aim was to investigate whether participants with different levels of ED symptoms would be differently affected by exposure to the vision of their body when performing the SSDT. It was found that participants presenting with high ED symptoms were more accurate in perceiving the touch during the SSDT when exposed to the vision of both their face and their hand. Vision of the body was therefore proposed to enhance tactile accuracy during the SSDT in high symptomatic participants. More specifically, vision of the body was proposed to enhance self-focused attention in high ED participants, and therefore their level of awareness and accuracy toward incoming sensory signals.

Studying the effects of vision of the body on perceptual processes in the context of EDs is particularly important considering that exposure to one's own image of the body is part of different protocols for the treatment of EDs, such as body exposure and mirror therapy (Vocks et al., 2008; Díaz-Ferrer et al., 2015). These protocols have been shown to be effective in reducing body dissatisfaction at the end of treatment (Moreno-Domínguez et al., 2012; Díaz-Ferrer et al., 2015). However, the somatosensory processes involved in these protocols have not been explained up to date.

Prior to the research reported here, only one study analysed the effects of vision of the body on interoceptive accuracy in a sample of AN patients (Pollatos et al., 2016). Participants completed an HPT in two conditions: while viewing a photograph of themselves, or another person as a control condition (Pollatos et al., 2016). Contrary to prior results in healthy controls (Ainley et al., 2012; 2013; See Chapter 1), this study showed AN patients to have lower interoceptive accuracy when viewing the photograph of themselves, as compared to another person. Therefore, while in the studies reported here vision of the body was found to increase perceptual accuracy, in the study carried out by Pollatos and colleagues (2016) vision of the body led to a decrease in perceptual accuracy.

In this respect, it should be noted that the two streams of research employed two different tasks for testing body perception, tapping into different components of somatic perception. While the HPT employed by Pollatos and colleagues (2016) assesses interoception, the SSDT used in this thesis assess exteroceptive visuo-tactile perception. Therefore, it could be the case that vision of the body and self-focused attention have a differential effect on participants with high ED symptoms depending on the task that they are required to perform.

It is worth noting that body perception in EDs has been linked to a preferential reliance on visual appearance and exteroceptive information (sensory data deriving from the outer world) over perception from inside the body (Mehling et al., 2009). Accordingly, EDs have been described in phenomenological psychology as having an "outward dispositional affective style", which means that ED patients anchor their sense of self to a greater extent to external bodily reference points in the service of visceral and internal somatic information (Arciero & Guidano, 2000; Arciero et al., 2004; Mazzola et al., 2014). At a higher behavioural level, this outward dispositional style manifest itself with ED patients placing a greater focus on their external physical appearance and on the way they are seen by other people (i.e., by external observers). Whereas they tend to perceive their own feelings (i.e., internal somatic sensations) and point of view (i.e., the way they see themselves regardless external observers) as secondary and/or abscure to read (Arciero & Guidano, 2000; Arciero et al., 2004; Mazzola et al., 2014).

Following this line of reasoning, it was proposed that enhancing self-focused attention through vision of the body in high ED participants may exacerbate their predisposition to place more focus on exteroception rather than interoception, ultimately leading to better performances in tasks where they are required to elaborate exteroceptive information (such as the SSDT) and worse performances in tasks assessing interoception (such as the HPT).

To test the validity of this hypothesis further research in clinical samples will be needed to test the effects of vision of the body on a battery of tasks assessing the perception of both exteroceptive and interoceptive information. If this hypothesis will be proven to be true, this would provide with informative data for treatment directions in enhancing body perception in EDs. Specifically, it is possible that recovery from EDs could benefit from a partial shift of focus from external to internal bodily information, therefore leading to a rebalance between exteroception and interoception. This rebalance could be pursued by the means of different treatment approaches: from mindfulness protocols aiming to increase awareness on internal bodily sensations to psychodynamic approaches aiming to modify the patient's relationship with the body through talking therapy (Abbate-Daga et al., 2015; Abbate-Daga et al., 2016; Cuzzolaro & Fassino, 2018). Longitudinal studies assessing exteroceptive and interoceptive processes in EDs during treatment and recovery will be necessary to further investigate this topic.

Results reported here, together with prior research on the effects of vision of the body on perceptual processes in the context of EDs (Pollatos et al., 2016), are also informative for better understanding existing treatments involving exposing patients to the vision of the body as part of their protocol, such as mirror therapy (see Chapter 1). Indeed, it is argued here that vision of the body can exacerbate ED patients' disposition to focus on external (exteroceptive) information to the detriment of interoceptive signals. Following this reasoning, vision of the body as an intervention seems unlikely to help with rebalancing unbalanced exteroceptive/interoceptive perceptual processes in EDs. Therefore, it could be the case that mirror therapy has beneficial effect only on cognitive aspects of body perception (e.g., encouraging body acceptance) but not perceptual aspects of body perception in EDs (e.g., rebalancing exteroceptive/interoceptive perception).

7.3.3 Body misperception in EDs and affective touch

The third aim was to investigate the effects of affective touch on multisensory processes during the SSDT. Affective touch, that is a low force/velocity stroking touch which preferentially stimulates a population of unmyelinated mechanosensory afferents – CTs, is considered as an interoceptive modality involved in the motivational aspects of social physical interactions (Vallbo et al., 1999; Essick et al. 2010; Croy et al. 2016, see Chapter 1, Section 1.4). Of relevance here is that the physiological substrates of affective touch have been linked to a brain network (i.e., posterior and anterior insula) involved in body awareness and multisensory integration (McGlone et al., 2012; McGlone et al., 2014; Morrison, 2016; Gazzola et al., 2012; see Chapter 5). In the current investigation we aimed to analyse whether affective touch could enhance body awareness when performing the multisensory task of the SSDT.

It was found that receiving affective touch induced a subsequent increase in tactile accuracy during the SSDT as compared to a neutral, non-affective touch. These results open the way to future research on a possible use of affective touch as a clinical tool for enhancing perceptual accuracy and multisensory integration in those clinical conditions that manifest aberrant perceptual processes, such as EDs.

Previous studies have shown affective touch to be successful in enhancing the sense of body ownership in neuropsychological conditions such as asomatognosia and somatoparaphrenia (van Stralen et al., 2011; Gentsch et al., 2016; Jenkinson et al., 2020). A future stream of research should therefore investigate whether the use of affective touch as an intervention can be expanded also to EDs to enhance perceptual accuracy and multisensory perceptual processes. Supporting this hypothesis, prelimiary correlational analyses performed in this thesis (see Chapter 5) showed that participants presenting with higher ED symptoms reported a greater increase in tactile accuracy (during the SSDT) after receiving affective touch. Although exploratory (due to a scarse sample size), these results suggest that affective touch may indeed increase perceptual accuracy in ED patients. A further step to test this hypothesis would be to replicate the design of Experiment 3 (testing the effects of affective touch vs. neutral touch on subsequent SSDT performance) in two samples of participants presenting with high vs. low ED symptoms.

While no studies up to date have tested a possible clinical use of affective touch in the context of EDs, it is worth mentioning that prior research has analysed how affective touch is perceived by ED patients as compared to healthy controls. In this respect, AN patients have been found to exhibit an abnormal perception of affective touch with significantly lower ratings of pleasantness compared to healthy controls (Crucianelli et al., 2016; Crucianelli et al., 2020). Reduced pleasantness rating after affective touch have been found also in recovered AN patients, suggesting this effect to be an enduring trait of this clinical population rather than an artefact secondary to acute conditions (Crucianelli et al., 2020). Following this line of research, it has been also shown that before receiving affective touch, AN patients display a reduced anticipation of predicted pleasantness of touch, as well as a reduced anticipatory neural response localized to the ventral mid-insula (Crucianelli et al., 2020; Bischoff-Grethe et al., 2018). Taken together, these findings suggest that in AN there is an attenuated prediction and interpretation of pleasantness of touch. In support of this view, it was proposed that ED patients may have a general dis-investment in social and affiliative behaviours that manifest also in primary perceptual processes that are involved in these behaviours, such as pleasant touch.

Thesse results partially question the validity of using affective touch as a clinical tool for ED patients. In this respect, it could be hypothesized that ED patients may be less susceptible to the use of affective touch as an intervention as compared to other clinical populations. However, the previously mentioned exploratory correlational analyses run in this thesis, and indicating ED symptoms to correlate with a stronger increase in tactile accuracy duirng the subsequent SSDT, seem to suggest otherwise (see Chapter 5). Indeed, these results suggest that ED patients may indeed be responsive to affective touch, and that affective touch may increase perceptual accuracy in this clinical population.

Moreover, it is important to mention that in previous research assessing affective touch responses in the context of EDs, touch manipulations were performed only on the day of testing and not in a prolonged manner. Therefore, up to date it is still uncertain what the response to affective touch in EDs may be over an extended period of time. As affective touch is an interoceptive modality (see Chapters 1 and 5), repeated administration over a prolonged time period may be helpful in shifting patients perceptual focus from exteroceptive to interoceptive information. In turn, this shift of focus may contribute in rebalancing multisensory processes in EDs. To address this hypothesis further cross-sectional and longitudinal research with ED patients will be needed.

7.3.4 The relationship between physiological arousal and SSDT performance

The fourth aim was to establish whether participants' state during the SSDT, and specifically the level of physiological arousal, could influence their performance during the SSDT. Physiological arousal was operationalized as Heart Rate Variability (HRV; Experiment 1) and Skin Conductance Levels (SCLs; Experiments 1, 3 and 4). In the studies reported here no significant results were found in regard to HRV. Conversely, evidence was found indicating a relationship between SCLs and perceptual accuracy during the SSDT, with higher SCLs being related to a greater perceptual accuracy during the SSDT. Overall, results of this thesis indicated that a higher level of arousal, as assessed using SCLs, may play a role in determining participants SSDT performance.

In this regard, it is worth noting that previous research has also linked higher arousal to a greater perceptual accuracy. Specifically, it was proposed that higher arousal (regardless of the emotional valence associated) can increase participants' attention towards incoming perceptual information. This in turn, would lead to a subsequent increase in perceptual accuracy (Wegner & Giuliano, 1980; Salovey, 1992; Liao & Masters, 2002).

However, this relationship between SCLs and SSDT performance was found to be stronger when analysing changes in SCLs and SSDT performance, due to experimental manipulations in each single study (Experiments 1 and 3). Conversely, when analysing the linear relationship between SCLs and SSDT performance without considering experimental manipulations (i.e. analysing the data of one experimental condition only), the effects found in the single studies levelled down (Experiment 4). It was therefore concluded that SCLs and tactile accuracy during the SSDT at baseline may not be linearly associated. Whereas changes in SCLs secondary to an experimental manipulation may have a stronger relationship with subsequent changes in participant' SSDT responses. In other terms, SCLs (as an index of a higher arousal) may be better conceptualized as a mediator connecting experimental manipulations to the SSDT performance[5]. Importantly, in the individual studies (Experiments

[5] This reasoning holds true regardless of the level of ED symptoms reported by participants, in the sense that the level of participants' ED symptoms was not taken into account when analysing the relationship between physiological arousal and SSDT outcomes. Therefore, we are not suggesting that SCLs mediate the relationship

1 and 3) it was not possible to test mediational models due to insufficient sample sizes. Therefore, further research with larger samples will be needed to test mediational models using the experimental manipulation as predictor, indices of arousal such as SCLs as mediator, and SSDT performance as outcome variable.

7.4 Methodological limitations

7.4.1 Study population

The experimental samples selected in the different studies consisted of female participants only. The choice to limit the study population to females was supported by the fact that EDs have been shown to have different manifestations in female and male cohorts (Stanford & Lemberg, 2012). However, while the literature on EDs is mostly based on studies on females, less is known about EDs in male populations (Stanford & Lemberg, 2012). This gap in knowledge is also driven by the fact that EDs are more prevalent among females as compared to males (APA, 2013). As a result, interest on EDs on males has developed only fairly recently (Murray et al., 2017). Using female samples across the different studies of the thesis had therefore the advantage to allow for comparability of results with previous literature and among the different studies of the thesis themselves. However, it would be worthwhile to investigate whether the findings of this thesis apply to males in future studies.

Moreover, it should be noted that all studies sampled a population of healthy subjects in which levels of subclinical ED symptoms were measured. Although this choice allows to control for the presence of confounding variables that characterize research in clinical samples (i.e., cognitive and perceptual impairments secondary to abnormal Body Mass Index (BMI), starvation, or medication treatment), it would be worthwhile to investigate whether the results of this study could be generalized to a clinical populations of ED patients.

Lastly, it is worth noting that in Experiment 1 and 2 participants presenting with a higher rate of ED symptoms were also found to report a higher BMI. This is consistent with some studies that showed higher BMI levels to be predictive of future onset of an ED (Killen et al., 1996). However, other studies failed to replicate these results by showing no influences or even an inverse relationship between BMI and ED risk (Patton et al., 1999; Stice et al., 2017). The role of the BMI in predicting ED onset as well as its influence on perceptual processes should be therefore further investigated.

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between ED symptoms and SSDT outcomes but rather the existence of a relationship between changes in arousal secondary to experimental manipulations and SSDT outcomes.

7.4.2 The SSDT paradigm

The main paradigm used across the studies was the SSDT, a measure for the assessment of visuo-tactile multisensory integration. As explained in Chapter 2, in comparison with other measures used in the previous literature (such as the RHI; Botvinick & Cohen, 1998), the SSDT can be considered a more objective instrument for the assessment of multisensory integration. Indeed, during the SSDT participants are unaware of whether or not their experience of touch is genuine (i.e., whether they have made a false alarm or hit), therefore it is less likely that demand characteristics influence their performance. Conversely, during the RHI, participants are aware of a distortion in their experience of an existing touch. Accordingly, it has been argued that participants' responses during the RHI can be driven by suggestibility or demand characteristics (Marotta et al., 2016; Lush, 2020).

Moreover, it should be noted that, because the SSDT involves detecting exteroceptive tactile stimuli, it allows to control over the amount and intensity of the stimulation presented. Indeed, the intensity of the tactile vibration administered during the testing phase of the SSDT is set and recorded at the end of the thresholding procedure. This makes the SSDT preferable as compared to tasks involving the detection of interoceptive information such as a HBP task, where no control over the intensity of the stimuli that participants are asked to detect is possible.

However, the SSDT is not without limitations. For example, it should be noted that the thresholding procedure to set the intensity of the vibration is fairly lengthy and can result with the elimination of a good number of participants (see Chapters 3, 4 and 5 for more details; Chapman, 2014). Moreover, the dispersion of HR data in No Light trials during the experimental phase of the SSDT (i.e., a condition comparable to thresholding trials) suggests the thresholding procedure not to be completely accurate in setting the intensity of the vibration between 40% and 60% as intended. Indeed, the standard deviations of HR in No Light trials at baseline across the different studies of this thesis was found to have a mean of 22.61 (See Chapters 3, 4 and 5 for raw scores) indicating a fairly large dispersion.

As discussed in Chapter 2, the SSDT has also the advantage of using signal detection theory (SDT) for analysing participants' responses. The SDT allows to distinguish between sensitivity (*d*', i.e., the ability to correctly discriminate whether the vibration was present or absent) and response criterion (*c*, i.e., the propensity to report feeling the vibration regardless of the type of trial; Smeets et al., 1999). In turn, this discrimination allows for a more thorough description of the data. This is particularly important in the context of EDs, where prior research has underlined the need to assess multisensory processes using tasks that can precisely weight the role of each sensory modality in contributing to aberrant multisensory integration

(Gaudio et al., 2014). However, it should be noted that using the SSDT, small differences in the pattern of hit rates and false alarm rates can lead to different conclusions regarding sensitivity (*d*') and response criterion (*c*). Therefore, caution should be taken when extrapolating from findings (Pastore & Scheirer, 1974).

7.4.3 Alterations to the original SSDT paradigm

In Chapters 3 and 5, a modified version of the SSDT was used, targeting the face rather than the hand (SSDT face-version; Sacchetti et al., 2020). The paradigm was partially informed by a previous experiment conducted by Durlik and colleagues (2014), during which participants were asked to detect a tactile pulse delivered to their left cheek while facing an LED placed in the middle of their visual field at a distance of around 100 cm. In their study, the presence of the light was found to induce greater reports of touch both in touch present (HR) and touch absent trials (FA; Durlik et al., 2014). In the studies reported here a similar paradigm was used in which the distance between the participant and the LED in front of them was shortened to 40 cm. In the Self condition of Experiment 1 and throughout Experiment 3, a mirror-reversed photograph of the participant's face was presented on the computer screen during trials. The LED was placed on the right cheek of the face depicted on the monitor, mirroring the location of the tactor on the participant's face.

In accordance with Durlik and colleagues' results (2014), and in accordance with some previous literature using the classic version of the SSDT (Lloyd et al., 2008; Mirams et al., 2010), in the Experiment 1 of the current thesis, the presence of the light was found to induce greater reports of touch in both correct (HR) and incorrect (FA) trials. Conversely, in Experiment 3, the presence of the light was found to induce an increase in the correct reports of touch only (HR). In contrast, the presence of the light was found not to have a significant impact on false reports of touch (FA). Indeed, in Experiment 3, false reports of touch were found to be slightly, and non-significantly, higher in trials during which the light was absent as compared to trials during which the light was present.

As previously mentioned, this is in contrast with some previous studies using the SSDT (Llyod et al., 2008; Mirams et al., 2010), in which the presence of the light induced greater false reports of touch. However, this is consistent with other studies in the literature where the light was found not to have a significant effect on FA (Sacchetti et al., 2020; Sacchetti et al., 2021; Lloyd et al., 2011; Mirams et al., 2017). In one of these studies carried out by Lloyd and colleagues (2011), in accordance with the results of Experiment 3, FA were even found to be higher in the absence vs. presence of the light. Moreover other studies in the previous literature only reported descriptive statistics for FA results, but did not test the significance of the effect of the light on FAs (Mirams et al., 2012; Mirams et al., 2013), and it is therefore difficult to compare their results with those found in the current thesis.

Therefore, the fact that in Experiment 3 no effect of the light on FA was found, does not per se undermine the validity of the face-version of the SSDT. However, it should be noted that up to date no study has directly compared participants' responses to the classic version of the SSDT with their responses to the face-version developed in the context of the current thesis. It would be therefore worthwhile for future research to carry out a repeated measures study in which the same sample of participants repeats both versions of the SSDT. This would allow to assess the consistency of participants' responses across the two versions of the paradigm, and to further ascertain the validity of the face-version of the SSDT.

Moreover, taken together results of previous research indicate that the presence of the light during the SSDT can influence both correct and incorrect reports of touch. However, it is not completely clear which variables explain the heterogeneity of results found in the previous literature. Some studies focusing on somatoform symptoms and medically unexplained symptoms, indicated that participants presenting with these symptoms tend to report more often incorrect reports of touch (FA) in the presence of the light (Brown et al., 2010; Brown et al., 2012). Moreover, results of the current thesis suggest that the presence of ED symptoms is associated with an increase in reports of touch from light-absent to light-present trials both in correct (HR) and incorrect (FA) trials. However, further research should systematically analyse whether participants' personality traits and psychopathological symptoms play a role in determining whether the presence of the light influences more correct or incorrect report of touch during the SSDT.

Additionally, it should be also noted that while in the original version of the SSDT the beginning of each trial was signalled by a visual cue (i.e., an arrow depicted on the computer screen), in the face-version of the SSDT, the beginning of each trial was signalled by an auditory cue (i.e., a beep sound delivered through earphones). Therefore, heterogeneity of results between the different studies of this thesis could be accounted for by differences in the cues used. In this respect, it could be the case that differences in the way participants were prompted to focus on upcoming tactile stimuli altered subsequent tactile perception during trials. However, a previous study by McKenzie and colleagues (2010), in which both visual and auditory cues were used, seem to discourage this interpretation. Indeed, in their study participants behaviours following visual or auditory cues were found to be statistically comparable.

Lastly, the face-version of the SSDT may be improved by the use of eye-tracking methods to investigate participants' visual processes when performing the task. This could be particularly informative especially to further investigate the results found in Experiment 1. Indeed, in Experiment 1, exposure to the vision of once own face during the SSDT was found to have a differential effect on high vs. low ED participants. High ED participants showed an increase in tactile accuracy when exposed to the vision of their face, while low ED participants were found to be more accurate when performing the task in the control conditions (i.e., while looking at a picture of another person' face or a scrambled face). Although in Experiment 1 gaze direction was minimized using a chin-rest that discouraged participants from moving their head, it is still possible that differences found in SSDT performance between high vs. low ED participants may be due to differences in visual observation of the faces and/or the LED. The use of eye-tracking methods in future research may be therefore informative to analyze low vs. high ED differences in visually inspecting photographs.

7.5 Conclusions

The main aim was to explore whether EDs symptoms would be related to alteration of visuo-tactile multisensory integration, as assessed using the SSDT. Taken together, the results suggest that multisensory bodily signals are indeed processed and integrated differently by women presenting with different levels of ED symptoms. Specifically, participants with higher ED symptoms were also found to have a stronger increase in touch reports in the presence of the light during the SSDT. We hypothesized these results to reflect the fact that ED patients show a preferential reliance on visual information over other sensory information (i.e., visual capture). These results also contribute to expand on the current understanding of multisensory integration processes in EDs. Abnormal multisensory integration processes in EDs may stem from a combination of visual capture and a decreased focus on interoceptive information. Therefore, greater abnormalities in tasks assessing multisensory integration are more evident when these tasks involve the elaboration of both exteroceptive and interoceptive information. Conversely, these abnormalities are less prominent in tasks assessing the integration of exteroceptive information only.

Moreover, high vs. low ED participants have been found to be differentially affected by exposure to the vision of the body (the face and the hand) during the SSDT. In participants with high (but not low) ED symptoms exposure to vision of the body was followed by an increase in tactile accuracy during the SSDT. Exposure to the vision of the body may exacerbate a predisposition in participants with ED symptoms to focus more on external perceptual information to the detriment of internal bodily signals. In turn, this would lead to a greater accuracy in the detection of exteroceptive information and a worse performance in the perception on inner body signals. A treatment direction for addressing body misperception in EDs could be to shift patients' focus from external to internal bodily information, therefore leading to a rebalance between exteroceptive and interoceptive signals.

The studies reported here have also opened the way for further research into the use of affective touch to address alterations in multisensory integration in EDs. Indeed, it is shown for the first time that, in a multisensory context, affective touch enhances subsequent perceptual accuracy. As affective touch is an interoceptive modality, it may well contribute in shifting patients perceptual focus form exteroceptive to interoceptive information. This, in turn, may help in rebalancing multisensory processes in EDs.

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Appendix A (Chapter 3)

3.5.1 High Frequency Heart Rate Variability (HF HRV)

3.5.1.1 HF HRV data extrapolation

ECG data were recorded continuously during each condition of the SSDT. For each of the 3 conditions, 2 recordings were obtained: at baseline and during the experimental phase, resulting in a total of 6 recordings per participant. Each recording was visually inspected for artefacts which were manually removed using Biopac (MP150) Systems. ECG signals were then imported into Kubios HRV software (University of Kuopio, Kuopio, Finland) for the frequency domain measure of the High Frequency band (0.15-0.4 Hz). Inter-beat (RR) intervals were retrieved from the original ECG signal and the smoothness priors method was applied to remove slow non-stationary trends from the HRV signal. Frequency domain estimates of HF HRV (in normalized units) were then derived using the power spectrum density with the fast Fourier transformation-based Welch's periodogram method. Six estimates of HF HRV were therefore obtained for each participant (one estimate at baseline and one during the experimental phase of each of the 3 conditions of the SSDT).

Crucially, there were no differences between groups (Low vs. High ED) in baseline HF HRV (bs HF HRV) in any of the experimental conditions (bs HF HRV Self: $t(51) = |1.85|$, $p = .07$, $d = .51$; bs HF HRV Other: $t(51) = |1.90|$, $p = .06$, $d = .52$; bs HF HRV Scrambled: $t(51) = |1.71|$, $p = .25$, $d = .33$). Three baseline-corrected estimates of HF HRV were then calculated by subtracting baseline values from their respective experimental values. The baseline-corrected estimates were later used for all the analyses described in the below results section.

3.5.1.2 Results

There were no significant main effects of Condition ($F(2,102) = .98$, $p = .38$, $\eta^2 = .02$) or group ($F(1,51) = .19$, $p = .66$, $\eta^2 = .004$), as well as no significant Condition × Group interaction ($F(2,102) = .42$, $p = .65$, $\eta^2 = .008$). No significant correlations were found between HF VRT and SCLs (all *ps* > .11). These results were supported by previous research that showed the SNS and the PSNS to respond independently to environmental stimuli (Berntson, Cacioppo & Quigley, 1991).

3.5.2 Visual Analogues Scales (VAS)

3.5.2.1 Methods

Self-report 15 cm VAS were administered at the end of the SSDT to investigate how participants interpreted the photograph of another person (Other) and the photograph of themselves (Self). Specifically, participants were asked to answer on a scale from 0 ("not at all") to 100 ("very much so") for the following questions: "How strongly did it feel as though someone/yourself was watching you?" and "How strongly did it feel as though you were watching the other person/yourself?". The first two questions investigated whether participants assumed a third-person/allocentric perspective, which implies perceiving oneself from the view point of an external observer (VAS Allocentric Other, VAS Allocentric Self). Conversely, the other two questions assessed whether participants assumed a first-person/egocentric perspective as active observers of external objects (VAS Egocentric Other, VAS Egocentric Self).

Two additional 15 cm VAS were added to control for the age and attractiveness of the person shown in the Other condition. Specifically, participants were asked to rate the level of attractiveness from a minimum of 0 to a maximum of 5 in accordance to the scale used by the Chicago Face Database (VAS Attractiveness), and then to estimate their age (VAS Age).

3.5.2.1 Results

No differences between the two groups were found on the perspective-taking VASs, suggesting that participants with High vs. Low ED symptoms did not differ in the way they interpreted the photographs presented during the SSDT. Both groups self-reporting to be more inclined to assume a first-person (VAS Egocentric Self, VAS Egocentric Other) rather than a third-person perspective (VAS Allocentric Self, VAS Allocentric Other) in both the Self and the Other conditions. Alongside, no between groups differences were found on the VAS Age and the VAS Attractiveness. Results of both groups were in line with the normative scores of the Chicago Face Database Results of comparisons are presented in the Table 1a.

Table 1a.

Descriptive statistics for VASs as dependent variables.

	Low ED	High ED				
	M (SD)	M (SD)	t	df	p	d
VAS Egocentric Self	39.36 (28.46)	46.58 (30.01)	.88	51	.38	.25
VAS Allocentric Self	33.96 (28.17)	41.15 (31.79)	.87	51	.39	.24
VAS Egocentric Other	59.33 (26.82)	55.11 (33.34)	.51	51	.85	.14
VAS Allocentric Other	47.30 (27.09)	45.81 (29.47)	.19	51	.38	.05
VAS Attractiveness	3.06 (.90)	2.64 (.94)	1.65	51	.10	.46
VAS age	25.59 (3.56)	25.96 (4)	.35	51	.72	.10