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Disentangling the social brain: Interactions between empathic abilities, personality traits and space boundaries

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Abstract

Human beings are social animals. It is important for our species to engage in healthy and fruitful relationships. Altruism and cooperative behaviors help us to improve these bonding relationships and are helpful for the survival of the species. In this framework, empathy and interpersonal space (IPS) are two crucial factors for social interactions. On the one hand, individuals with better empathic abilities will have lasting relationships and a predisposition for cooperativeness and altruistic behaviors that are fundamental skills to develop in large groups. On the other hand, the development of maladaptive or dysfunctional personality traits can hinder these processes, leading to impairment in relationships. Evidence from cognitive neuroscience demonstrate that empathy, social space, and psychopathy seem to rely – at least partially – on a common neural network, in turn being intrinsically linked and potentially influencing each other.

The general aim of the present work is to disentangle the relationship between these constructs, investigating how personality and psychopathic traits in the general population shape and modulate interpersonal space and empathic abilities. Furthermore, this contribution presents an exploration of the effects of brain damage on social cognition, emotional response, and social space.

In particular, Study 1, investigates the relationship between mentalizing abilities, empathy, psychopathic and maladaptive personality traits in a large (N=309) healthy population. Results show the relation between empathic abilities, personality traits and psychopathy, highlighting the relationship between primary and secondary psychopathic dimensions and maladaptive personality traits (specifically those related to disinhibition, impulsivity, and aggression), and between the latter and social sensitivity (as assessed by a complex emotions recognition task).

Given the results of Study 1, Study 2 further explores the relationship between empathic abilities, personality, and psychopathic traits, taking into consideration their influence of IPS extension. This study sheds light on the role of impulsivity, aggressivity, along with psychopathic features and cognitive empathy in shaping social space. In particular, I provide a first novel evidence that IPS is primarily influenced by disinhibition and the ability to assume the others point of view (i.e., perspective taking ability). Both of these factors are associated with a shorter comfort distance.

Finally, Study 3 is aimed at exploring how brain damages causing frontal behavioral symptoms affect IPS and empathy, in light of the fact that behavioral dysregulation has been proposed as a crucial determinant of interpersonal space changes. Study 3 also takes into account possible links between IPS and empathy, given their common neural substrates. The results do not confirm that IPS size is altered in patients with frontal behavioral dysfunctions, as compared to neurologically healthy controls. However, the exploration of the performance on an individual base highlights the presence of two different profiles: a portray of positive symptomatology entails a reduction of IPS extension, while a profile characterized by negative symptoms seem to enlarge IPS. Finally, Study 3 reveals a selective impairment of affective empathy in brain-damaged patients.

In conclusion, the present research project offers novel insights on the complex relations between psychopathic and personality traits, the cognitive and affect sides of empathy, and their impact on the regulation of the IPS size in healthy individuals. This evidence extends current understanding of psychopathological conditions characterized by lack of empathy and behavioral dysregulation. Additionally, the last study on brain-damaged patients suggests that the interpersonal distance and the affective side of empathy may be affected, in a non-linear way, by brain damages concurrently causing behavioral dysfunctions.

Chapter 1

Empathy, Psychopathy and social space

General introduction

Empathy: definition

Theodor Lipp (1907) was the first author to introduce the concept of empathy and to formulate a theory on how we understand others' mental states. According to his theory, empathy involves an imitation component and an expression component: when we see a gesture or expression by another individual, we tend to imitate it and also to associate the normal feelings and emotions of that gesture. Moreover, Lipp looked at empathy as a "*natural instinct*" (Montag, Gallinat, & Heinz, 2008; Baird, Scheffer, and Wilson, 2011). A first critic of this theory came from Scheler (1954) that criticized Lipp's definition of empathy that is too similar to the concept of emotional contagion. In particular, Scheler states that in the process of emotional contagion there is no component belonging to the understanding of emotion: we can experience an emotional state and be literally absorbed by it without knowing what that is about (Scheler, 1954). Scheler, as well as other phenomenologists, refused the idea that empathy relies on imitation, or mimicry or emotional contagion (for a review Zahavi, 2008; 2010). For phenomenologists, empathy is "*a basic, irreducible, form of intentionality that is directed towards the experiences of others. It is a question of understanding other experiencing subjects. However, this doesn't entail that the other's experience is literally transmitted to us*". On the last two centuries authors tried to define empathy in many ways, but still, there is no agreement on a univocal definition (Baird et al., 2011; Preston and de Waal, 2002). In particular, the main focus of the actual debate on empathy is if empathy relies more on cognitive or affective processing. Some authors view empathy as a strictly emotional response that overlaps emotional contagion. In this perspective, empathy is defined as the ability to share others' emotions (Mehrabian and Epstein, 1972; Bryant, 1982). On the other hand, there are theories that looked at empathy as separate from emotional resonance and relying on higher cognitive processes. In this perspective, empathy refers to the ability to recognize and understand others' emotions, thoughts, and intentions (Hogan, 1969; Borke, 1971). Among this duality in the debates, there are also multi-dimensional approaches to empathy (Davis, 1980, 1983; Baron-Cohen & Wheelwright, 2004). Davis (1980) theorized the existence of a multi-dimensional model of empathy in which both cognitive and affective components are taken into consideration. From this point of view, empathic abilities entail either cognitive processes, such as the recognition of others' emotion states (i.e., Theory of Mind, ToM; Frith and Frith, 2005;

Goldman, 2012), and an affective dimension, namely the emotional resonance of others' experienced emotions. To corroborate this theory, Davis developed an instrument to assess both dimensions of empathy (i.e., the *Interpersonal Reactivity Index*, IRI; Davis, 1980; 1983). IRI is a self-report questionnaire that evaluates empathic abilities on four subscales, namely: *Perspective taking* (i.e., the ability to take others' point of view), *Fantasy* (i.e., the tendency to fantasize and transpose themselves in emotions and actions experience by fictitious characters depicted in movies or books), *Empathic concern* (i.e., feelings of sympathy to others misfortune) and *Personal distress* (i.e., personal feelings of anxiety in tense situations). *Perspective taking* and *Fantasy* scales measure cognitive empathy, while *Personal distress* and *Empathic concern* measure the affective dimension of empathy. IRI's reliability in measuring four different and separates component is corroborated by the low association between these subscales (Davis, 1983; Albiero, Ingoglia, Lo Coco, 2006).

Neuroscientific theories of empathy

Modern neuroscientific conceptualizations of the construct of empathy can be grouped in theories that rely on the mirror neurons system (MNS; Gallese, 2001; Iacoboni & Lenzi, 2002), simulation theories (Adolphs, 1999; Gallese & Goldman, 1998) or perception-action theories (Blakemore & Decety, 2001; Preston & de Waal, 2002). MNS theories about empathy descend from the discovery of mirror neurons (Di Pellegrino, Fadiga, Fogassi, Gallese and Rizzolatti, 1992; Gallese, Fadiga, Fogassi and Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese and Fogassi, 1996). According to this perspective, the perception of a particular emotion and the observation of the same emotional states in others activate the same neural networks that process the own emotional states. This theory is corroborated by recent neuroscience findings that highlight the existence of a broad neural network for mirroring other's actions and sensations (Gallese, Keysers and Rizzolatti, 2004; Keysers and Gazzola, 2009; Keysers, Kaas and Gazzola, 2010). The discovery of mirror neurons in the motor domains highlighted the presence of a system that responds both for performed actions and for the observation of the same actions (di Pellegrino et al., 1992; Gallese et al., 1996; Rizzolatti et al., 1996). Recent evidence has further expanded these findings also to other domains, such as the somatosensory domain. When we observe other people being touched there is a vicarious activation of the same neural areas (e.g. the primary somatosensory cortex) involved in the perception of touch on our own body (Keysers et al., 2004; Ebisch et al., 2008; Keysers and Gazzola 2009; Keysers et al. 2010). So the vicarious activity of brain areas normally involved in somatosensation also support our ability to understand, through a simulation mechanism, others tactile experience, the so-called

tactile mirror system. Simulation theories assume that we use our mental processes to infer the behavior and the responses of our conspecifics, thus inferring their own mental states (Adolphs, 1999; Gallese & Goldman, 1998). Simulation theory relies upon a cognitive view of empathy. In order to understand how others would feel, think or act we need to have a mental representation of others' feelings. This will allow to take others' perspective and better predict their behavior.

Finally, according to perception-action theories, when we perceive a behavior in another human being, there is an automatic activation of our own representations for the same behavior. Consequently, an output from this shared representation automatically goes to motor areas of the brain where responses are prepared and executed (Preston and deWaal, 2002).

A convincing support to the mirror theories of empathy is offered by a peculiar condition, the so-called "*Mirror Touch Synaesthesia*" (MTS; Banissy and Ward, 2007; Fitzgibbon et al., 2012). Individual showing this condition experience an actual tactile sensation while observing a touch delivered on another individual. MTS is of particular interest for social cognition because the synesthetic experience is generated by the actual and real experience observed on another person and, most important in the present context, this condition is linked to higher levels of empathy (Blakemore et al., 2005).

Neural substrates of empathy

Studies investigating neural correlates of empathy found the existence of a vast brain network involved in empathy. Different results depend on different paradigms, but also different theoretical framework underneath the investigation.

A lot of neuroimaging studies focused on the vicarious brain response to the observation of pain (Singer et al., 2004; Jackson et al., 2005; Avenanti, Minio-Paluello, Sforza, and Aglioti, 2009; Bufalari, Aprile, Avenanti, di Russo, and Aglioti, 2007; Bufalari and Ionta, 2013) showing the activation of anterior insula (AI), anterior cingulate cortex (ACC), and primary and secondary somatosensory cortices (SI and SII). Research that focuses on cognitive empathy and mentalizing abilities highlight the role of frontal and temporal lobes. In particular, medial frontal lobe and ventromedial prefrontal cortex (VM; Eslinger, 1998; Gallagher and Frith, 2003; Shamay-Tsoory et al., 2004; 2009) are activated by ToM tasks (Mitchell, Nacrae, and Banaji, 2006). In a study on brain-damaged patients, Shamay-Tsoory, Peretz, and Perry (2009) demonstrated how lesions circumscribed to VM lead a deficient performance on false belief

task (used to assess mentalizing abilities). These findings are a strong evidence supporting the role of this area in cognitive empathy. Concerning the temporal lobe, a crucial role in cognitive empathy seems to be played by the temporoparietal junction (TPJ; Saxe and Kanwisher, 2003; Saxe, Carey and Kanwisher, 2004; Samson, Apperly, Chiavarino, and Humphreys, 2004) and the superior temporal sulcus (STS; Frith and Frith, 2003). Other researches focused on the neural correlates of emotional and affective components of empathy. Altogether these studies highlight the role of insula in the internal experience others' emotional states (Wicker et al., 2003; Singer et al., 2004) and of the inferior frontal gyrus (IFG; Dapretto et al., 2006; Kaplan and Iacoboni, 2006; Schulte-Ruther, Markowitsch, Fink, & Piefke, 2007). For example, Dapretto and colleagues found an activation of IFG both during observation and imitation of emotional faces. Another study by Kaplan and Iacoboni (2006) showed a correlation between IRI's empathic concern (EC) subscale and activity in IFG during observation of videos. Crucially, EC subscales rely on the affective dimension of empathy. Thus it seems reasonable that IFG is the neural correlate of emotional contagion.

Uncovering the neural underpinnings of empathy is of fundamental importance for social cognition and for understanding human interactions. Human beings are social animals; thus it is important for their well-being to cooperate with their conspecifics and to adopt altruistic behaviors. Furthermore, the investigation of empathy may help to a clear understanding of some psychopathological disorders. In some psychological and psychiatric disorders, empathic abilities seem to be impaired. Among them, there is psychopathy in which lack of emotional responses and understanding seem to be a core feature (Cleckley, 1941; Hare 2003). In the following paragraphs, I will briefly describe this pathology.

Psychopathy: definition of the construct

The term "*psychopathy*" has been used for the first time by the German psychiatrist Julius Koch (1888) who used psychopathy to point out a variety of personality disorders with a biological substrate. A first attempt to classify psychopathic disorder is made by Emil Kraepelin at the beginning of the twentieth century. Kraepelin identifies different types of psychopathic personality disorders that have some commons features, i.e., antisocial behavior, tendency to manipulate and deceit others, egocentrism, emotional impairment, impulsivity and lack of complex emotions (Kraepelin, 1904; Dazzi & Madeddu, 2009). However, this first

classification included a broader spectrum of personality disorders with heterogeneous symptomatology (Cleckley, 1941; McCord & McCord, 1964).

Some authors tried to focus on the core symptomatology of psychopaths to differentiate this disorder from other personality disorders.

The model by Cleckley

Cleckley in his book "*The mask of sanity*" (1941) identifies several core symptoms of psychopathic:

- superficial charm and good intelligence;
- absence of delusions and other signs of irrational thinking;
- absence of psychoneurotic manifestations;
- unreliability;
- untruthfulness and insincerity;
- lack of remorse or shame;
- inadequately motivated antisocial behavior;
- poor judgment and failure to learn by experience;
- pathologic egocentricity and incapacity for love;
- poverty in major affective reactions;
- loss of insight;
- unresponsiveness in general interpersonal relations;
- fantastic and uninviting behavior with drink and sometimes without;
- suicide rarely carried out;
- sex life impersonal, trivial, and poorly integrated;
- failure to follow any life plan.

These 16 criteria can be used to assess the presence of psychopathy. I will briefly review these criteria. Psychopaths are characterized by superficial charm and good intelligence. Usually, their charm and authenticity help them in having pleasant relationships. Furthermore, despite their lack of emotional response, they do not show any sign of their disorder. Often, their performance at intelligence test is superior to the norm. Contrary to other psychological disease, psychopaths do not manifest delusions or other thinking disorders. They have preserved the exam of reality and logical reasoning. Psychopathic individuals do not seem to

experience anxiety or nervousness. Despite a good "first impression" sooner or later psychopaths exhibit a lack of responsibility. They are not interested in maintaining a long-term commitment. Moreover, these individuals show a pathological inclination to lie accompanied by a total lack of remorse and a total denial of responsibility. Psychopaths also show a tendency for unjustified antisocial behaviors that do not seem to have any explainable goal or aim. Furthermore, despite their good level of intelligence, these individuals are apparently unable to learn from experience and show lack of judgment. This deficit is particularly evident in behavior compared to theoretically reasoning: they can evaluate correctly what they should (or would) do in a given situation, but when they are in the real situation they will act differently. There seems to be a dissociation in judgment abilities: they show a deficiency in the judgment of situations involving emotional or ethical evaluations while when an intellectual judgment is required their abilities seem to be unaffected. Regarding the emotional sphere, psychopaths show a pathological egocentrism paired with an incapacity for love and a general poverty in affective reactions. These are the core features of psychopathy that are related to the emotional sphere. According to Cleckley, psychopathic individuals exhibit a poverty in emotions; emotions tend to be superficial and a "copy" of the real ones that seem to be understood just from an intellectual perspective. Loss of insights for psychopaths is different for the loss of sense of reality exhibited by psychotic patients. Indeed, psychopaths have an unimpaired sense of reality, but they are unable to see themselves as others do. The loss of insight in psychopaths is probably related to their lack of responsibility and to the tendency of shame others for the consequences of their behavior. Another characteristic of psychopaths is the unresponsiveness in interpersonal relationships: they do not show the ordinary response to special consideration, trust or kindness. They are not at risk for suicide, rather, Cleckley points out that suicide attempts are used in a manipulative way. Another aspect concerning the interpersonal dimension is related to sex life: psychopaths seem to receive less gratification from sexual intercourse and show fewer impulses related to the sexual sphere. Once again, the affective component is scarcely present in their sexual life. The last feature identified by Cleckley is the failure to follow long-term life plans. They do not maintain any effort in reaching long-term goals, but they continuously shift from one activity to another.

The model of Hare

The research by Robert Hare focused on the lack of a clinical instrument to diagnose psychopathic disorder; on the other on the absence of a clear aetiological model of the disorder.

In particular, he underlined the difference between antisocial personality disorder and psychopathy and the need for diagnostic criteria based on empirical data. His research on clinical diagnostic criteria will lead to the development of a clinical instrument to diagnose psychopathy: the *Psychopathy Check-List* (PCL; Hare, 2003).

Regarding the etiopathology of the disorder, he criticized the role of environmental factors in the development of psychopathy. He recognizes the importance of the family environment and the role of emotional deprivation and violence during childhood, but these factors are not sufficient to explain the distribution of psychopathology among the general population (Blair, Peschardt, Budhani, Mitchell & Pine, 2006). Hare highlights the importance of individual factors in the developing of psychopathy, especially the development of moral consciousness. The author recalls Cleckley's model, focusing on the emotional and interpersonal factors on the one hand, and on behavioral symptoms on the other. His work leads to the theorization of a two-factor model of psychopathy, each factor has two facets (Figure 1). According to Hare, the core features of psychopathy are, on the one hand, the interpersonal and affective traits, i.e., narcissistic and grandiose self-worth, an external locus of control, with lack of responsibility, sense of guilt and empathy. Psychopathic individuals are not able to build a mental and emotional representation of others, considering human beings as objects easy to manipulate. They exhibit superficial and labile emotivity, and experience "proto-emotions", that is a primitive response to immediate needs (Cleckley, 1976; Williamson, Hare, and Wong, 1987). They tend to manipulate others and to have an inclination for pathological lying and deceitfulness.

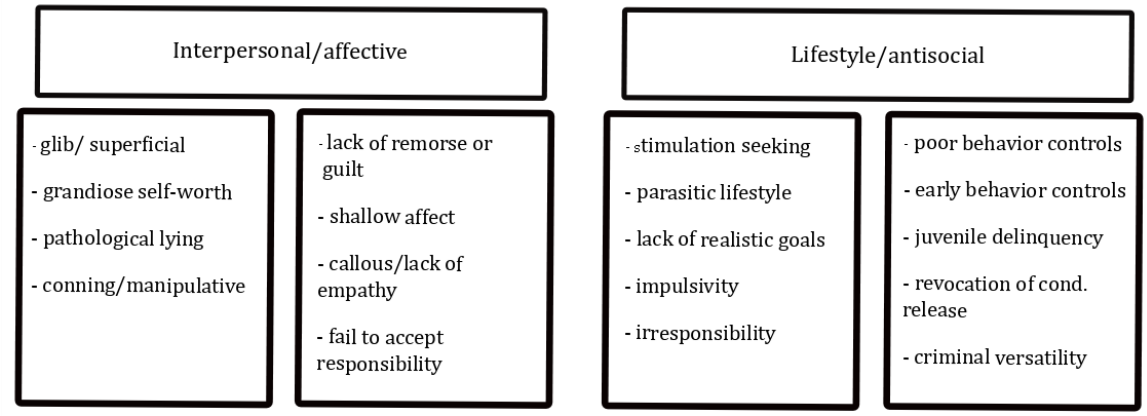

Figure 1. Hare's two-factor model of psychopathy. Adapted from Glenn and Raine (2014).

On the other hand, according to Hare, another core trait of psychopathy belongs to the behavioral domain. Psychopaths are prone to sensation seeking and impulsivity, all symptoms of dysregulation in behavioral control. Their behavior seems to be driven by the immediate satisfaction of their needs. Furthermore, it is possible to identify some signs of the disorder during childhood or adolescence such as delinquency, cruelty towards animals and antisocial behavior (Hare, 1993; Blair, Peschardt, Budhani, Mitchell, and Pine, 2006). Hare classifies psychopaths into three categories: the *primary psychopaths* are successful individuals, usually charming and oriented to success they are deceitful and usually succeed in saving a "normal" appearance masked by their ability in manipulating other. The *secondary psychopaths* have a great emotion deficit and are socially isolated. In the third category, there are individuals with antisocial behavior usually caused by environmental factors, namely *dyssocial psychopaths* (Hare, 1998).

Psychopathy in diagnostic classification

In the classification of psychological disorders, psychopathy has been usually associated with an antisocial personality disorder. The symptomatology of antisocial personality disorder is focused merely on behavioral dysfunction. With the third edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III; APA 1980), the authors introduced symptoms belonging to the emotional and affective sphere, but antisocial personality disorder and psychopathy remain two different disorders. Studies using the DSM-III classification revealed that these two diseases are not always contemporarily diagnosed, thus confirming the role of psychopathy as a disorder *per se* (Hare, 1998; Ogloff, 2006). In the fifth edition of DSM (DSM-5; APA, 2013), diagnostic criteria of antisocial personality disorder still reflect the behavioral symptoms of psychopathy, but the emotional and interpersonal features of psychopathy are not included. Only the criterion "lack of remorse" belongs to the affective sphere (McWilliams, 2012). For all these reasons the two diagnoses are not overlapping. Another fundamental aspect to support the evidence that antisocial disorder and psychopathy are different psychopathological categories is the antisocial behavior. There are different reasons underlying violent behavior in individuals affected by antisocial personality disorder and in psychopaths. The first ones act violently because of impulsivity or the belongings to criminal groups. The latter one's violence is an instrumental behavior to pursue a goal, an

advantage or a superior position on others. Violent conduct in psychopathic is not material but emotional (Gabbard, 2014).

Psychodynamic theories, on the other hand, look at psychopathy and antisocial personality disorder on a continuum with narcissistic pathology (Kernberg, 1989; Gabbard, 2014). On this continuum, psychopathy is seen as an extreme primitive expression of the disorder. The common feature between narcissistic and psychopathic pathology is the grandiose self-worth. However, the important difference between the two is that in narcissistic disorder, egocentrism and grandiose self-worth, are necessary to the restoration of a fragile ego; while psychopaths use their grandiosity to achieve power and control (Kernberg, 1984; 1989). According to Kernberg, the etiopathology of psychopathy can be found in a dysfunctional development of personality during early childhood. This leads to immature self-defense mechanisms and an impairment in the affective evolution and moral sense (Kernberg, 1992). The *Psychodynamic Diagnostic Manual* (PDM; Lingiardi and McWilliams, 2015) reflects the psychodynamic theories about personality disorders. Indeed, in the manual, there is a "*psychopathic personality disorder*" among the personality disorders category that reflects Cleckley and Hare's vision of psychopathy.

In accordance with this conceptualization of psychopathy, recent theories look at psychopathy as a continuum of personality traits that may exist in the general population (Levenson, 1995). It has been suggested to examine the degree of severity of both interpersonal/affective and behavioral traits of psychopathy and how these traits influence personality (Skeem, Poythress, Edens, Lilienfeld & Cale 2003). These maladaptive core personality features have a dimensional characterization; in this perspective, different degrees of dysfunctional traits can be present in the general population. For this reason, some authors suggested extending research on psychopathy also to the general population (Lilienfeld, 1994; 1996). DSM-5 proposes, alongside the categorical model, a new alternative model of personality pathology, that assesses personality disorders according to a dimensional model to investigate the presence of a pathological personality on a continuum (Skodol, 2011). Another diagnostic instrument has been introduced (i.e., *Personality Inventory for DSM-5*, PID-5; Krueger, Derringer, Markon, Watson & Skodol, 2011) to evaluate five main domains (i.e., Negative affect, Disinhibition, Detachment, Antagonism, and Psychoticism). Maladaptive personality traits can be related to psychopathic traits (Strickland Drislane, Lucy, Krueger & Patrick, 2013). The Disinhibition and Antagonism facets seem to reflect two domains of psychopathy (secondary and primary respectively). A study on an Italian sample corroborated these findings: the authors

found that personality traits on the Antagonism domain correlate with primary psychopathy, while Disinhibition and Detachment are linked to secondary psychopathy (Fossati et al., 2013).

Neural substrates of psychopathy

In recent years, neuroscience gave a great contribution to the understanding of neural correlates of psychopathy (e.g. Tiihonen et al., 2000; Kiehl, Smith, Hare, Forster & Liddle, 2001; Blair, 2003; 2008; Blair, Mitchell and Blair, 2005; Pera-Guardiola et al., 2016; Medina, Kirilko, Fifer, 2016). Neuropsychological evidence from brain-damaged patients and patients with a particular form of dementia suggested the involvement of frontotemporal lobe in some of the core symptoms of psychopathy (for a review Glenn and Raine, 2014). Patients affected by frontotemporal dementia (FTD; Boxer and Miller, 2005) show peculiar symptomatology concerning behavioral and personality changes. Usually, this kind of patients are impulsive, disinhibited, show labile emotions. All these symptoms emerge after the onset of the disease. Noticeably, their personality change and their interpersonal behavior are similar to psychopathic behavior (Levenson and Miller, 2007). Another proof in favor of the role of frontal areas in the development of psychopathy comes from studies on brain-damaged patients with post-stroke focal lesions. Indeed, a damage to the orbitofrontal cortex causes impulsivity, irresponsibility and reactive aggression (Damasio, Grabowski, Frank, Galaburda and Damasio, 1994). These symptoms are similar to psychopathic traits, and for this reason, this neurological condition has been called "*acquired psychopathy*" (Eslinger and Damasio, 1985). The emotional processing deficits can be reconducted to a dysfunction in the limbic system, specifically in the amygdala (for a review Blair, 2013). This subcortical nucleus is involved in emotional processing (Phelps and LeDoux, 2005) and fear learning (Davis and Whalen, 2001; LeDoux, 2003). In the development of psychopathic traits, amygdala dysfunction seems to have a strong role (e.g., Blair, 2003; Jones, Laurens, Herba, Barker and Viding, 2009; Dolan and Fullam, 2009; Marsh, 2016). In particular, there is an hypoactivation of the amygdala (Damasio, Tranel & Damasio 1990; Blair, 2001) in response to fearful stimuli both in young population with antisocial behaviour and psychopathic traits (Birbaumer et al., 2005; Marsh et al., 2008; Jones et al. 2009; White et al., 2012), as well as in adults with a clinical diagnosis of psychopathy (Blair, 2001). In addition to aberrant functionality patterns, recent neuroimaging studies also found structural abnormalities in the amygdala (Yang, Raine, Narr, Colletti, Toga, 2010; Pardini, Raine, Erickson, and Loeber, 2014; Vieira et al., 2017). Other neural areas

involved in the development of psychopathic traits are the caudate and the ventromedial prefrontal cortex (Blair, 2003).

Interpersonal space

Interpersonal space (IPS) is a concept derived from social psychology. It defines a space surrounding the body very sensitive to intrusion (Horowitz, Duff, and Stratton, 1964; Hayduk, 1978). IPS have very peculiar characteristics and can be modulated by many factors (contextual factors and intraindividual factors). It can also be called "*social space*" or "*comfort zone*". It can be seen as the socially appropriate distance that we set between us and our conspecifics (Hayduk, 1983). In this perspective, IPS has attracted the interest of many scientists engaged in studying factors modulating the social space but also its core characteristics. A first distinction needs to be made to separate interpersonal space from peripersonal space (PPS). IPS is a construct derived from the social psychology and referring to the comfort zone surrounding the body and sensitive to threats and violations; the latter is a neuropsychological construct concerning the reachable space (Patané, Fanè, Frassinetti, 2017).

Origins and theoretical framework

The concept of "*comfort-space*" or "*social space*" descends from ethology and animal psychology. One of the first scientists interested in this self-defensive space was the Swiss zoologist Heini Hediger (1955). Thanks to the observation of animal behavior in captivity, he theorized the concept of "*flight distance*". Indeed, according to his theory, fear and flight behavior are the most important instincts necessary for the survival of animals. Hediger (1955) observed and accurately described spacing mechanisms in animals. He classified four different spaces:

1. *Flight distance.* It is the minimum distance an animal will set between itself and a predator before fleeing. Flight distance is an interspecies spacing mechanism.
2. *Critical distance.* As the flight distance, this is another space involved in interspecies interactions. This is the space where the flight behavior reverses into attack. If an animal perceives a menace, but there is an obstacle preventing him from fleeing, its behavior reverses from flight to fight.
3. *Personal distance.* This is the "normal" distance that two conspecifics maintain between themselves. Personal distance relies on social hierarchy: dominant animals

tend to have larger personal distance compared to lower levels members of the social organization.

4. *Social distance.* It is defined as a "psychological distance" among social groups. This is the distance at which animals of the same herd feel safe one from each other.

The anthropologist Edward Hall (1966) transposed these findings from animal psychology to social psychology and called the study of space "*proxemics*". Hall believed that there was a parallelism between animals and human beings: our species has rules governing the spacing between conspecifics. In particular, he looked at personal space as a series of concentric circles surrounding the body. Hall, as well, identified different spaces each governed by different rules and each one with a defined measurable distance (see Figure 2). The intimate space (0-45 cm) is the space characterizing very close relationships (familiars and partners). Personal space (45-120 cm) is the zone reserved for friends and colleagues; Social space (120-360 cm) is the distance set in groups of unknown people or newly formed groups. Public space is the space for larger audiences such in lectures, conferences and so on.

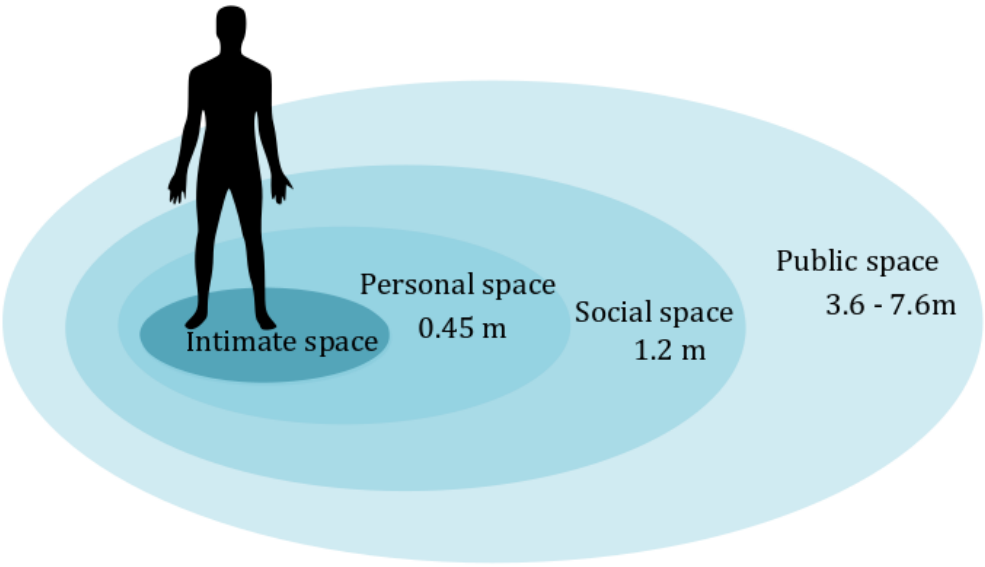

Figure 2. Representation of Hall's classification of personal space.

Interpersonal space is both a biological mechanism, designated to one's own survival, and a social mechanism governed by different rules and shaped by interactions with other

conspecifics. At the beginning of personal space research, social psychologists took interest in the social mechanisms ruling and shaping this space. Scientists developed different theories such as the *attribution theory*, the *equilibrium theory* and the *expectancy theory* (Hayduk, 1978; 1983). According to attribution theory (Middlemist, Knowles, & Matter, 1976), any alteration in interpersonal distance leads to different levels of arousal that trigger a behavioral response. Another theory, namely the *equilibrium theory* (Argyle and Dean, 1965), states that there are several dimensions occurring during interactions. These dimensions are ruled by different forces - directed towards approach or avoidance – the equilibrium of which determines the intimacy of the relationship and the distances between the individuals that are interacting. On the other hand, Burgoon and Jones (1976) formulated the so-called *expectancy theory*, according to which interpersonal distance is set according to situational norms, individual characteristics, and experience.

Factors influencing interpersonal space

Hayduk describes two core characteristics of personal space (1981): *permeability* and *flexibility*. *Permeability* refers to the degree of intrusion tolerance that distinguishes every individual. If one has scarce tolerance to his space intrusion, he has an impermeable space; while if one has no or minimal reaction to invasion, his space is permeable. *Flexibility* refers to the changing in the space depending on several factors, such as gender, familiarity, age.

Gender

Research on gender differences in social space is quite extensive. Historically, studies on gender differences about interpersonal space are based on the observation of dyadic interactions (Heshka and Nelson, 1972; Beck and Ollendik, 1976; Hayduk, 1983; Aiello, 1987; Sawada, 2003; Sommer, 2002; Uzzell & Horne, 2006). In the literature, there is general agreement about males keeping greater distances from each other compared to female dyads and on a broader perspective there seem to exist a general patter MM> MF> FF (M=males; F=females) (Hayduk, 1983; Iachini et al., 2016). Usually, the more affiliative behavior exhibit by women is thought to be due to gender stereotypes that picture women as more submissive. This affiliative approach cause women to show more proximity to others (Remland, Jones and Brinkman, 1995). A possible account for the difference between males and females in the

preferred interpersonal distance could be the maintenance of the stereotypical sex roles: i.e., females' shorter distances can be due to the stereotype that pictures women as more submissive and in need for protection (Hayduk, 1983). However, some studies demonstrated that gender effect is moderated by age (Gifford, 1997; Iachini et al., 2016). For example, Iachini and colleagues found that females participants exhibit shorter distance when interacting with children compared to adults; additionally, males show larger distances compared to females, but only for young adults not for children or elderly participants.

Age

IPS seems to vary and develop during childhood and adolescence: there is a large body of evidence suggesting that children prefer short distances and from 5-years of age this distance increase (e.g. Aiello and Aiello, 1974; Dean, Willis, and LaRocco, 1976; Willis, Carlson, & Reeves, 1979; Aiello, Headly, and Thompson, 1978; Folarin, 1989; Gifford and Price, 1979; Lomraz, Shapira, Choresh, & Gilat, 1975; Pegan and Aiello, 1982; Sarafino and Helmuth, 1981; Okano, 1985). The preferred distance used during social interactions seem to follow a curve an stabilize to an "optimal distance" in early adolescence (Aiello, 1987; Bar-Haim, Aviezer, Berson and Sagi, 2002). To summarize the majority of findings, suggest that interpersonal distance increase with age because of cultural differences and the independence need (Argyle and Dean, 1965; Iachini et al., 2016). On the other hand, other studies that focused on a broader range of age seem to suggest a curvilinear shape of IPS with an increase during childhood and adolescence, larger distances during adulthood and then a decrease during the older age (Remland, Jones and Brinkman,1995; Camperio Ciani and Malaman, 2002).

Attachment style

Overall, studies investigating the attachment style in relation with IPS demonstrate an association between emotional closeness and the regulation of IPS (Bar-Haim et al., 2002; Kaitz, Bar-Haim, Lehrer, and Grossman, 2004). Specifically, children security/insecurity attachment predicts the permeability of social space (Bar-Haim et al., 2002): children who are classified as secured attached with their mothers tolerate less intrusion into their interpersonal space in comparison with children who have an ambivalent attachment. Bar-Haim and colleagues found that adolescents classified as ambivalent showed shorter preferred distances and were less sensitive to intrusion. According to the authors, this can be explained by the fact that during childhood the ambivalent responses of their caregivers did not allow the constructions of solid boundaries of IPS and so the children did not develop a preferred

interpersonal distance. Moreover, another study by Kaitz and colleagues (2004), found that individuals with avoidant attachment style exhibit a preference for larger distances and were less tolerant to social space intrusion.

Familiarity

The acquaintance between two interacting individuals has been proven to influence IPS (Aiello, Thompson and Baum, 1981; Hayduk, 1983). Friends maintain closer distances compared to strangers. Indeed, friends are more in control with the situation during the interaction, and they do not feel any threat coming from the other person, so they do not need to use spacing as a control mechanism. Another explanation is that friendship is usually related to cooperative behaviors and this factor can explain the proximity showed by friends.

Culture

Since the beginnings studies on proxemics also focused on differences among different cultural backgrounds (Hall, 1966). Hall distinguished "*non-contacts cultures*" (e.g., Americans and North European people) from "*contact cultures*" (e.g., Latin Americans, Mediterranean and Arabian people). Individuals belonging to "*contact cultures*" generally tend to prefer nonverbal communication compared to people from "*non-contact cultures"*, so it is assumed that they maintain closer proximity with other people. These findings are supported by recent ecological studies that used videotape recording to observe interactions between individuals from North and South Europe (Remland et al., 1991; 1995).

Personality traits

Differences in social space have also been investigated in correlation with different personality features, but the evidence from this research are not consistent (Hayduk, 1983). One factor that seems to correlate with a reduction of IPS is extraversion (Lloyd, 2009). A study by Loo (1978) demonstrates that children with high levels of anxiety and hyperactivity exhibit an increase of IPS extension. Moreover, it has been shown that callous and unemotional traits are associated with a decrease of IPS. Recent studies, for instance, suggest that psychopathic traits as "Coldheartedness", namely insensitivity and lack of sympathy, seem to be associated with a reduction of interpersonal space (Vieira and Marsh, 2014). Finally, aggression seems to be related to IPS: studies on violent criminals found that these individuals have enlarged IPS and are more sensitive to intrusion (Hayduk 1983; Schienle, Wabnegger, Leitner, and Leutgeb, 2017).

Psychopathological disorders

Studies on clinical population showed an alteration of IPS in children with Autism Spectrum Disorder (ASD) (Gessaroli et al., 2013; Candini et al., 2017), as well as, in individuals with schizophrenia (Holt et al., 2015). Candini and colleagues (2017), for instance, investigated the permeability and flexibility of IPS in ADS children. They showed that children with autism present an enlargement of interpersonal distance, as compared to typically developing children; of relevance, the degree of social impairment influence IPS flexibility. Another study (Holt et al., 2015) explored the neural correlates and the preferred interpersonal distance in individuals affected by schizophrenia. The authors found a hyperactivation of the dorsal intraparietal sulcus in schizophrenic individuals in response to approaching faces. This hyper-activation was related to enlarged IPS. A study by Schienle and colleagues (2015), investigated space intrusion in women affected by borderline personality disorder. They found that in this kind of patients there is an increased extension of personal space.

Contextual factors

Other factors can shape and influence IPS. For example, the spacings and the lighting of a room: little rooms and poor lighting favored an increase of spacings between individuals. This is possibly due to the fact that close spaces and the poor lighting enhanced alertness and the perception of menace (Adams and Zuckerman, 1991). Another crucial factor in human interactions is the facial expressions of confederates: we are more prone to approach happy faces compared to angry faces (Vieira et al., 2017; Ruggiero et al., 2017). Moreover, Hayduk noticed that also social status of interacting people influences the spacing between them.

IPS measurements

Traditionally, two main classes of measurement has been used to study interpersonal distance: (1) *projective measures*; (2) *real-life measures. Projective measures* require the manipulation of dolls, silhouettes and paper, and pencil drawings. An example of a paper and pencil test is the "Comfortable Interpersonal Distance" scale (CID; Duke and Nowicki, 1972). In this test, on a piece of paper are depicted eight lines with a central hub; participants have to imagine standing on the hub and mark the lines indicating the minimum distance at which they would feel comfortable from another person approach. Another example of projective measures is the manipulation of dolls or silhouettes using the same criterion as the pencil and paper test.

Real-life measures involve the observation of actual spacing mechanisms, or paradigms that require to stop an experimenter at a minimum comfortable distance, or chair selection and placement. An example of real-life observations is more ecological experiments using video recordings or photographs or real-life interactions between participants (Heshka and Nelson, 1972: Remland et al., 1995; Kaitz et al., 2004). Among real-life measurement, the most utilized paradigm is the so-called "Stop-Distance paradigm". In this task, an experimenter stood at a certain distance from the participant and began to walk toward him/her. The participant is instructed to stop the experimenter when he/she begins to feel uncomfortable. At this point, the distance between the two is measured and used as an index of individual preferred interpersonal distance. Usually, except for experiments that require other manipulations, the experimenter and the participant are strangers. This precaution is taken to avoid possible effects of familiarity. During the task, the experimenter maintains a neutral expression and is instructed to look participant in the eyes. Usually, measurement with stop-distance paradigms, involve two conditions, namely "active" and "passive" (for example Iachini, Coello, Frassinetti and Ruggiero, 2014; Iachini, Pagliaro and Ruggiero, 2015; Patané et al., 2016). During the active condition is the participant that moves toward the experimenter, while in the passive condition is the experimenter that walks toward the participant. The comfortable distance is measured both in the active and passive condition. These two distances can be used as separate indexes or averaged in a unique index of mean preferred interpersonal distance.

Thanks to the advent of new technologies it has been possible to introduce another type of measurement that is in between the two above mentioned categories (i.e., paradigms involving the use of virtual reality). In VR paradigms, participants are projected in a virtual environment where a virtual confederate move toward them. Participants need to stop the virtual confederate at a comfort distance (for example see Bailenson, Blascovich, Beall, and Loomis, 2001; Ruggiero et al., 2016; Iachini et al., 2016).

In a review by Hayduk (1983), the author noticed that projective measures are not considered particularly reliable. Furthermore, the correlation between real-life and projective measures is considered particularly low (.39). So, it seems that there is no close correspondence between the two type of measurement. Another issue with projective measures is that it is difficult to transpose the measures obtained with dolls or CID scales into real-life environments. For this reason, these types of paradigms cannot be considered reliable indexes of real preferred interpersonal distance.

Since several studies utilized the stop-distance paradigm, in Table 1 is reported a brief review of the mean IPS found by studies that utilized this type of paradigm to assess IPS. For studies on clinical samples, I reported the measurement for the normative sample size.

Table 1. Review of studies that used the stop-distance paradigm to measure IPS. The mean IPS is expressed in meters. Also, the number of subjects for each study and mean age or age range of the sample are reported.

Authors	*Sample size*	*Age range or mean age*	*Mean IPS*
Greenberg et al., 1980	50	18-30	0.38 m
Hayduk, 1981	24	18-30	0.59 m
Hayduk, 1981	40	18-30	0.74 m
Kennedy et al., 2009	17	22-51	0.64 m
Gessaroli et al., 2013	23	9.6	1.59 m
Vieira et al., 2014	46	18-25	0.80 m
Holt et al., 2014	8	22-31	0.61 m
Iachini et al., 2014	36	18-37	0.51 m
Patané et al., 2016	24	19-27	0.66 m
Perry et al., 2015	42	18-35	0.55 m
Perry et al., 2015	13	24	0.85 m
Perry et al., 2016	10	53-65	0.69 m
Ruggiero et al., 2017	34	19-29	1.28 m
Patané et al., 2017	20	21-25	0.61 m
Candini et al., 2017	14	9.7	1.09 m

It can be seen that there are not univocal results on IPS measurement. This can be due to several factors: the different dimension of samples, different range of age, sex, cultural background and also subtle differences in the paradigm. For example, in the study by Perry and colleagues (2015) the experimenter was instructed to maintain a neutral facial expression, but his gaze was directed toward participants' knees.

Neural substrates of IPS

The origins of spacing mechanisms seem to rely on defensive mechanisms as already pointed out by the observations of Hediger (1955). A study by Graziano and Cooke (2005) on non-human primates identified two connected brain areas that seem to be implicated in defensive

actions: the *ventral intraparietal area* (VIP) and an area in the precentral gyrus, called *polysensory zone* (PZ). These two areas are located in the parietal lobe and the frontal lobe respectively. Graziano and Cooke (2005) hypothesized that VIP and PZ subserve sensory-motor defense mechanism of the body. VIP and PZ neurons exhibit a response bias to near or looming objects. Moreover, these neurons preferentially respond to object in the proximity of the body (near space < 20 cm), particularly to the head. VIP and PZ neurons can be considered as approaching detectors: they increment their fire rate to approaching stimuli and decrease their activity while objects are withdrawing from the animal head. So, this frontoparietal circuit in animals subserves behaviors in the space close to the body. Within these behaviors, it is reasonable to hypothesize that there are interpersonal interactions and the preservation of a comfort zone distance from other individuals. Findings from the research in animals are also supported by studies on human beings that confirm the role of this frontoparietal network in regulating the preferred interpersonal distance (Holt et al., 2014; Perry et al., 2016). A neuroimaging study by Holt and colleagues (2014) compared the responses of intraparietal sulcus and ventral premotor cortex to approaching stimuli. They found that both areas responded strongly to approaching faces compared to control stimuli and that the two areas were interconnected. The involvement of the frontal lobes in the regulation of interpersonal distance seem to rely specifically on the orbital frontal cortex, as demonstrated by studies on human beings and non-human primates: a lesion to this area leads to a reduction of IPS (Machado and Bachevalier, 2008; Schienle, Wabnegger, Schöngassner, and Leutgeb, 2015; Perry et al., 2016).

Another structure involved in the regulation of IPS is the amygdala (Kennedy, Gläscher, Tyszka, and Adolphs, 2009; Schienle et al., 2015). Amygdala is a subcortical nucleus involved in recognition of valence of emotional stimuli, in recognition of facial expression with emotional valence and in social cognition tasks. This structure is also involved in fear perception; thus, it is likely involved in warning mechanisms for threatening approaching stimuli (Kennedy et al., 2009). Evidence from animal studies suggests that amygdala is involved in regulating approach-avoidance mechanisms in social context (Emery et al., 2001; Mason, Capitanio, Machado, Mendoza, and Amaral, 2006). Rhesus monkeys with bilateral amygdala lesions show an increase of affiliative behaviors, a decrease of anxiety, particularly with first interactions with newly met individuals (Emery et al., 2001). Furthermore, monkeys with amygdala lesions seem to exhibit an increment of disinhibition in new situations (Mason et al., 2006). This evidence is corroborated by an exemplary single case study on a patient with

bilateral amygdala lesions (Kennedy et al., 2009) that showed a sensible decrease of preferred interpersonal distance.

Aims of the present research project

Given the premises discussed above, it seems reasonable that empathic abilities, psychopathic traits, and social space are tied constructs that share a common neural representation. The general aim of my dissertation is to disentangle their relationship investigating how personality and psychopathic traits in the general population shape and modulate interpersonal space and empathic abilities. Furthermore, I would like to explore how different brain lesions affect social cognition, emotional response, and social space.

Accordingly, Study 1 explores the presence of psychopathic and maladaptive personality traits in the general population. Moreover, I examined how different levels of dysfunctional traits influences social sensitivity and empathy.

Given the results of Study 1, that shows a positive relation between empathic abilities and personality and psychopathic traits in the general population, I have further investigated the relationship between these constructs and IPS. To this aim, Study 2 assesses different degrees of empathy, psychopathic and maladaptive personality features in relationship with the preferred interpersonal distance. Results of Study 2 highlight the role of personality traits related to impulsivity, aggressivity and psychopathic features in shaping social space.

The last study was aimed at exploring how brain damages affect IPS and empathy abilities. Since behavioral dysregulation seems to be a crucial factor for altering spacing mechanisms, Study 3, focused on the investigation of brain-damaged patients with behavioral symptomatology to confirm and explore their influences on the modulation of IPS. The second aim of Study 3 is to explore how brain damage affects empathic abilities.

Chapter 2

How personality and psychopathy traits predict empathic abilities and social sensitivity.

Study 1

Introduction

Psychopathy is a disorder characterized by a group of dysfunctional personality traits such as callousness, deceitfulness, impulsivity, behavioral and emotional dysregulation (Hare, 1993). The core features of this disorder are antisocial behavior and emotional dysfunction. Research on psychopathy primarily focused on the emotional dysfunction of these individuals. It has been demonstrated that psychopaths have an impairment in emotion recognition (Marsh and Blair, 2008; Wilson, Juodis and Porter, 2011; Dawel, O'Kearneya, McKonea, Palermo, 2012). Originally, the deficits in emotional recognition seemed to be linked to fear and sadness (Blair, 1995; Blair et al., 2004; Blair, 2006; Marsh and Blair, 2008). This evidence is important because one theory that explains the core deficits of psychopathy states that at its basis there is a lack of responsiveness to distress cues (Blair, Jones, Clark and Smith, 1997). However, recent findings suggest that the impairment in emotion recognition could be more general and not restricted to expressions of fear (Dawel et al. 2012). In any case, there is strong evidence to support a deficit in the recognition of emotions in different sensory modalities (e.g., visual, auditory). For instance, in a study by Blair and colleagues (2002) psychopaths did not show facilitation in response to auditory stimuli with an emotional valence compared to neutral stimuli.

In recent years, neuroscience gave a great contribution to the understanding of neural correlates of psychopathy (Tiihonen et al., 2008; Yang and Raine, 2009; Kiehl, Smith, Hare, Forster & Liddle, 2001; Blair, 2003; Pera-Guardiola et al., 2016; Medina, Kirilko, Fifer, 2016). The emotional processing deficits can be reconducted to a dysfunction in the limbic system, specifically in the amygdala (for a review Blair, 2013). This subcortical nucleus is involved in emotional processing (Phelps and LeDoux, 2005) and in fear learning (Davis and Whalen, 2001; LeDoux, 2003). In the development of psychopathic traits, amygdala dysfunction seems to have a strong role (Blair, 2003; Jones, Laurens, Herba, Barker and Viding, 2009; Dolan and Fullam, 2009; Marsh, 2016). In particular, there is an hypoactivation of the amygdala (Damasio, Tranel & Damasio 1990; Blair, 2001) in response to fearful stimuli both in young population with antisocial behaviour and psychopathic traits (Marsh et al., 2008; Jones et al. 2009; White et al., 2012), as well as in adults with a clinical diagnosis of psychopathy (Blair 1999, 2001). In addition to aberrant functionality patterns, recent neuroimaging studies also

found structural abnormalities in the amygdala (Yang, Raine, Narr, Colletti, Toga, 2010; Pardini, Erickson, Loeber, Raine, 2014; Vieira et al., 2017). Other neural areas involved in the development of psychopathic traits are the caudate and the ventromedial prefrontal cortex (Blair, 2003).

From a clinical point of view, some theories look at psychopathy as a continuum of personality traits that may exist in the general population (Levenson, 1995). These maladaptive core personality features have a dimensional characterization; in this perspective, different degrees of dysfunctional traits can be present in the general population. For this reason, the fifth version of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; APA, 2013) proposes, alongside the categorical model, a new alternative model of personality pathology, that assesses personality disorders according to a dimensional model to investigate the presence of a pathological personality on a continuum (Skodol, 2011). They also introduced a diagnostic instrument, the *Personality Inventory for DSM-5* (PID-5; Krueger, Derringer, Markon, Watson & Skodol, 2012) to evaluate five main domains (i.e., Negative affect, Disinhibition, Detachment, Antagonism, and Psychoticism). Maladaptive personality traits can be related to psychopathic traits (Strickland, Drislane, Lucy, Krueger & Patrick, 2013). The Disinhibition and Antagonism facets seem to reflect two domains of psychopathy (secondary and primary respectively). A study on an Italian sample corroborated these findings: the authors found that personality traits on the Antagonism domain correlate with primary psychopathy, while Disinhibition and Detachment are linked to secondary psychopathy (Fossati et al., 2013).

Given this evidence, if psychopathic traits may also be detectable in the general population, it is important to study non-clinical and non-institutionalized populations to better understand psychopathology. The relationship between personality features, psychopathological traits and empathy is still a matter of debate. This is one of the few studies that tested a large sample of healthy participants on personality traits, psychopathic features, and empathy to investigate how psychopathic and personality traits affect empathic abilities and the ability to understand complex emotions.

The aims of this research were: 1) investigate the association between specific personality traits and empathic abilities, considering the distinction between cognitive and affective components; 2) disentangle the relationship between psychopathic and personality traits, and a main component of the Theory of Mind, namely the ability of attribution of the relevant mental/emotional state of a person.

Materials and methods

Participants

309 healthy subjects took part in study 1 (mean age ± s.d. = 38 ± 16; range 18-70; 185 females). Participants were recruited among students of the University of Milano-Bicocca (younger subjects) and outside university for the elderly. Prior to experiment participation, they all gave their informed consent. All participants were introduced to the experimental procedure, but they were blind to the main purpose of the study. The experiment was conducted according to the local Ethics Committee and in line with the principles of the Declaration of Helsinki (World Medical Association, 2013).

Procedure

Personality Inventory for DSM-5

In order to assess personality traits, we used the Personality Inventory for DSM-5 (PID-5, Krueger, Derringer, Markon, Watson & Skodol, 2011). PID-5 is a self-report questionnaire that, according to the theoretical model of DSM-5 aims to evaluate personality traits from a dimensional perspective rather than in a categorical manner. It is composed of 220 items with a 4-point response scale. The instrument evaluates 25 maladaptive personality facets that can be grouped in 5 broader domains: *Negative Affectivity, Detachment, Disinhibition, Antagonism, and Psychoticism.* Here we used the Italian version of the brief form of PID-5 (PID-5-BF; Fossati, Somma, Borroni, Markon & Krueger, 2015). This short version includes 25 items; each item is rated on a 4-point Likert scale from 0 (= "*very false or often false*") to 3 (= "*very true or often true*"). Each item assesses a maladaptive personality trait; these items can be grouped to measure one domain. Every domain is measured by five items, so the total score for each broader facet is 15.

Table 1. Personality domains assessed by PID-5 BF and facets of personality traits for each domain.

Trait domain	Facets contributing to the domain
1. Negative affectivity	Emotional lability Anxiousness Separation insecurity Hostility Perseveration Restricted affectivity Submissiveness
2. Detachment	Anhedonia Depression Withdrawal Intimacy avoidance Suspiciousness
3. Antagonism	Manipulativeness Grandiosity Deceitfulness Callousness Attention seeking
4. Disinhibition	Impulsivity Irresponsibility Distractibility Rigid perfectionism Risk taking
5. Psychoticism	Perceptual dysregulation Eccentricity Unusual Beliefs and experiences

Levenson Self-Report Psychopathy Scale

The Levenson Self-Report Psychopathy Scale (LSRP, Levenson, Kiehl e Fitzpatrick, 1995) is a self-report questionnaire created to evaluate the presence of psychopathic traits in non-clinical population. This scale assesses psychopathy on two dimensions (i.e., primary

psychopathy and secondary psychopathy), according to Hare's conceptualization of psychopathy (Hare, 1993). Primary psychopathy refers to manipulativeness, lack of emotion, egocentrism, and deceitfulness; secondary psychopathy refers to antisocial behavior due to difficulties in controlling impulsivity and emotion.

The LSRP is made of 26 items. For each item, subjects must indicate their agreement on a 4-point scale from (1) strongly disagree (2) disagree somewhat (3) agree somewhat (4) strongly agree. From the LSRP, a primary psychopathy scale score can be derived (range 0-64), along with a secondary psychopathy scale score (range 0- 40) and a total score (range 0-104).

Interpersonal Reactivity Index

The Interpersonal Reactivity Index (IRI; Davis, 1983; Italian version Bonino, Lo Coco, Tani, 1998) is a self-report questionnaire that evaluates empathic abilities from a multi-dimensional perspective, measuring empathic abilities both in their affective and cognitive components. The affective dimension of empathy refers more to the feeling of sympathy and emotional resonance, while cognitive empathy refers to higher order abilities like Theory of Mind (ToM).

This instrument consists of 28 items that can be grouped in four subscales: (1) Perspective taking (PT) is the ability to adopt the point of view of others, while (2) Fantasy (FS) is the disposition to identify with imaginary characters in books and movies; PT and FS subscales are designed to measure the cognitive aspects of empathy. (3) Empathic concern (EC) refers to the feelings of sympathy and concern, and (4) Personal distress (PD) concern the anxiety in tense interpersonal situation; these two subscales reflect the affective side of empathy. Each item is measured on a 5-point Likert scale from 1 "never true" to 5 "always true".

Reading the Mind in the Eyes

Reading the Mind in the Eyes Test (RMET; Baron-Cohen, Wheelwright, Hill, Raste and Plumb, 2001) was created to test social intelligence. The task involves describing the emotional/mental state of a person based on only an image of their eyes, in a fixed-choice paradigm. Hence, it evaluates the Theory of Mind (ToM), even though the authors themselves state that RMET assesses only the first stage of ToM (i.e., attributing one's mental state).

Here we used the Italian version of RMET (Serafin & Surian, 2004); the RMET shows black and white pictures depicting the ocular region of actors and actress (stimuli examples are depicted in Figure 1). Below each picture there are four adjectives; the subjects' task is to

indicate which of them better describes the mental state of the portrayed person. Moreover, if subjects are unsure about some word meaning, they can refer to a glossary. All the adjectives refer to complex emotions and mental states (e.g., hopeful, hostile, tentative, intrigued, playful). All images are 4,8 x 12,2 cm; they are printed in A5 sheets on paper 80gr/m2. The total number of stimuli is 37 (the first is an example image and this item score is not added to the total score).

Figure 1. Examples of items from the Reading the Mind in the Eyes Test stimuli.

Statistical analysis

Data analyses were performed with R (R Core Team 2017). In order to assess the associations between questionnaires scores while controlling for other variables, we performed Pearson's partial correlations (James, 2002; Johnson and Wichern, 2002; Whittaker, 1990). Multiple regressions were conducted to investigate the relationships between psychopathy dimensions, personality traits, emotion recognition and empathy subscales. In order to explore possible influences of gender and age, we performed hierarchical regressions. Outliers detection was conducted using Grubb's test using the online software QuickCalcs (https://www.graphpad.com/quickcalcs/grubbs1/; ©GraphPad Software, 2018).

Results

Empathic abilities and psychopathy

A first exploration of gender differences on the IRI subscales revealed that female participants have higher scores than males on all empathy subscales. T-tests showed a significant statistical difference on "Perspective taking" (PT, $t_{(251)} = 4.3$, $p<.001$), with females (mean ± s.d. = 25.6 ± 4.2) scoring higher than males (mean ± s.d. = 23.4 ± 4.5). Females have also enhanced abilities regarding the "Fantasy" subscale (FS, mean ± s.d. = 24.8 ± 4.94) as compared to males (mean ± s.d. = 21.9 ± 4.9) ($t_{(263)} = 5.0$, $p<.001$). "Empathic concern" is significantly different between males (EC, mean ± s.d. = 24.5 ± 4.5) and females (mean ± s.d. = 27.8 ± 3.9): $t_{(238)} = 6.6$, $p<.001$. The same trend is revealed in "Personal distress" (PD) scale: males score is lower (mean ± s.d. = 16.0 ± 4.5) than females (mean ± s.d. = 20.1 ± 4.3).

In order to investigate the presence of an association between psychopathy and empathy, I performed partial correlations between IRI subscales and the two scales of LSRP (i.e., primary and secondary psychopathy scales). Results showed that primary psychopathy scores are negatively correlated to the ability to adopt the point of view of others: higher scores on PT scale are associated with lower scores on primary psychopathy ($r=-0.13$, $p=.02$). Moreover, there is a significant negative correlation between primary psychopathy and "other-oriented" feelings of sympathy and concern ($r=-0.30$, $p<.001$). No other significant correlations were found, neither for FS scale ($r=0.09$, $p=.11$) nor for PD ($r=-0.03$, $p=.62$). See Figure 2.

Regarding the other dimension of psychopathy, results unravel a positive correlation between secondary psychopathy and the natural tendency to be in fictitious characters' shoes and the anxiety in tense interpersonal situations: higher score on secondary psychopathy scale are associated with higher scores on FS ($r=0.17$, $p<.01$) and PD scales ($r=0.21$, $p<.001$). On the other hand, we found that secondary psychopathy is negatively correlated with empathic concern ($r=-0.20$, $p<.001$). No significant correlations were found with perspective taking ($r=-0.08$, $p=.18$). Results are shown in Figure 3.

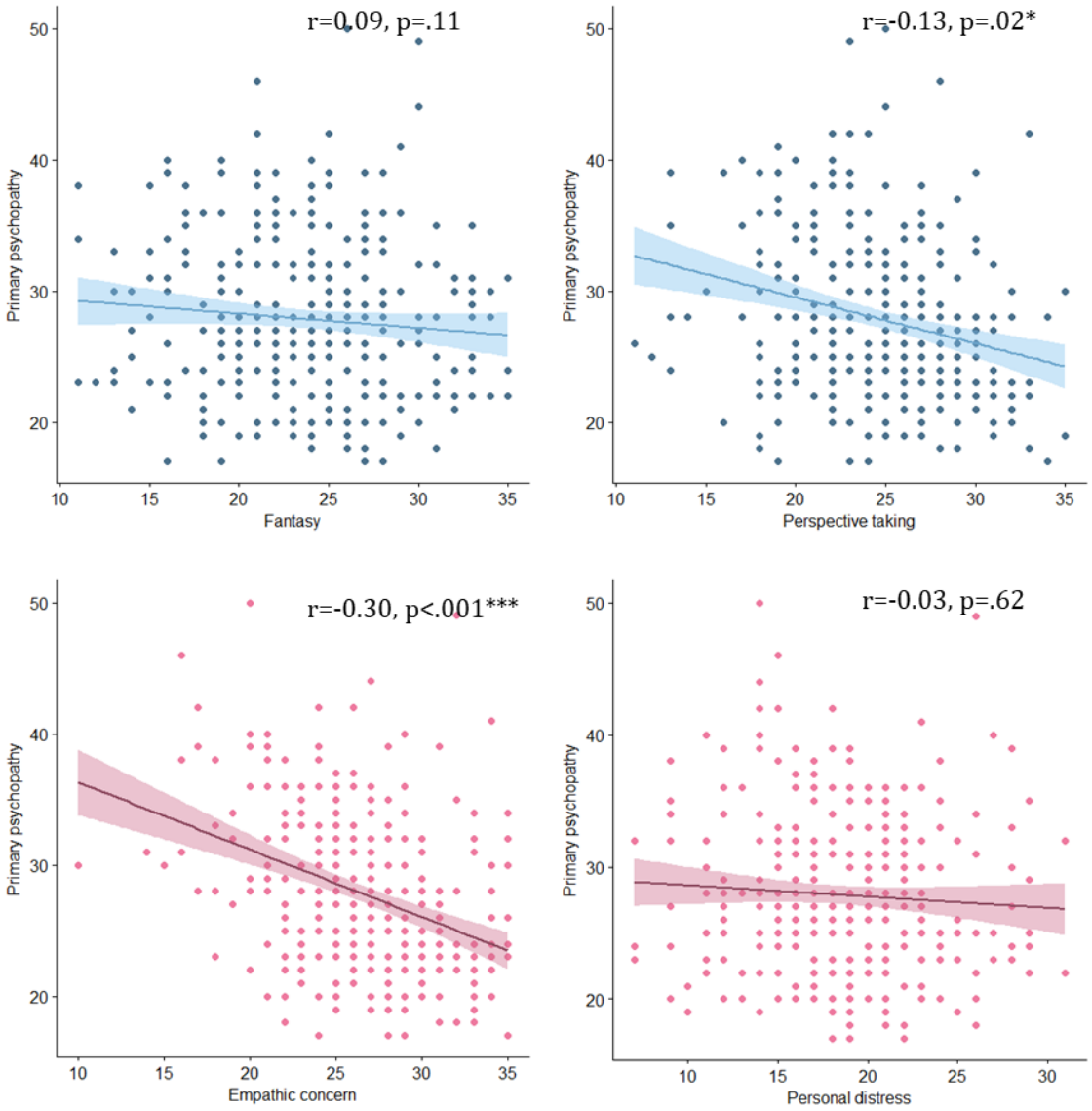

Figure 2. Scatterplots depicting associations between primary psychopathy and IRI subscales.

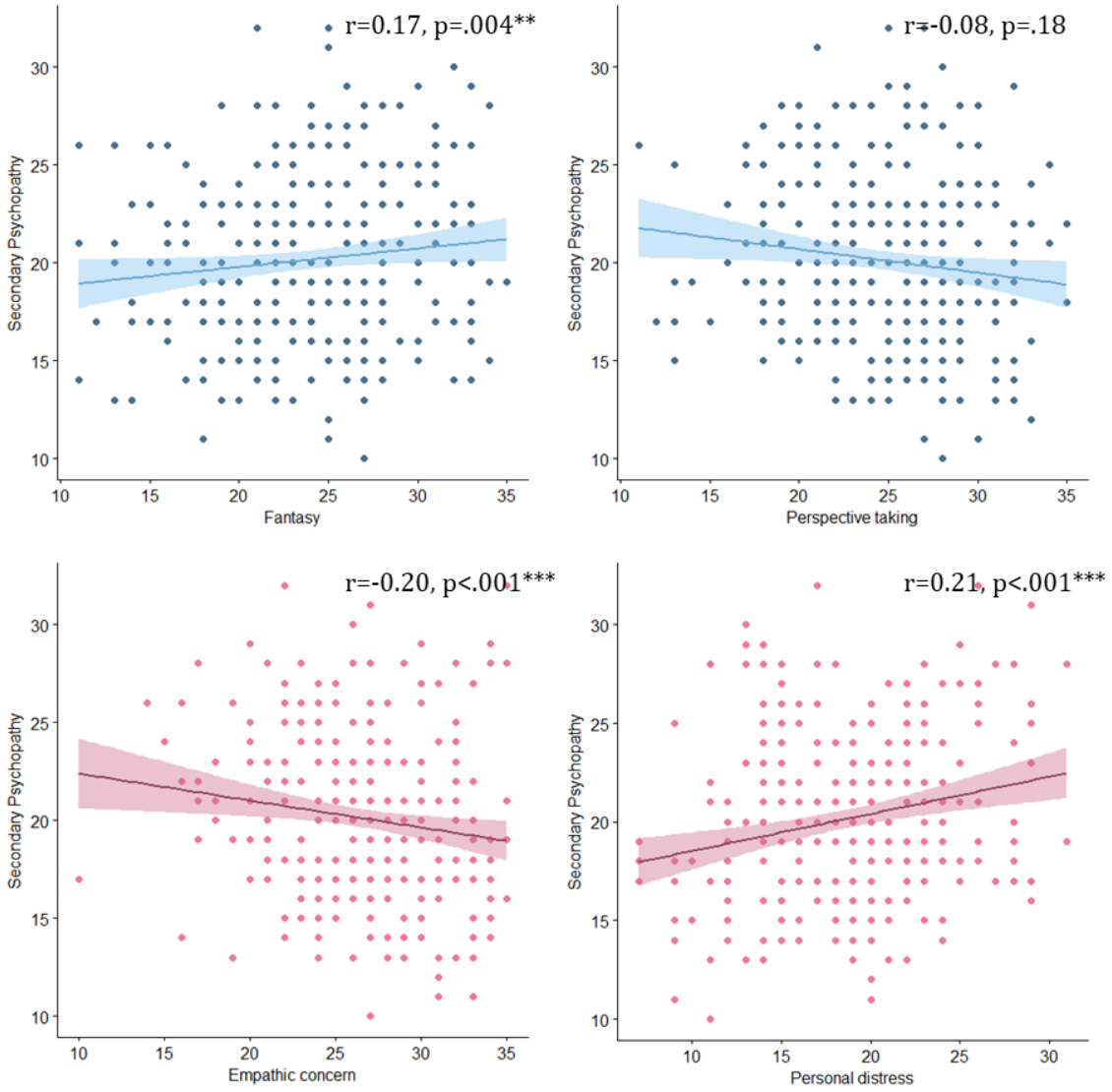

Figure 3. Scatterplots depicting associations between secondary psychopathy and IRI subscales.

In order to further investigate the relationship between empathic abilities and psychopathic traits, I performed multiple regressions with LSRP scales as predictors and IRI subscales as independent variables. Four separate regressions were conducted with one of IRI's subscales as predicted variables. Results are shown in Table 2.

Table 2. Multiple regressions models and coefficients

	β	adjusted R^2	F	p-value
Perspective taking				
Model goodness of fit		0.06	11.04	<.001
Primary psychopathy	-0.17***			
Secondary psychopathy	-0.06			
Fantasy				
Model goodness of fit		0.02	4.73	<.05
Primary psychopathy	-0.11*			
Secondary psychopathy	-0.18**			
Empathic concern				
Model goodness of fit		0.13	24.28	<.001
Primary psychopathy	-0.25***			
Secondary psychopathy	-0.05			
Personal distress				
Model goodness of fit		0.06	10.34	<.001
Primary psychopathy	-0.11*			
Secondary psychopathy	-0.29***			

Note *** significant at p<0.001; ** significant at p<0.01; * significant at p<0.05

Regressions highlighted that both scales predicted empathic abilities. In particular, primary psychopathy scores predicted all four subscales scores, while secondary psychopathy predicted "Fantasy" and "Personal distress".

With the aim to explore the influence of gender and age I conducted hierarchical regressions with *Gender* and *Age* as covariates. Results showed that *Gender* and *primary psychopathy* explains better the variance in PT scores (*Gender* β=0.19, p<.01; *primary psychopathy* β=-0.19, p<.01; adjusted R^2=0.10, F=9.27, p<.001). Females (mean ± s.d. = 25.6 ± 4.2) have higher scores than males (mean ± s.d. = 23.4 ± 4.5) on PT, while there is an inverse trend on the primary psychopathy scale (females: mean ± s.d. = 26.36 ± 5.59; males: mean ± s.d. = 30.12 ±

6.33). So gender seems to mediate the effect of primary psychopathy on perspective taking. Participants' gender seems to have an effect also on EC with females having higher empathic abilities than males (females: mean ± s.d. = 27.8 ± 3.9; males: mean ± s.d. = 24.5 ± 4.5). Again the best model to explain variance in empathic concern is the one that takes into account the contribution of *Gender* and *primary psychopathy*: *Gender* β=0.29, p<.001; *primary psychopathy* β=-0.25, p<.001; adjusted R^2=0.21, F=21.06, p<.001. For what concerns PD, I found an effect of *Gender* (β=0.41, p<.001) and *secondary psychopathy* (β=0.20, p<.001) (model goodness of fit: adjusted R^2 =0.21, F= 21.33, p<.001). Regarding secondary psychopathy, females seem to have slightly higher scores than males (females: mean ± s.d. = 20.26 ± 4.23; males: mean ± s.d. = 19.92 ± 4.13). Finally, FS scores seem to be better explained by *Gender* (β=0.25, p<.001) and *Age* (β=0.23, p<.001), but not by psychopathy dimensions (*primary psychopathy*: β=-0.08, p=.16; *secondary psychopathy*: β=-0.11, p=.05) (model goodness of fit: adjusted R^2 =0.13, F= 12.6, p<.001). Results are displayed in Table 3.

Table 3. Hierarchical regressions with gender and age as covariates, LSRP dimensions as predictors and IRI subscales as predicted variables

	Model 1				Model 2				Model 3			
	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value
Perspective taking		0.05	18.67	<.001		0.06	10.01	<.001		0.10	9.37	<.001
Gender	0.24***				0.24***				0.19**			
Age					-0.06				-0.1			
Primary psychopathy									-0.19**			
Secondary psychopathy									-0.09			
Fantasy		0.07	25.36	<.001		0.12	22.67	<.001		0.13	12.6	<.001
Gender	0.28***				0.28***				0.25***			
Age					-0.23***				-0.23***			
Primary psychopathy									-0.08			
Secondary psychopathy									-0.11			
Empathic concern		0.13	46.34	<.001		0.14	26.08	<.001		0.21	21.06	<.001
Gender	0.36***				0.36***				0.29***			
Age					0.12***				0.08			
Primary psychopathy									-0.25***			
Secondary psychopathy									-0.08			
Personal distress		0.18	65.81	<.001		0.18	34.05	<.001		0.21	21.33	<.001
Gender	0.42***				0.42***				0.41***			
Age					-0.07				-0.06			
Primary psychopathy									-0.01			
Secondary psychopathy									0.20***			

Note: *** significant at p<0.001; ** significant at p<0.01; * significant at p<0.05

Theory of Mind, empathy, personality traits, and psychopathy

To investigate the presence of an association between empathic abilities and ToM abilities, I performed partial correlations between either IRI's subscales and RMET scores. Results, shown in Figure 4, highlighted that FS is positively correlated with the recognition of complex emotions (r=0.12, p<.05); a small trend was found for PT (r=0.11, p=.05) and no other significant correlations were found (EC: r=-0.11, p=.067; PD: r=-0.04, p=.48).

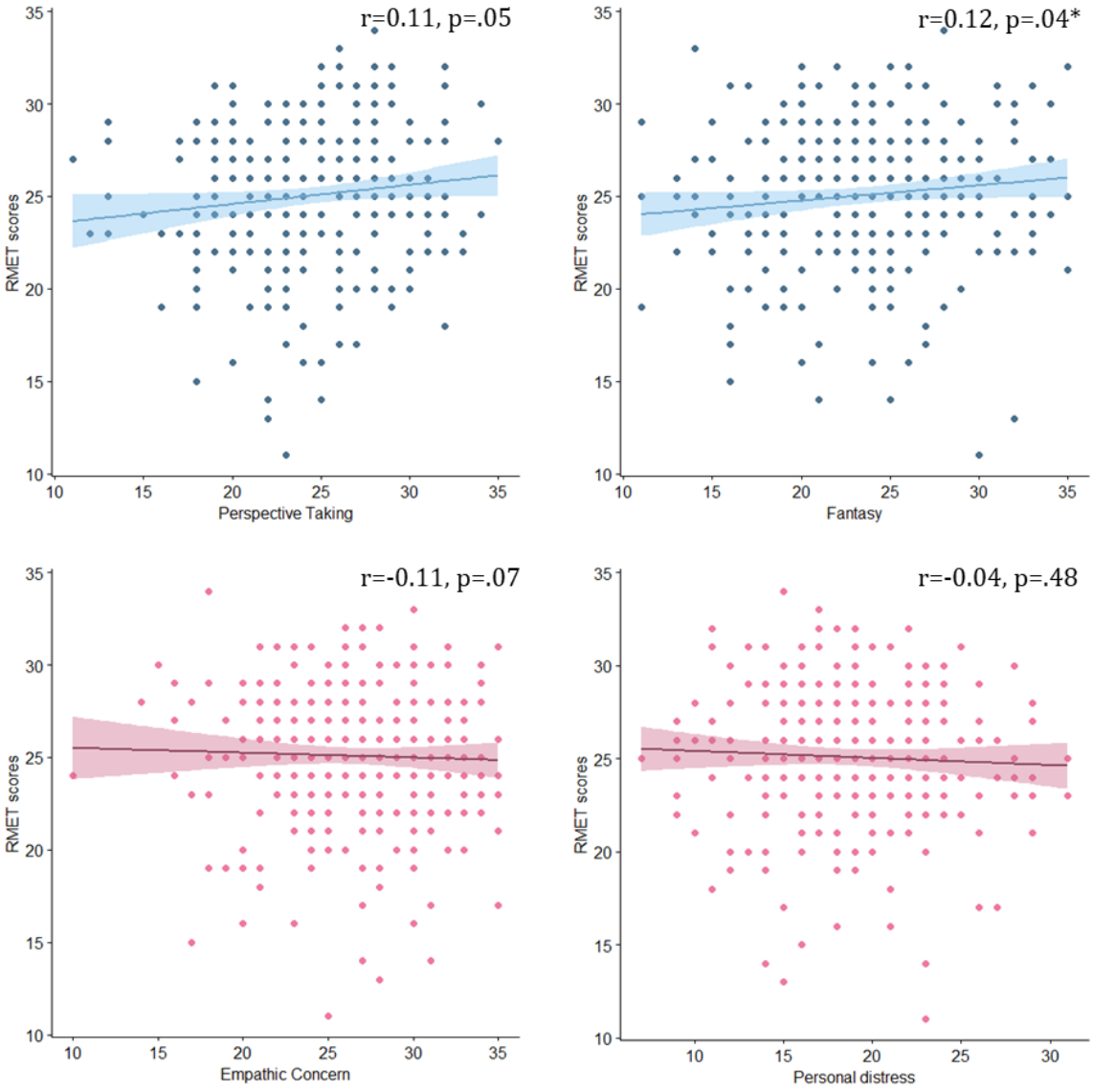

Figure 4. Scatterplots depicting the relationship between mental states recognition and empathic abilities.

Another goal of the present study was to explore the relationship between psychopathic traits and ToM abilities. I performed a multiple regression between LRSP scales and RMET performance. Results showed that neither primary psychopathy nor secondary psychopathy seems to predict RMET scores (primary psychopathy: β=-0.20, p=.54; secondary psychopathy: β=-0.07, p=.18; adjusted R^2 =0.002, F= 1.33, p=.27).

My final aim was also to explore the relationship between personality traits and emotions recognition, so we conducted partial correlations between PID-5 BF domains and RMET scores (results in Figure 5).

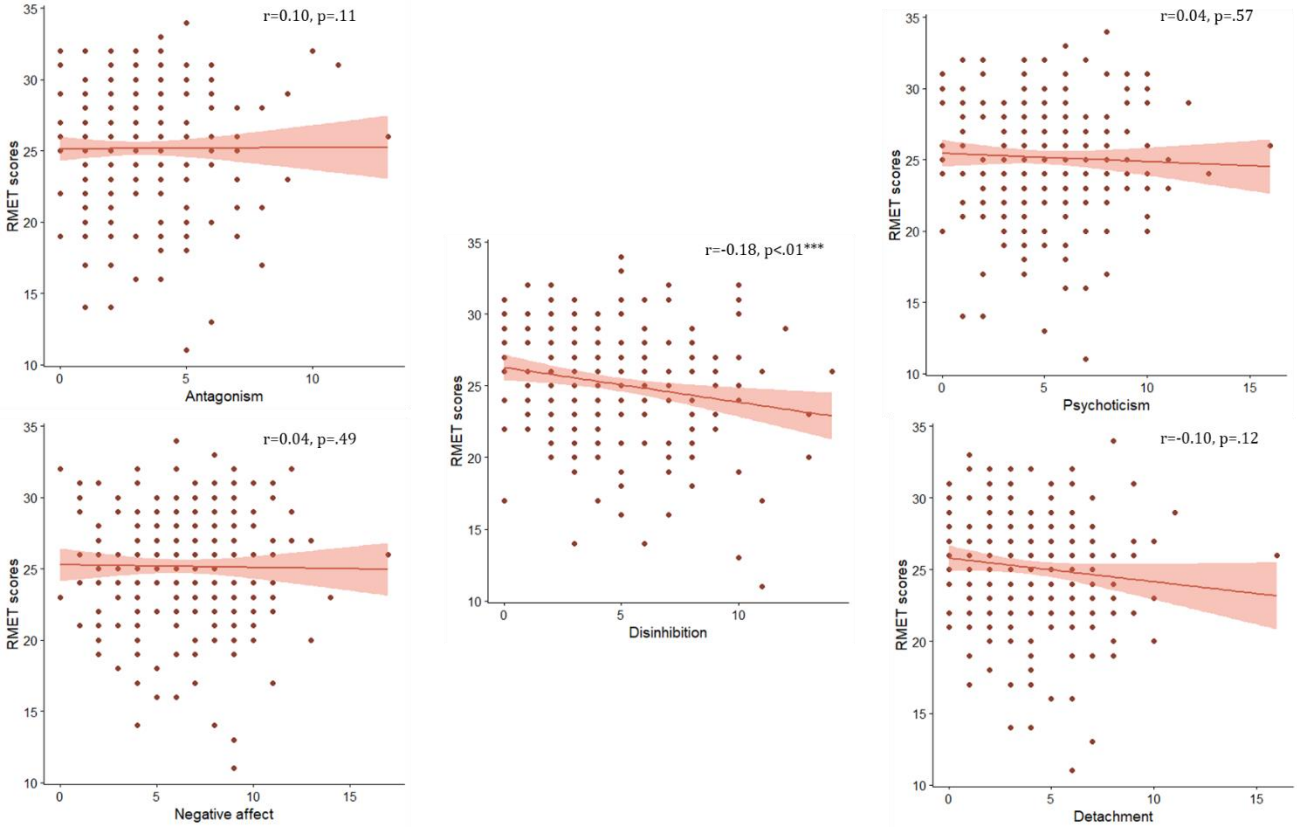

Figure 5. Scatterplots showing the relationship between PID-5 BF domains and RMET scores.

Results showed that *Disinhibition* scores were negatively correlated with participants' performance at the RMET (r=-0.18, p<.01). No other significant correlation was found (*Antagonism*: r=0.10, p=.11; *Negative affect*: r=0.04, p=.49; *Psychoticism:* r=0.04, p=.57; *Detachment*: r=-0.10, p=.12). To further investigate the relationship between core personality

facets and the ability to attribute complex mental states I conducted multiple regression with PID-5 domains as predictors and RMET scores as the dependent variable. Results again confirmed that Disinhibition domain predicted the performance at the RMET (β=-0.29, adjusted R^2=0.03, p<.01). The other personality facets do not seem to predict RMET score (*Antagonism*: β =0.21, p=.11; *Negative affect*: β =0.07, p=.49; *Psychoticism:* β =0.07, p=.57; *Detachment*: β =-0.21, p=.12). A hierarchical regression was also performed with *Gender* and *Age* as covariates (see Table 4).

Table 4. Multiple hierarchical regressions

	Model 1				Model 2				Model 3			
	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value
		0.001	1.3	0.26		0.04	6.66	<.01		0.07	3.83	<.01
Gender	0.07				0.08				0.06			
Age					-0.21**				-0.22***			
Negative affect									0.04			
Detachment									-0.01			
Antagonism									0.13			
Disinhibition									-0.21**			
Psychoticism									-0.003			

Note: *** significant at p<0.001; ** significant at p<0.01; * significant at p<0.05

Results display how *Age* and *Disinhibition* seem to predict performance at RMET (Age: β =-0.22, p<.001; Disinhibition: β =-0.21, p<.01; adjusted R^2 =0.07, F=3.83, p<.01). Gender does not seem to influence RMET score nor the other domains of PID-5.

Discussion

The present study tries to disentangle the relationship between empathic abilities, emotion recognition, core personality features and psychopathic traits on a large non-clinical sample. To my knowledge, this is the first study that tries to unravel the deep connections between all these domains in a non-clinical population. Moreover, there is no evidence about the relationship between psychopathic traits and the different cognitive and affective components of empathy in a non-institutionalized sample.

Previous studies investigated the connection between psychopathic or antisocial feature and empathic abilities or ToM's tasks, but not from a broader perspective. The findings of previous studies are conflicting because of different methodologies applied and different samples. For example, Sandvik and colleagues (2014) examined the link between psychopathy and the capacity to infer others' mental states in a group of male inmates. They found a dissociation in

the ability to mentalize: an impairment of mentalizing abilities in subjects with psychopathic traits related to antisocial and impulsive conduct and intact ToM skills in subjects with psychopathic traits related to the interpersonal and affective domain. Another study found that people with antisocial personality disorder and psychopathic traits have no difficulties in the recognition of complex emotions and simple ToM tasks (Dolan and Fullam, 2004). Ali and Chamorro-Premuzic (2010) found that primary psychopathy is associated with deficits in mentalizing abilities in a non-clinical sample. One hypothesis for this impairment in emotions recognition is that psychopathic individuals have scarce attention to emotional stimuli (Medina, Kirilko, Grose-Fifer, 2016). This proposal is in line with the results found by Medina and colleagues (2016), who measured brain responses to emotional stimuli in a college population. They found a reduced neural response in stimuli with emotional valence in subjects with higher psychopathic traits.

The results of the present study highlighted an association between empathic abilities and both subtypes of psychopathy. In particular, I found that scores on the primary psychopathy scales predicted the ability to adopt the point of view of others, the disposition to identify with imaginary characters in books and movies, the feelings of sympathy and concern and the anxiety in tense interpersonal situation; while the scores on the secondary psychopathy scales predicted the natural tendency to be in fictitious characters' shoes and the uneasiness in anxious interpersonal context. However, these effects were mediated by participants' age and gender. Taking into account these variables, primary psychopathy seems to predict empathic concern and perspective taking. This is in line with the construct of primary psychopathy that seems to reflect the tendency to manipulate others, lack of emotion, egocentrism, and deceitfulness; on the other hand, secondary psychopathy refers to antisocial behavior due to difficulties in controlling impulsivity and emotion. Once again this is in line with its relation to personal distress that relates to self-oriented feelings of discomfort in tense situations. These findings are in line with previous works on forensic population (Burke 2001) that found an impairment of empathic concern and perspective taking in adolescent sexual offenders.

I also found that the ability to attribute mental states is related to one specific empathic ability, namely the cognitive ability of an individual to identify with or imagine experiencing the events of fictitious characters (i.e., "Fantasy"): participants with higher level of this ability have better ToM skills. These findings are in line with the classical view of cognitive empathy that is usually linked to mentalizing functions (Davis, 1996; Ickes, 2003; 2009).

On the other side, psychopathic traits do not seem to predict nor correlate with emotions' recognition, at least when measured with the RMET. So, it seems that the presence of psychopathic features does not impair the recognition of complex emotional states from others' glance. These findings are in line with some studies that found preserved emotions recognition in the psychopathic population, highlighting the role of emotion recognition as a possible tool psychopaths use to manipulate their conspecifics subtly (Book, Quinsey and Langford, 2007; Pham, Ducro and Luminet, 2010; Migdley & Vrouva, 2013). Pham, Ducro and Luminet (2010), for example, found that inmates perceived themselves as better able to recognize other's emotions and to manage emotional states. Book, Quinsey, and Langford (2007) studied a forensic population and showed how psychopathic individuals were better in recognizing other's emotion and also emotional vulnerability. These findings seem to suggest that a preserved ability to recognize others emotion can be useful to psychopathic individuals to charm and manipulate their conspecifics.

However, the present results also showed that scores on the "Disinhibition" facet of the PID-5 predict participants' performance at the ToM test. Disinhibition is a personality feature related to antisocial traits, dysregulated behavior, and poor emotional control. Recent studies demonstrate that Disinhibition is related to secondary psychopathy (Strickland et al., 2013, Fossati et al., 2013). According to Hare's theory (1983), this type of psychopathy is more connected to antisocial personality traits, characterized by antisocial behavior, impulsivity, aggression, behavioral and emotional dysregulation. This is in line with the work by Fossati and colleagues (2013) that found a correlation between "Disinhibition" domain and secondary psychopathy. So, it seems highly probable that Disinhibition traits pertaining to impulsivity and risk-taking are linked with secondary psychopathy. This evidence is of particular interest because, on the other hand, primary psychopathy dimension does not seem to correlate with impairment of ToM. Primary psychopaths are usually manipulative, insensitive and show a lack of emotion (Karpman, 1948, Hare, 1983). This match the profile of "successful" psychopaths, individuals that save their "normal" appearance and show higher manipulativeness. To summarize, our findings show the presence of a deficit in ToM abilities in individuals with personality features linked to impulsivity and antisocial behavior. This again is in line with the findings of Sandvik and collaborators (2014), who showed, in a forensic sample, a dissociation in mental states recognition: an impairment of this ability in individuals with psychopathic traits on the antisocial domain; a preservation in psychopaths with dysfunctions in affective and emotional domain.

In conclusion, the present study offers novel insights on the complex relations between psychopathic and personality traits, empathic and mentalizing abilities in healthy individuals. Both psychopathy and empathy are multi-facets constructs: the presence of psychopathy traits on the two dimensions predicts different impairments in empathic skills. On the other hand, my evidence suggests that traits related to secondary psychopathy are related to ToM impairment. Also, my evidence seems to suggest a relationship between maladaptive personality domains, secondary psychopathy, and mentalizing abilities.

Chapter 3

Shaping social space: the role of psychopathy, personality, and empathic traits

Study 2

Introduction

Interpersonal space (IPS) or "*social space*" is the space surrounding the body that we maintain between us and our conspecifics (Hall, 1966). IPS is conceptually different from *peripersonal space* (PPS), that is a neuropsychological construct referring to an "*action space*" where we interact with objects in the environment. These two spaces can share some characteristics, but are functionally dissociated (Iachini, Coello, Frassinetti, Ruggiero, 2014; Patané, Farnè, & Frassinetti, 2017). IPS is a construct that belongs to social psychology, and it can be intended as the "*comfort distance*" that we set between us and other human beings (Sommer, 1969; Horowitz, 1964; Hall, 1966; Dosey & Meisels 1969). This area around our body is highly sensitive to intrusion and menace (Hediger, 1955; Hall, 1966): if an intruder invades our social space our anxiety, and aggression levels rise up. The flexibility and permeability of social space depend above all by the familiarity that we have with people around us (Pedersen & Shears, 1974; Hayduk, 1983). There are other factors that influence the social space surrounding us, as gender (Aiello, 1987; Sommer, 2002; Wabnegger, Leutgeb and Schienle, 2016), age (Aiello, & Aiello, 1974; Bar-Haim, Aviezer, Berso, Sagi, 2002), personality (Sommer, 2002; Lloyd, 2009), cultural background (Remland, Jones, & Brinkman, 1995; Hall, 1966; Beaulieu, 2004). Moreover, since interactions with our conspecifics shape the space around us, another crucial factor modulating its extent is the emotional valence of facial expressions of persons approaching our body: happy faces induce an approaching behavior, while angry faces lead to avoidance (Ruggiero et al., 2017; Vieira et al., 2017).

In some neurodevelopmental and psychiatric disorders, the IPS is altered: for instance, in individuals with autism, IPS extension is increased compared to individuals with typical development (Candini et al., 2017; Gessaroli, Santelli, di Pellegrino, & Frassinetti, 2013), in schizophrenia it is enlarged too (Holt et al., 2015). Such pathological alterations of IPS might explain some clinical symptoms of autism and schizophrenia, such as impaired social interactions. On a broader perspective, it is important to investigate how these pathologies affect the IPS distance in order to understand the mechanisms underlying the social space, paying the way for developing novel interventions for their treatment.

With respect to personality, it has been shown that callous and unemotional traits are associated with a decrease of IPS. Recent studies, for instance, suggest that psychopathic traits as "Coldheartedness", namely insensitivity and lack of sympathy, seem to be associated with a reduction of interpersonal space (Vieira and Marsh, 2014). Cold-hearted and callous personality traits are typically associated with psychopathy (Frick and White, 2008). It has been suggested that psychopathy and social space may rely on the same neural circuits. Vieira and Marsh (2014), found that psychopathic traits are associated with a reduction of amygdala activation. Psychopaths show dysfunctional and structural abnormalities within the amygdala (Birbaumer et al., 2005; Gordon, Baird and End, 2004; Yang, Raine, Narr, Colletti, Toga, 2010; Marsh and Cardinale, 2012; Ermer, Cope, Colhoun, Nyalakanti, Kihel, 2012; Marsh, 2016). Amygdala is a subcortical nucleus related to emotional processing but also to threat-avoidance mechanisms. There is evidence from neuropsychological studies supporting the theory that amygdala is involved in personal space processing. Studies on brain-damaged patients demonstrate that amygdala lesions led to impairment of emotional processing, but also to alteration of interpersonal space (Kennedy, Gläscher, Tyszka, Adolphs, 2009). The findings of this study support the hypothesis that psychopathy and interpersonal distance rely on the same neural mechanisms.

With respect to the neural basis of IPS, studies on animals (Graziano & Cooke, 2005) and humans (Holt et al., 2014) further showed the existence of a frontoparietal network involved in the regulation of IPS. In particular, the intraparietal sulcus and the ventral premotor cortex seem to respond to approaching stimuli that risk violating our comfort-zone. These findings are in line with the original theorization of our comfort zone as a *flight-zone* (Hediger, 1955). In addition to frontal and parietal areas, also the limbic system belongs to this neural network. Beyond the amygdala, the insula is also activated by IPS intrusion (Schienle, Wabnegger, Schöngassner, & Leutgeb, 2015; Schienle, Wabnegger, Leitner, Leutgeb, 2017).

So far, many studies shed light on contextual and personal features that influence the safe-space around us. However, there are conflicting findings about inter-individual differences in the extension of the IPS. This can be due to differences in methodologies applied to measure the comfort-zone. Indeed, some studies used virtual reality (VR) that can be useful but lacks in ecological validity (Iachini et al., 2014; 2016; Ruggiero et al., 2017). Even if VR is commonly used in neuroscience because it allows to have great experimental control while reproducing an environment similar to the one experienced in daily life, it is due to note that this approach

could still be perceived as artificial compared to the social interactions experienced by human beings. Another factor that could explain the controversial evidence concerning IPS could be the sample size: in previous studies, the authors focused on relatively small groups. In order to supply to this conflicting evidence, the aim of the present study was to investigate factors shaping IPS in a large population of individuals without history of psychological or neurological disorders. Moreover, the link between IPS extension and empathic abilities is still unknown. Previous scientific works on social space focused on "empathy" as a broader construct suggesting that personality traits as extraversion - that are usually connected with higher levels of emotional mirroring - may modulate the interpersonal distance that features the IPS. Other researchers investigated the role of emotional context in modulating IPS and once again the correct recognition of emotional interpersonal context is necessary for empathy (Ruggiero et al., 2017; Vieira et al., 2017). Additionally, works on psychopathic traits suggest a link with empathic ability because the core symptomatology of this disorder is a lack of empathy. However, previous studies did not look at empathy as a multi-dimensional construct from a cognitive and affective perspective. We hypothesized that individuals with increased empathic abilities – both cognitive and affective – may prefer proximity with other human beings. From an evolutionary perspective, proximity with conspecifics and increased empathy may help altruistic behavior and cooperation. Given these premises, I wanted to investigate the relationship between the IPS distance and personality features (as measured with the PID-5) and psychopathic traits, as well as with empathic abilities.

Materials and Methods

Participants

I recruited 267 healthy participants between 18 and 70 years of age (mean age = 37.33 ± 16.29; 166 females, 101 males). All participants gave their consent to take part in the experiment. The experiment was conducted according to the local Ethics Committee and in line to the principle of the Declaration of Helsinki (World Medical Association, 2013).

Procedure

I used the *Levenson Self-Report Psychopathy Scale* (LSRP; Levenson, Kiehl e Fitzpatrick, 1995) to assess psychopathic traits, the *Personality disorders Inventory for DMS-5* (PID-5, Krueger, Derringer, Markon, Watson & Skodol, 2011) to evaluate dysfunctional personality

facets and domains, the *Interpersonal Reactivity Index* (Davis, 1983) to measure empathic abilities (see Study 1 for details). Additionally, participants were tested with a paradigm to assess the preferred IPS (conceptualized as "comfort" distance) using an adapted *stop-distance paradigm* from Patané and collaborators (2016).

Stop-distance paradigm

Participants stood in front of the experimenter at a distance of four meters in correspondence of a marked position on the floor. In the "*Active comfort distance*" condition, participants were asked to walk toward the experimenter and stop when they did not feel comfortable anymore. In a second condition, the so-called "*Passive comfort distance*" condition, it was the experimenter to walk toward the subjects. In this case, the participant received the instruction to stop the experimenter whether they did not feel comfortable. The experimental paradigm is depicted in Figure 1. The two conditions were administered in two blocks in a randomized order. Within each condition, we collected five measures for a total of 10 measures per conditions and a total number of 20 trials. During all the paradigm the experimenter maintained a neutral facial expression and was told to look directly at participants' face. All experimenters were females and were not familiar with participants.

All distances were measured by a digital laser measurer (Zamo, Bosch), which has a sensitivity of 3 mm. I calculated the mean of preferred IPS distance for each condition.

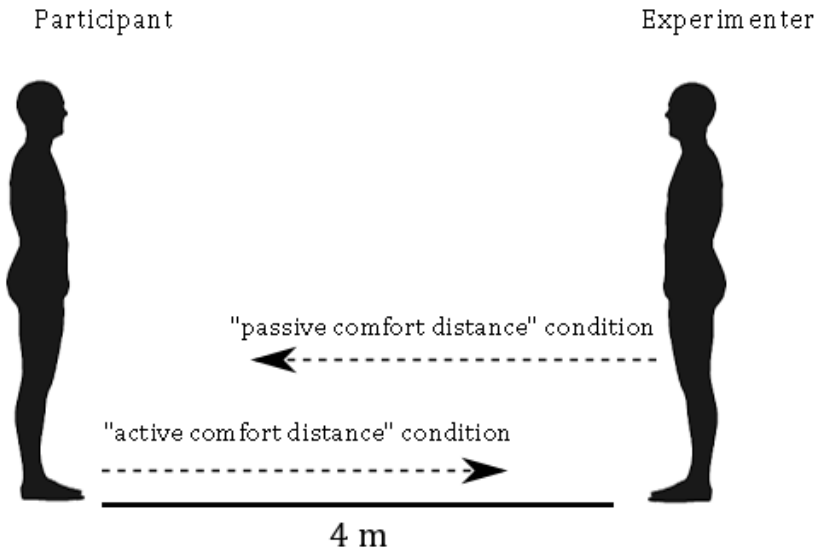

Figure 1. Illustration of the stop-distance paradigm.

Data analysis

Statistical analysis was performed with R (R Core Team 2017). No performance outliers were detected with the online software QuickCalcs (https://www.graphpad.com/quickcalcs/grubbs1/; ©GraphPad Software, 2018). To verify the association between questionnaires scores while controlling for the influence of other variables Pearson's partial correlations were used. Multiple regressions were conducted to investigate the relationship between personality domains or psychopathic traits and IPS distance (in cm). To evaluate the influence of gender and age on all these variables we used hierarchical regressions.

Results

First, I compared the two approaching conditions of the interpersonal distance paradigm (i.e., "Active comfort-distance" and "Passive comfort-distance"). The means (± standard deviation) of the two conditions were not significantly different (*Active comfort-distance* = 40.47±24.52

cm; *Passive comfort-distance* = 40.81±27.59 cm; $t_{(536)}$ =-0.15, p=.88). For this reason, I decided to collapse the two conditions and use the mean as an index of interpersonal distance. In order to investigate the presence of an association between IRI's sub-components and comfort-distance, I performed partial correlations. I found that only the IRI's Perspective taking (PT) subscale is negatively correlated with the mean interpersonal distance: higher scores on PT scale are associated with smaller comfort distance (r=-0.14, p<.05). No other significant correlations were found (EC: r=0.01, p=.8; PD: r=0.07, p=.23; FS: r=0.04, p=.49). Results are shown in Figure 2.

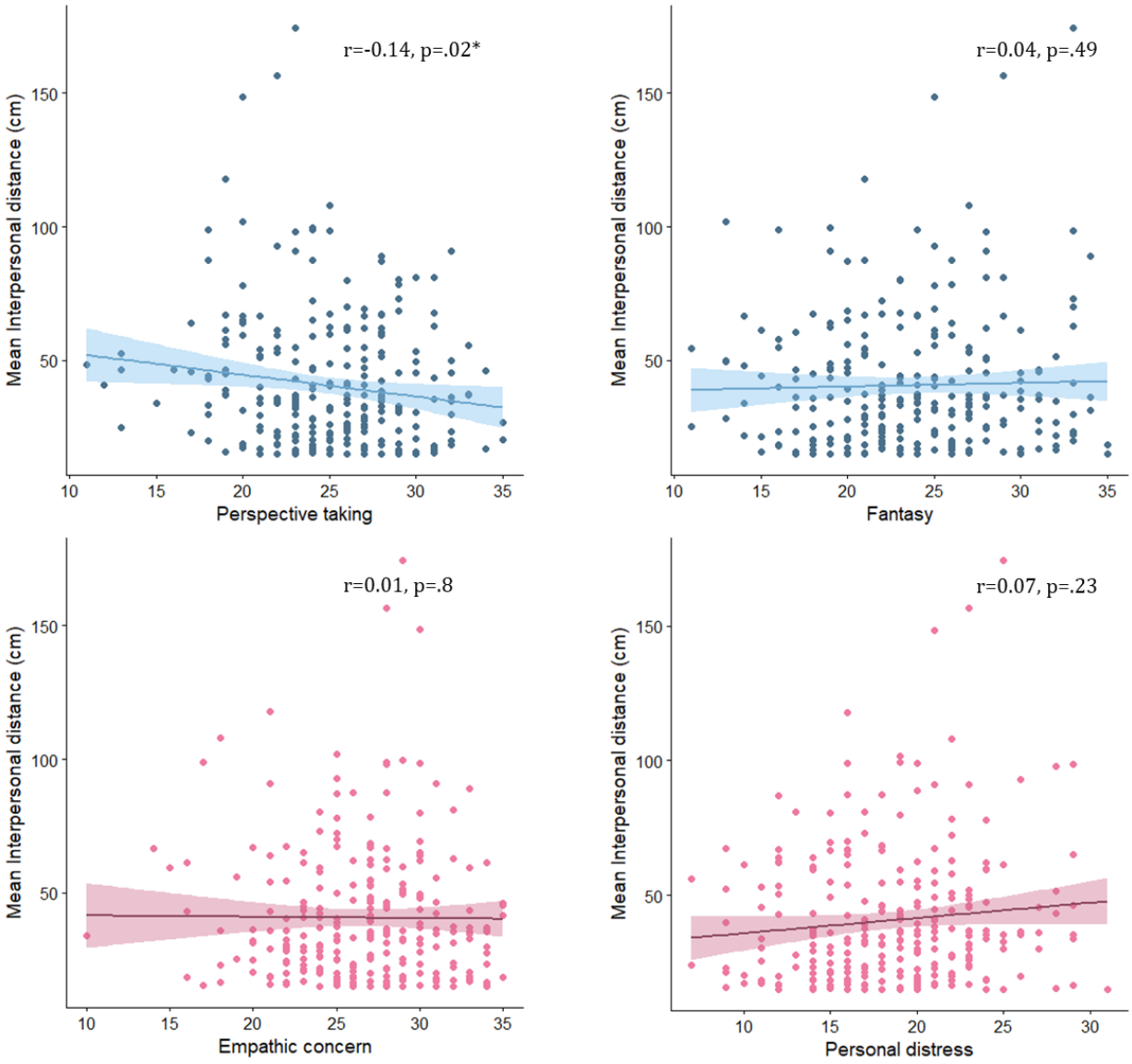

Figure 2. Scatterplots depicting correlations between IRI's subscales and the mean interpersonal distance.

To further explore the relationship between empathic abilities and social space, I performed a multiple regression with IRI's subscale as predictors and mean interpersonal distance as a dependent variable. Results showed that only PT scale predicts interpersonal distance (β=-0.91, p<.05). The effect of other predictors was not statistically significant (EC: β=0.09, p=.81; FS: β=0.24, p=.49; PD: β=0.42, p=.24). See Table 1 for results.

Table 1. Coefficients of multiple regressions with IRI's subscales.

	β	t	p-value
Empathic concern	0.09	0.24	.81
Perspective taking	-0.91	-2.29	.02
Fantasy	0.24	0.68	.49
Personal distress	0.42	1.19	.24
adjusted R^2 = 0.02, F=2.11, p=.07			

In order to control for *Gender* and *Age* effects, I performed a hierarchical regression. Results showed that neither *Gender* nor *Age* predicts participants' preferred distance (β= 0.01, p=.85 and β= 0.04, p=.56, respectively). PT seems to remain the best predictor for interpersonal distance (β= -0.16, p<.05); however, the fitted model is not the best to explain the variance in participants' preferred distance: adjusted R^2=0.01, F=1.47, p=.19. Results are shown in Table 2.

Table 2. Hierarchical regressions with gender and age as covariates.

	Model 1				Model 2				Model 3			
	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value
		-0.003	0.23	.63		-0.006	0.2	.82		0.01	1.47	.19
Gender	0.03				0.03				0.01			
Age					0.03				0.04			
Perspective taking									-0.16*			
Fantasy									0.06			
Empathic concern									0.04			
Personal distress									0.08			

Note: *** significant at p<0.001; ** significant at p<0.01; * significant at p<0.05

Another aim of the present study was to investigate the relationship between psychopathic and personality traits and social space. In order to achieve this goal, I first run two separate correlations between LSRP subscales and mean interpersonal distance. Results did not

highlight any significant association between psychopathy and interpersonal distance (*primary psychopathy*: r=-0.09, p=.15; *secondary psychopathy*: r=0.04, p=.53).

Partial correlations were executed to investigate the association between PID-5 scales and interpersonal distance. I found a negative correlation between Disinhibition and mean interpersonal distance (r=-0.15, p<.05). The other domains of PID-5 seem not to correlate with social space (*Antagonism*: r=-0.04, p=.52; *Detachment*: r=0.07, p=.28; *Negative affect*: r=-0.02, p=.76; *Psychoticism*: r=0.03, p=.64). See Figure 3.

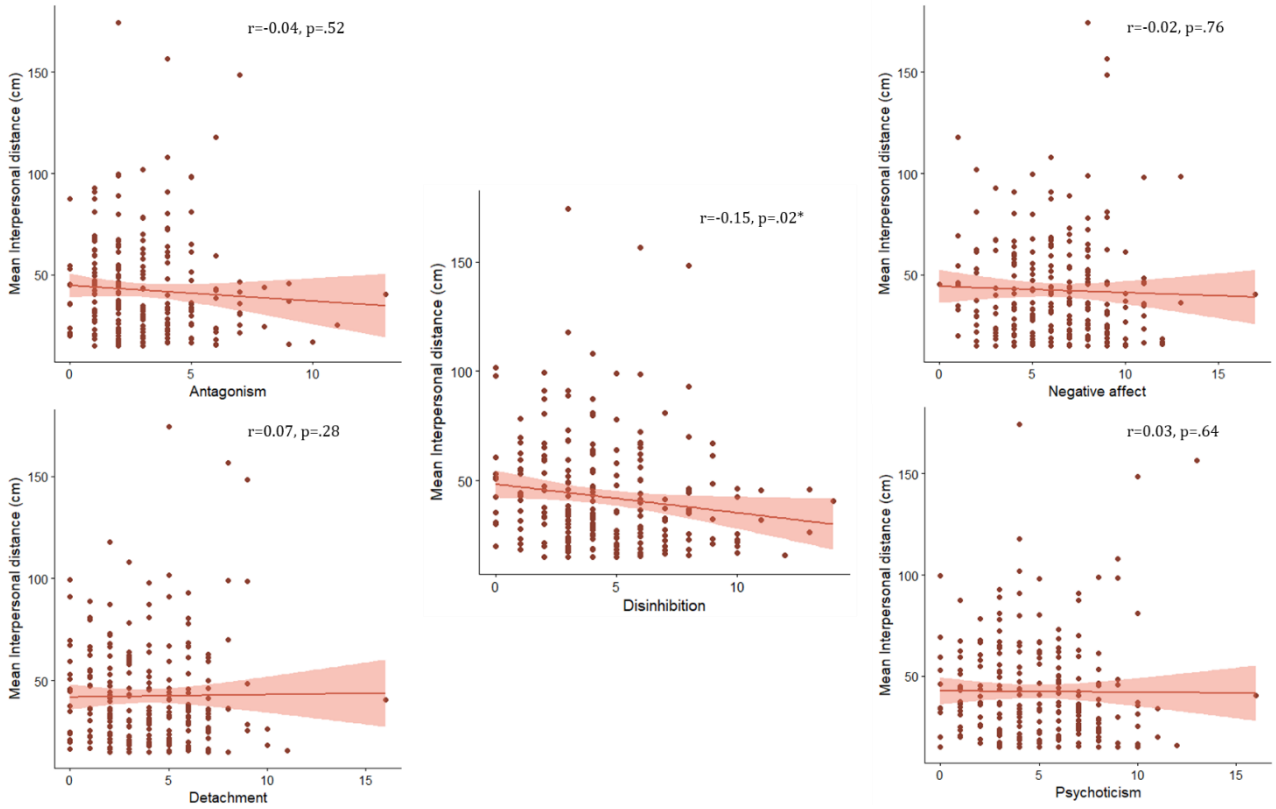

Figure 3. Scatterplots depicting the association between personality domains and social space.

I then performed a multiple regression with PID-5 domains as predictors and interpersonal distance as a dependent variable. Results highlighted that traits pertaining to *Disinhibition* facet seem to predict social distance (β=-0.16, p<.05), while the other domains have no significant effects (*Negative affect*: β=-0.24, p=.76; *Antagonism*: β =-0.61, p=.52; *Psychoticism*: β=0.41,

p=.64; *Detachment*: β=1.04, p=.28). Nevertheless, this model is not the best to explain the variance in the social space (adjusted R^2=0.01, F=1.41, p=.22).

In order to exclude the influence of *Gender* and *Age*, I also conducted a hierarchical regression with these variables as covariates (results in Table 3) and PID-5 domains as predictors. Results showed that neither Gender (β =0.06, p=.40) nor Age (β =0.12, p=.08) seem to predict IPS. Once again, the only personality facet that seem to predict the preferred comfort distance is *Disinhibition* (β =-0.17, p<.05), however the model does not seem to be the best to explain the variance in IPS (adjusted R^2=0.02, F=1.59, p=.14).

Table 3. Hierarchical regression with gender and age as covariates and PID-5 domains as predictors.

	Model 1				Model 2				Model 3			
	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value	β	adjusted R^2	F	p value
		0.002	1.44	.23		0.01	2.26	.11		0.02	1.59	.14
Gender	0.08				0.07				0.06			
Age					0.12				0.11			
Negative affect									-0.05			
Detachment									0.09			
Antagonism									-0.04			
Disinhibition									-0.17*			
Psychoticism									0.08			

Note: *** significant at p<0.001; ** significant at p<0.01; * significant at p<0.05

Given the fact that in the previous study (see Chapter 2) I found a correlation between the Disinhibition domain and secondary psychopathy, I have also performed two separate multiple regressions with PID-5 domains as predictors and primary and secondary psychopathy respectively as dependent variables. Results show that *Negative affect* and *Antagonism* better predict primary psychopathy traits (β=-0.40, p<.05 and β = 1.17, p<.001; adjusted R^2= 0.19, F=12.1, p<.001); on the other hand, *Detachment* and *Disinhibition* seem to predict secondary psychopathy (β= -0.49, p<.001 and β= 0.36, p<.001; adjusted R^2= 0.32, F=22.92, p<.001).

Discussion

The present findings showed how the interpersonal distance between us and our confederates is correlated with the disposition to embrace the psychological perspective of others. Additionally, the Disinhibition facet of PID-5 is also linked to the interpersonal distance: higher scores on the Disinhibition scale are associated with a decrease of the comfort distance. Disinhibition reflects impulsivity, irresponsibility, and distractibility, characteristics usually

associated with psychopathy. Accordingly, Disinhibition predicts psychopathic traits pertaining the so-called secondary psychopathy. On the contrary, no relationship between primary nor secondary psychopathy and interpersonal space were found.

Current scientific literature suggests that psychopathy, social space, and empathic abilities may be linked, but the nature of their relationship is still controversial. A first evidence of the common base of these constructs comes from their common neural correlates: anatomical structures belonging to the limbic system may be involved in spatial processing as well as in empathy and the development of psychopathy.

Our findings extend and elucidate previous findings by showing how the interpersonal distance between us and our confederates correlates with the disposition to embrace the psychological perspective of others. An increased capacity to take others' point of view, as reflected by PT subscale of the IRI, entails a reduction of IPS. This is in line with evidence that suggests that social skills shape the interpersonal distance between us and our conspecifics (Lloyd, 2009). It has been proven that personal features, like empathy and extraversion, can influence social space, but this is the first study to demonstrate, in a large sample, how empathy (considered from a multi-dimensional perspective) shape social space. Perspective taking seems to be the only facet of empathy that is associated with the comfort distance: indeed, the ability to take others' point of view is related to a shorter interpersonal distance. An explanation of this effect could be that increased cognitive empathy abilities facilitate the proximity with other human beings, and on the other side, the closer we are with our conspecifics, the better we can improve the ability to understand their perspective. Contrary to our expectations I did not find any relation with the affective facet of empathy: it is not the closeness with our conspecifics that help us to develop a better ability to mirror others' feelings. My findings are party different from the results of Ruggiero and colleagues (2017). They found that empathic concern and personal distress are correlated with interpersonal distance. The different findings can be explained by different methodologies employed: first of all, in the previous study the authors used a virtual reality version of the stop-distance paradigm. Secondly, the approaching stimuli had an emotional valence. They consisted in virtual confederates with happy, angry and neutral expressions. I, on the other hand, used a more ecologically version of the stop-distance paradigm. Moreover, there was no emotional component in our task, because the experimenter was told to maintain a neutral facial expression. These two big differences in the experimental task can account for the different results.

Furthermore, the present study provides novel evidence about the link between personality and IPS extension. No previous studies investigated how the presence of maladaptive personality facets influence the extension of social space. My results show that it is the Disinhibition facet (PID-5) that is correlated with the interpersonal distance: higher scores on the Disinhibition scale were associated with a decrease of comfort distance. Disinhibition is defined as "orientation toward immediate gratification, leading to impulsive behavior driven by current thoughts, feelings, and external stimuli, without regard for past learning or consideration of future consequences" (APA, 2013, p.780). It reflects impulsivity, irresponsibility, and distractibility, characteristics usually associated with psychopathy. Accordingly, we also found a that Disinhibition predicts the presence of secondary psychopathy, which refers to behavioral dysregulation linked with the propensity to aggression and antisocial behavior (Karpman, 1948; Lykken, 1957; Hare, 1993). On the contrary, no relationship between primary nor secondary psychopathy and interpersonal space were found. In literature, there is conflicting evidence about the relationship between psychopathy, antisocial behavior, and personal space. Studies on forensic and criminal population indicate that individuals with high levels of aggressivity and disposition to assault, two landmarks of the psychopathic behavior, have enhanced sensitivity to personal space intrusion (Schienle, Wabnegger, Leitneg, Leutgeb, 2017). It seems that an increase of alertness related to space intrusion could be an explanation for their propensity to violent conduct. On the other hand, a study conducted by Vieira and Marsh (2014) found that in college population cold-heartedness traits, usually linked with psychopathy, are associated with shorter preferred distance. The present findings confirm the existence of an indirect connection between psychopathy and decrease social space: maladaptive personality traits correlate with a decrease of IPS and at the same time these dysfunctional features predict the presence of psychopathic traits.

Moreover, Von Borries and colleagues (2012) demonstrate how psychopaths have reduced avoidance to threatening social stimuli. In our daily life, we tend to avoid threats for our sake; social space is also compared to animals' *flight-zone*: if we perceive danger approaching us our brains and bodies engage safety measures. Recent researches demonstrate how perceived social threats can modulate interpersonal distance (Vieira et al., 2017; Ruggiero et al., 2017). In a study by Vieira and collaborators (2017), participants maintained a greater distance from angry faces (perceived as threatening) compared to happy faces. Psychopathic features, combined with shorter preferred interpersonal distances, enhanced sensitivity to space intrusion and lack of mechanisms to avoid threats, can explain why these individuals tend to assault others.

In conclusion, our findings highlight the role of personality facets associated with impulsivity and secondary psychopathy in shaping social space. Behavioral dysregulation is associated with psychopathic traits and shorter interpersonal distance. The present findings highlight the role of maladaptive personality traits in shaping social space: the presence of dysfunctional traits in the normal population and the consequences on social interactions can shed light also on the symptomatology typical of individuals with personality disorders. A reduction of IPS is related, on the one hand, to impulsivity and disinhibition, on the other hand, to preserved cognitive empathic abilities. This could explain why psychopaths show a tendency for antisocial behavior, but also how their preserved mentalizing abilities help them to manipulate other human beings.

To summarize, the major features that may influence interpersonal space are impulsivity traits and the ability to assume the others point of view. Both of these individual core characteristics seem to be associated with a shorter comfort distance.

Chapter 4

How brain damage affects interpersonal space and empathy

Study 3

Introduction

Interpersonal space (IPS) is defined as the space surrounding the body and working as a defensive zone; it has been suggested that IPS can be similar to animals' flight-zone and it relies on defensive-mechanisms being sensitive to intrusion (Hediger, 1955). This space can be seen as a flexible "comfort-zone", modulated by social and biological mechanisms.

The neural basis of preferred interpersonal distance seems to rely on a frontoparietal network, as well as on subcortical regions such as the amygdala (Kennedy et al. 2009; Holt et al., 2014; 2015; Schienle, Wabnegger, Schöngassner, and Leutgeb, 2015; Perry et al., 2016). Animal studies show that interconnected areas of the frontal and parietal cortex are involved in defensive mechanisms (Graziano and Cooke, 2005). A dysfunction in the connectivity between frontoparietal areas, or a lesion to these brain regions, appears to be related in a modification of the social space (Holt et al., 2014). A neuroimaging study by Holt and colleagues (2014) compared the responses of intraparietal sulcus and ventral premotor cortex to approaching stimuli. They found that both areas responded strongly to approaching faces compared to control stimuli and that the two areas were interconnected. Regarding the role of the amygdala in the regulation of social space, a single case study on a patient with bilateral amygdala lesion demonstrates that a selective impairment to this structure leads to a reduction of IPS extension (Kennedy et al., 2009). The involvement of the frontal lobes in the regulation of interpersonal distance seems to rely specifically on the orbital frontal cortex, as demonstrated by studies on human beings and non-human primates: a lesion to this area leads to a reduction of IPS (Machado and Bachevalier, 2008; Machado, Kazama and Bachevalier, 2009; Perry et al., 2016).

It is still unclear in which direction (i.e., expansion vs. reduction) this change in the IPS should go and, more importantly, how these alterations are related to traits as impulsivity and behavioral changes. Previous studies found a reduction of IPS subsequent to selective damage to the amygdala (Kennedy et al., 2009; Harrison et al., 2015) or the orbital frontal cortex (Machado and Bachevalier, 2008; Perry et al., 2016); on the contrary other evidence suggests that impairment in this network leads to an increase of IPS extension (Bachevalier et al., 2006; Holt et al., 2015; Schienle et al., 2015). My previous research (Chapter 3) demonstrates that personality traits as disinhibition and impulsivity are related to a reduction of the preferred

interpersonal distance. Furthermore, studies on individuals with psychopathological disorders involving symptoms such aggression, impulsivity, and emotional lability showed a reduction of preferred interpersonal distance (Vieira et al., 2014; Schienle et al., 2017). Also, brain-damaged patients with lesions involving the frontal cortices showed behavioral changes in the direction of aggression, impulsivity, and disinhibition. Given these premises, we hypothesized the presence of an alteration of IPS in brain-damaged patients exhibiting a behavioral dysregulation.

Since amygdala and orbitofrontal cortex are part of a neural network involved in emotional processing, and on a broader perspective, on empathy (Fan et al., 2011), another aim of the present work is to investigate empathic abilities in a brain-damaged population. Moreover, as mentioned above, empathy is one of the factors influencing IPS. For example, recent studies suggested that individual with lack of empathy, such as psychopaths (Viera et al., 2017), exhibit a reduction of IPS. A recent study has shown that individual differences in empathic traits are related to the preferred comfort-distance (Ruggiero et al., 2017): an enhancement in empathic concern traits is associated to shorter comfort distance, while elevated levels of personal distress correlate with enlarged distances. Additionally, in the previous chapter, I showed that, in neurologically healthy individuals, perspective taking abilities are associated with a decrease of IPS extension. To further investigate the impact of brain lesions on empathic traits, and the relationship between behavioral dysregulation and IPS regulation, the present study examines the differences in empathy and IPS in a specific brain-damaged sample compared to neurologically unimpaired individuals. I have focused on BD patients with a clinical symptomatology of dysexecutive and behavioral disorder. The hypothesis of an alteration of social space was based on previous evidence showing a modulation in the social space in human beings and primates with a frontal lobe damage (Butter and Snyder, 1972; Izquierdo et al., 2005; Perry et al., 2016) or a subcortical lesion involving amygdala (Kennedy et al., 2009). The inclusion criteria for the patient group was a diagnosis of dysexecutive impairment and behavioral and personality changes in the sense of disinhibition (assessed by neuropsychological examination and by FAB and FBI). To summarize the present study aims at 1) investigating if a behavioural dysregulation due to brain damage impairs the social space; 2) exploring how brain damage affects empathic abilities and examine the role of empathy in the regulation of IPS.

Materials and methods

Participants

Seven brain-damaged (BD) patients (mean age = 60.63, sd= 17.92), were recruited from hospitals Istituto Auxologico of Milano and Istituti Clinici Zucchi of Carate Brianza.

The inclusion criteria for the patient group was an impairment of executive functions associated with a behavioral dysregulation syndrome not necessarily due to damage circumscribed to the frontal cortex. BD patients' demographics and causes of brain lesion are reported in Table 1. For the control group, 40 participants with no history of neurological or psychological disorders were recruited. The two groups did not differ for age (BD patients: mean ± ds = 60.63 ± 17.92; healthy participants mean ± sd = 61.05 ± 14.21; $t_{(46)}$=-0.074, p=.94) nor for years of education (BD patients: mean ± sd =13.88 ± 5.49; healthy participants: mean ± sd = 13.55 ± 4.16; $t_{(46)}$=0.19, p=.85).

Every patient underwent a standard neuropsychological assessment of cognitive deficits; since patients were recruited in different clinical institute, they were tested with different psychometric tests for measuring frontal deficits, such as *Behavioral Assessment of Dysexecutive Syndrome* (BADS; Wilson, Evans, Alderman, Burgess, & Emslie, 1997) and the *Wisconsin Sorting Card Test* (WCST; Heaton, Chelune, Talley, Kay, and Curtiss, 1993).

Table 1. Demographics and cause of brain damage of the patients.

	Gender	***Age***	***Years of education***	***Aetioloy***
P1	F	49	18	trauma
P2	M	84	13	vascular
P3	M	62	18	aneurysm anterior communicating artery
P4	M	72	5	trauma
P5	M	49	13	trauma
P6	M	75	21	vascular
P7	M	28	10	trauma

Lesion mapping

I collected computerized tomography (CT) and magnetic resonance (MR) images to identify the brain lesions. Lesion mapping was performed with the free software MRIcro (http://www.mricro.com; Rorden & Brett, 2000). Only one patient did not have any brain image available so lesion mapping was performed only on seven BD patients. In order to correctly locate each lesion, the patient's scan was re-oriented and adapted to an MRI standard template (ch2 template; Holmes et al., 1998). Then the lesion was manually mapped on each correspondent template slice. Finally, the lesion is rotated back in order to adapt to the stereotaxic template. Overlays of brain lesions are shown in Figure 1; the minimum degree of overlapping is colored in violet, the maximum overlapping is in red. Mean lesion volumes were 91.01 cc^3 (±85.71 , range 3-228.1). As it can be seen the area with the maximum degree of overlapping is in the frontal lobe (mean of voxels affected by the lesion = 3933.49 ± 3668.10). However, the patient group present heterogeneity of lesioned areas.

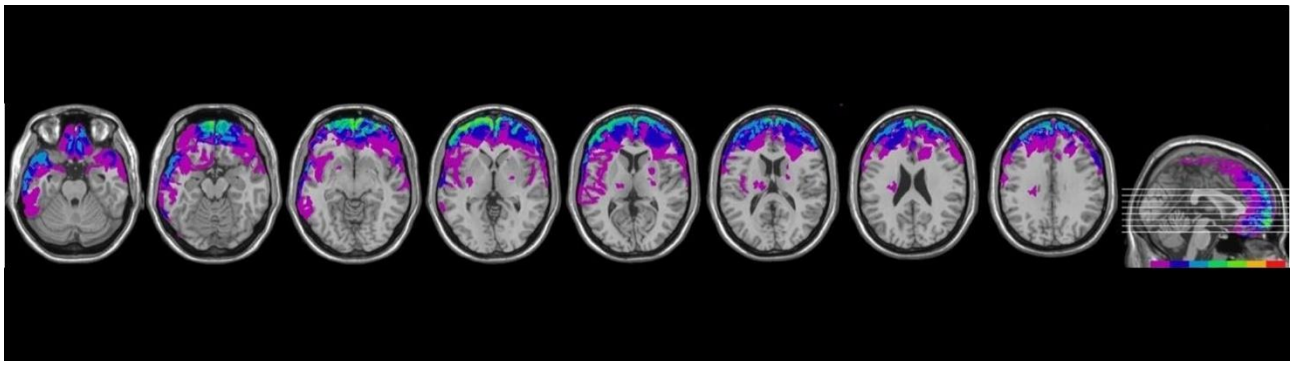

Figure 1. Overlays of lesions mapping for the seven brain-damaged patients. Each color represents 20% increments, from green areas indicating maximum overlap, pink areas minimum overlap.

Procedure

Assessment of frontal dysfunctions

Frontal Assessment Battery

In order to evaluate the presence of dysexecutive syndrome, the Italian version of the *Frontal Assessment Battery* (FAB; Appollonio et al., 2005) was administered. FAB was used since the neuropsychological evaluation carried out at the hospital admission comprised different clinical tests. FAB is a screening test that evaluates multiple cognitive or behavioral domains related to the frontal lobes (i.e., sensitivity to interference, mental flexibility, conceptualization,

motor programming, inhibitory control, and environmental autonomy). The global performance on these six subtests gives a composite score summarising the severity of the dysexecutive syndrome, whereas individual subscores might suggest a descriptive pattern of executive dysfunction in a given patient. Each section has a range score between 0 and 3; the maximum total score is 18. The raw score is corrected for age and years of education.

In Table 2 are shown patients' FAB scores. P5, was not collaborating, so FAB was not administered.

Frontal Behavioral Inventory

The *Frontal Behavioral Inventory* (FBI; Kertesz, Davidson, & Fox, 1997) is a questionnaire, directed to patients' caregivers, developed to assess the severity of behavioral symptoms. FBI assess not only the presence of symptoms but also their severity. Caregivers need to indicate on a scale from 0 (="none") to 3 (="severe") personality or behavioral changes of the patient. The instrument is made of 24 items, divided into two sections (A and B). Section A assesses negative symptoms (e.g., apathy, aspontaneity, inattention); the second section evaluates positive symptoms (e.g., irritability, impulsivity, aggression, obsessions).

Table 2. FAB and FBI scores for each patient.

	FAB raw score	***FAB adjusted score***	***FBI A section***	***FBI B section***	***FBI total***
P1	17	16.7	5	2	7
P2	8	9.7	3	0	3
P3	11	10.2	5	1	6
P4	7	9.54	10	11	21
P5	NA	NA	21	8	29
P6	17	16.7	3	2	5
P7	11	9.74	17	14	31

Empathic abilities assessment

The Italian version of the *Interpersonal Reactivity Index* (IRI; Bonino, Lo Coco, Tani, 1998) was used in order to evaluate empathy. IRI is 28-items self-report questionnaire that measures

empathic abilities from a multi-dimensional perspective. The 28 item can be arranged in four subscales: Perspective taking (PT), Empathic concern (EC), Personal distress (PD), and Fantasy (FS). Each item is evaluated on a 5-point Likert scale from 1 "never true" to 5 "always true". For more details see Chapter 2.

Stop-distance paradigm

In order to assess the interpersonal distance, we used the stop-distance paradigm adapted from Patané and colleagues (2016). The test starts with the experimenter and the participant at a distance of four meters. The starting position is marked on the floor. There are to approaching conditions (i.e., "*Active-comfort distance*" and "*Passive- comfort distance*"). During the "*Active comfort distance*" condition, the participant is told to walk toward the experiment and stop when he/she feels at a comfortable distance from the experimenter. During the "*Passive-comfort distance*" condition the experimenter walks toward the participant, and he/she is told to stop the experiment when the latter is at a comfortable distance from the participant. The experimenter approached the participant at a constant pace with neutral facial expressions and looked into participants eyes. We took five measures for each condition, the conditions were arranged in blocks, and each block comprised ten trials. The order of the conditions was randomized between blocks. Each participant underwent two blocks of trials for a total number of 20 trials. The distance was measured with a laser measurer (Zamo, Bosch; sensitivity ± 3 mm).

The assessment of frontal dysfunction (i.e., FAB and FBI), as well as, the measure of empathy (i.e., IRI) occured prior to the administration of the stop-distance paradigm.

Data analysis

Statistical analysis was performed with R (R Core Team 2017). No performance outliers were detected with the online software QuickCalcs (https://www.graphpad.com/quickcalcs/grubbs1/; ©GraphPad Software, 2018). I used Welch independent t-test to assess differences between groups (patient vs. controls) in preferred interpersonal distance (measured in centimeters) and in empathic abilities. Welch t-test is a modified version of the classical Student's t-test, commonly used when groups have unequal variance or unequal sample size (Welch, 1947; Ruxton, 2006). To verify the association between questionnaires scores and IPS Pearson's or Spearman correlations were used.

Results

Given the fact that the two conditions of the stop-distance paradigm were not statistically different ($t_{(94)}$ =0.14, p=.89), they were collapsed, and a mean of IPS distance was subsequently used for the analysis.

First of all, I ran a Welch two sample t-test to explore the difference in IPS between patient and control group. The two groups did not differ significantly: $t_{(6)}$ =0.69, p=.51. Means for the groups are shown in Figure 2.

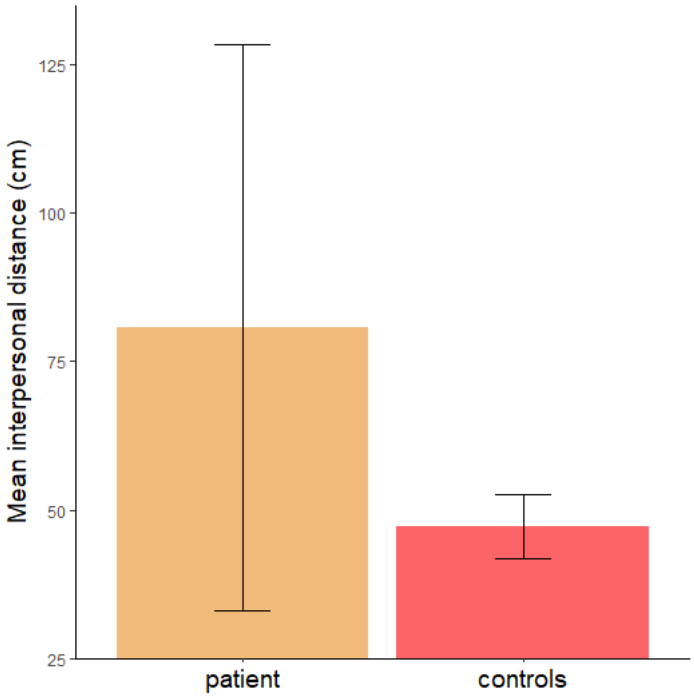

Figure 2. Means for the preferred interpersonal distance for each group. On the left are shown the means for the patient group, on the right the means for the controls.

A possible explanation for the not significant results could be the different numerosity of the two samples; it is possible that means comparison did not highlight the existence of a difference in IPS extension. In order to compare each patient's performance with the performance of the control sample, I then perform the Crawford test (Crawford, Garthwaite, & Porter, 2010). Crawford test is a modified t-test that looks if a patient's performance on a task is significantly different from the performance of the control group on the same task. Results are reported in Table 3. Crawford test showed that only the performance of P5 is significantly different from the control group. In this patient, the extension of social space is significantly increased (362.5 cm).

Table 3. Crawford test for IPS. Distances are shown in centimeters (cm).

	IPS score	*t*	*p-value*
P1	40.5	-0.19	0.85
P2	59.0	0.34	0.74
P3	20.5	-0.76	0.45
P4	61.0	0.39	0.69
P5	362.5	8.99	<.001***
P6	21.5	-0.73	0.47
P7	0	-1.34	0.09

In order to assess the presence of a correlation between the extension of the lesion and IPS, a Pearson's correlation was run. As can be noted from Figure 3, no significant correlation was found (r=0.68, p=.09).

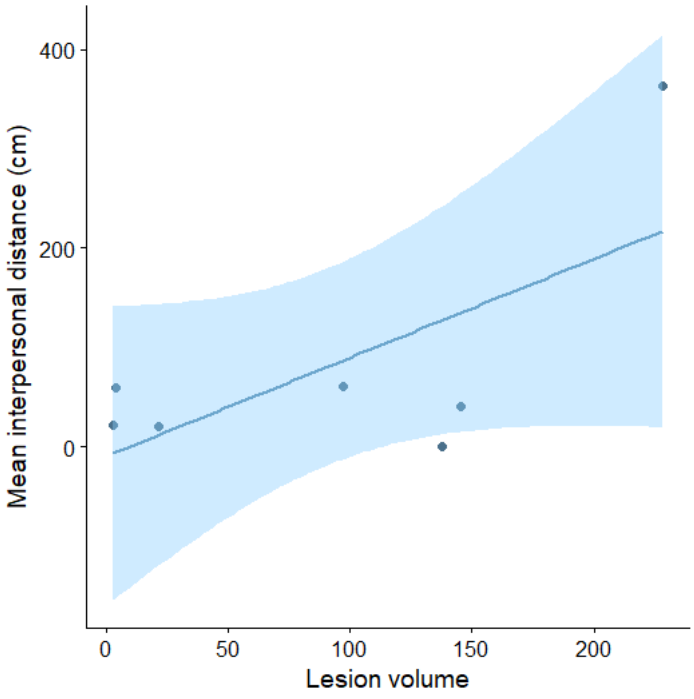

Figure 3. Scatterplot depicting the association between volume lesion (expressed in cc) and the mean of preferred IPS.

A second aim of the study was to explore the presence of a possible correlation between the patients' behavioral dysregulation (evaluated with FBI) and social space. Because of the small

sample size, all the variables were converted into ranks, and a Spearman rank correlation between IPS and FBI scores was then performed (see Figure 4). Three separate correlations were run, one for each section of the FBI and the last with the total score of FBI (sum of scores of the two sections). Results did not show any significant correlation between behavioural symptoms and IPS (FBI A: rho=0.22, p.64; FBI B: rho = -0.2, p=.97; FBI total score: rho= 0, p=1).

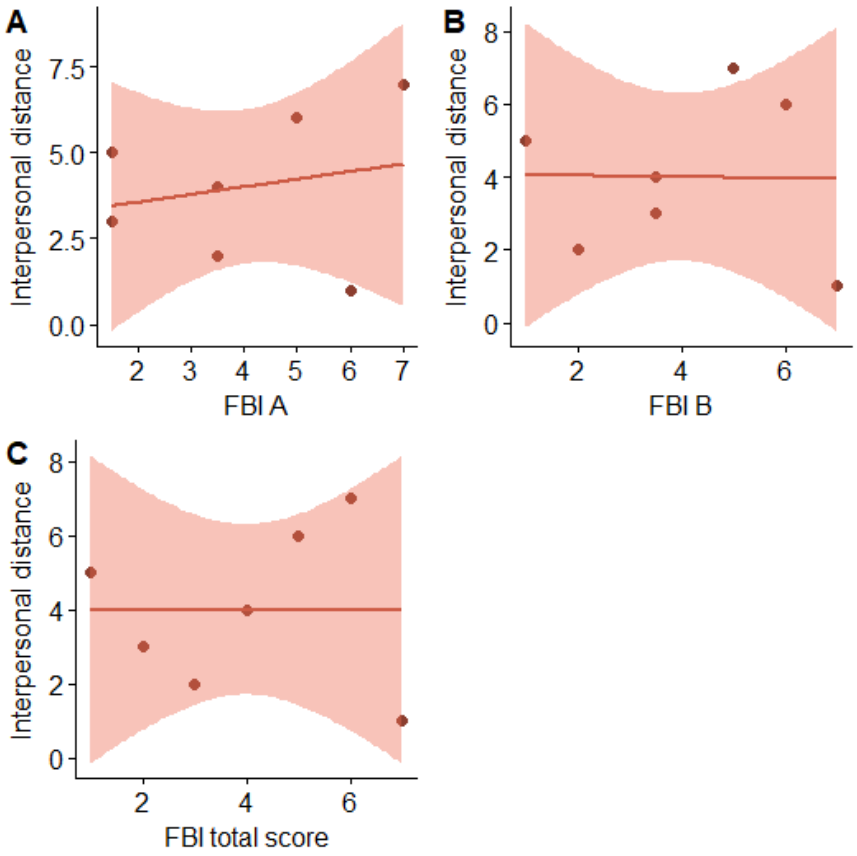

Figure 4. Scatterplots showing correlations between IPS and FBI. All variables are converted in ranks. A) Correlations with scores of FBI section A; B) Correlations with scores of FBI section B; C) Correlations with FBI total score.

A correlation between FAB scores and IPS scores were run to investigate the relationship between dysexecutive symptoms and patients preferred interpersonal distance. No significant correlation was found (rho =-0.50, p=.31) (Figure 5).

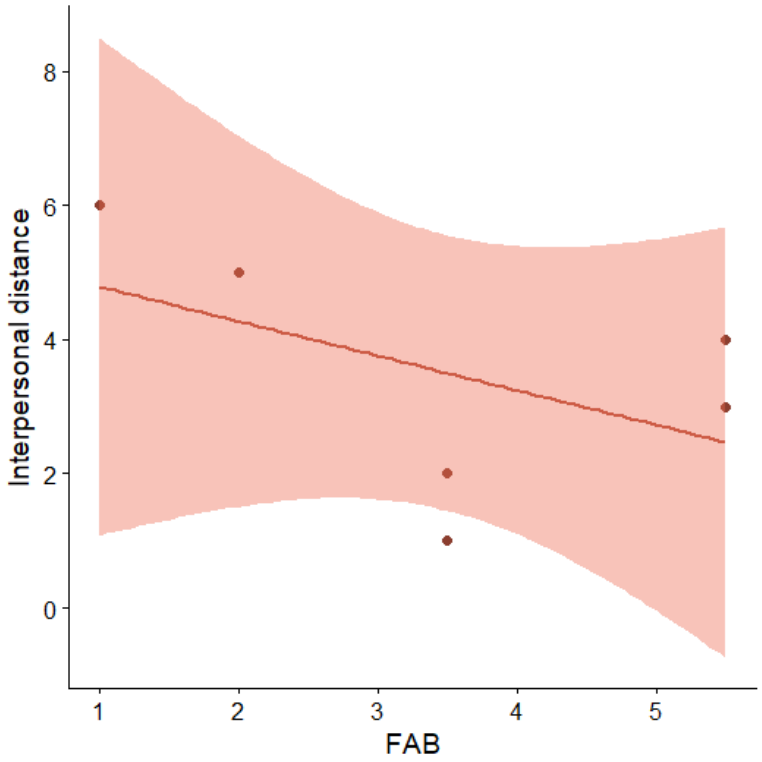

Figure 5. Scatterplot showing relationship between FAB scores and Interpersonal distance.

Another aim of the study was to investigate the possible difference in empathic abilities between brain-damaged patients and a comparable control group. Because of the difference in the numerosity of the two groups (BD vs. controls), Welch t-tests (which is an adaptation of the Student's t-test) were used when two groups have unequal variance or different numerosity. Four different Welch t-tests were performed in order to assess differences in each IRI scales between BD and control group. Results showed PD scores are significantly different between patients (mean ± sd = 16.28 ± 3.15) and controls (mean ± sd = 22.43 ± 6.50) ($t_{(7)} = -3.91$, $p<.01$). There was no significant difference in PT scores (BD: mean ± sd = 20.57 ± 7.16; controls: mean ± sd = 17.88 ± 6.12), nor in EC (BD: mean ± sd = 21.00 ± 6.24; controls: mean ± sd = 23.23 ± 5.21) between the two groups ($t_{(7)} = 0.94$, $p=.38$ and $t_{(7)} = -0.89$, $p=.40$). A trend, although not significant, was found for FS (BD: mean ± sd = 18.29 ± 5.91; controls: mean ± sd = 22.88 ± 5.292) $t_{(7)} = -1.90$, $p=.09$). See Figure 6 for results.

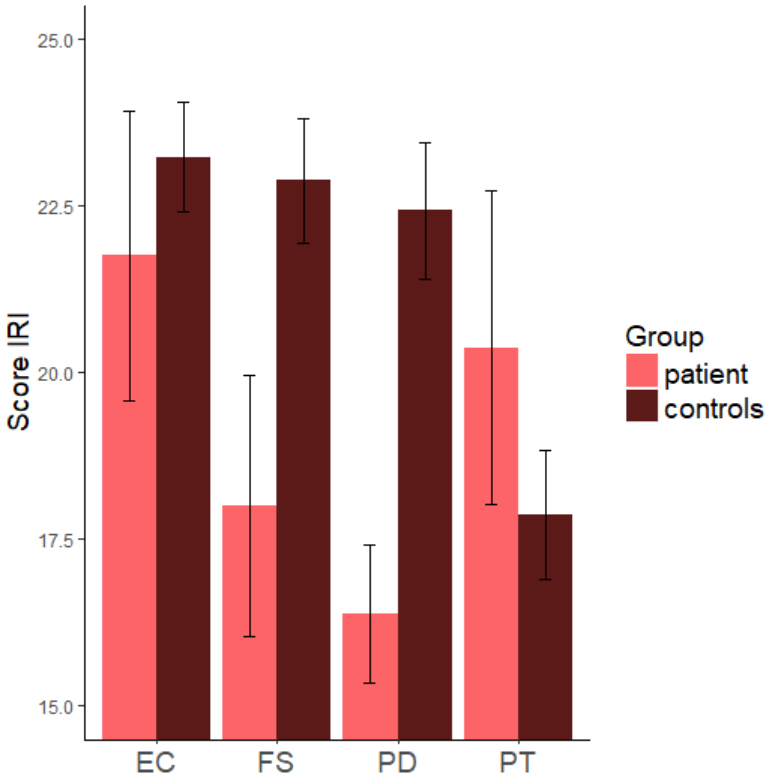

Figure 6. Histogram depicting IRI's subscales scores for the two groups (patient vs. controls).

In order to further explore empathy impairment for each patient, the Crawford test was performed. Results showed that P5 in all four subscales compared to control group. P6 also exhibit an alteration of empathic abilities specifically for PT. Contrary to P5 the direction of the alteration was an increased score on PT subscale. Results are shown in Table 4.

Table 4. Crawford test for IRI's subscales.

	EC	*t*	*PD*	*t*	*PT*	*t*	*FS*	*t*
P1	25	0.34	19	-0.52	25	1.15	20	-0.48
P2	20	-0.61	16	-0.98	19	0.18	14	-1.48
P3	29	1.09	17	-0.83	24	0.99	19	-0.65
P4	21	-0.42	19	-52	17	-0.14	22	-0.15
P5	10	-2.51*	10	-1.89*	7	-1.76*	7	-2.65**
P6	25	0.34	15	-1.13	29	1.80*	22	-0.15
P7	17	-1.18	18	-0.67	23	0.83	24	0.19

Note: PT "Perspective taking"; FS "Fantasy"; EC "Empathic concern"; PD "Personal distress"*** significant at p<0.001; ** significant at p<0.01; * significant at p<0.05

Discussion

The present study aimed to disentangle the possible alteration of IPS and empathy in BD patients with a frontal behavioural syndrome. The findings, although preliminary given the sample size, showed that there is no difference in preferred interpersonal distance between BD patients with a behavioural dysregulation and a control group. Only one patient (P5) had a performance significantly different from the control group: in this patient, there seems to exist an increased extension of social space. I also wanted to explore the relationship between patients behavioral and personality changes and interpersonal distance: the findings do not show any association between these two variables. The last question focused on investigating differences in empathic abilities due to brain damage. Interestingly, I found that the ability to fantasize and the sense of discomfort in stressful situations seem to be selectively impaired in patients with the dysexecutive syndrome.

I did not find a change in IPS in brain-damaged patients on average. This is in contrast with the findings of Perry and colleagues (2016) that found a reduction of IPS extension in individuals with orbitofrontal lesions compared to neurologically unimpaired participants; at variance, in the present study the trend (although not significant) was toward an increase, rather than a reduction, of IPS in BD patients. The different findings can be explained by different inclusion criteria and methodology applied to measure IPS. First of all, the inclusion criteria for the patient group in Perry et al. was a selective lesion of the prefrontal cortex, while the

present study used a symptomatology criterion to select BD individuals: individuals with the dysexecutive syndrome were included independently from the lesion location.

Secondly, in their study, Perry and colleagues (2016) took different measures of interpersonal distance: besides comfort distance, they took an additional measure, namely the "*uncomfortable distance*". In this condition, participants were instructed to go beyond their comfort zone and stop when they felt uncomfortable. They found a difference between patient with orbitofrontal damage and controls in comfortable distance but only a slightly significant trend for uncomfortable distance. Furthermore, the two stop-distance paradigms differ in respect to the starting position between participant and experiment: in the present study the task began with the participants at four meters from the experimenter; in the study by Perry and collaborators (2016) the distance was reduced to 2.8 meters. It is worth to make a note about the control groups recruited for this study and that of the study by Perry and colleagues. In the present study, the mean preferred IPS distance in our control (47.19 cm) is different from the mean found by Perry and colleagues (comfortable distance: 69.15 cm; uncomfortable distance: 27.36 cm). This differences can be explained by sample size: here I recruited 40 participants; Perry et al. recruited just 10 healthy subjects.

Another possible explanation for the lack of evidence of an IPS alteration is the small sample size of the present study. Nevertheless, the comparisons between the single performance of each patient and the control group on the *stop-distance paradigm* highlighted that P5 had an increased extension of IPS significantly different from the control group. In order to understand the alteration of comfort distance in this specific case compared to the other patients, it is necessary a qualitative discussion of the lesion and symptomatology of P5.

In P5, the lesion involved frontal-temporal areas and the limbic system, in particular, a portion of the right amygdala. Overall, P5 has a most vast lesion than the other BD patients. These could be possible explanations for the different modulation of IPS.

Evidence from animal studies (Machado et al., 2008; 2009) and neurological patients (Kennedy et al., 2009; Harrison et al., 2015) demonstrate that a bilateral damage to the amygdala leads to an alteration of the extension of IPS in the sense of a reduction. P5 showed the opposite alteration, namely an abnormal extension of the preferred interpersonal distance (mean 362.50 cm). A possible explanation is that in P5, the amygdala was only partially affected by the lesion,

at variance of the complete abolition of amygdala functions of above mentioned studies on human beings and primates (Machado et al. 2009; Perry et al., 2016).

Concerning the location of brain damage, all patients have lesions involving prefrontal cortex. This again is in contrast with findings on brain-damaged patients with lesions involving orbitofrontal cortex, showing a reduction of IPS in this population (Perry et al., 2016).

Furthermore, previous evidence suggests the existence of a brain network for the regulation of IPS. This network involves prefrontal cortex, a parieto-frontal circuit, subcortical-frontal connections and limbic system (in particular, the amygdala). In this case, it is possible that a lesion to only one area of the network is not sufficient to modulate IPS; the preserved areas could supply maintaining unaltered the social space. This is in line with the hypothesis of Machado and colleagues (2009) that found preserved threat avoidance mechanisms in animals with selective lesions to orbitofrontal or hippocampal cortex; the authors hypothesized that other areas of a broader network might compensate for the selective damage and leave intact the interpersonal space mechanisms.

Another point to take into consideration is the behavioral symptomatology. In Chapter 3 I found that personality traits linked with disinhibition lead to a decrease of IPS extension. For this reason, I expected that patients with a dysexecutive syndrome involving behavioral symptomatology in the sense of dysregulation and disinhibition would show a reduction of comfort-distance. The behavioral examination of P5 shows oppositive-aggressive conduct, emotional lability, irritability, loss of insight, all these symptoms are typically associated with the frontal syndrome. Moreover, it is due to note that the FBI score of P5 is one of the highest in our sample. Especially regarding the questionnaire section that assesses negative behaviors (personal neglect, loss of insight, inattention, apathy, indifference/emotional flatness). P5 symptomatology focused on negative behaviors could explain the significant increase of IPS. Another patient, P7, had high scores on FBI. P7 shows negative symptoms but also high score on disinhibition section, showing aggression, impulsivity, utilization behavior, inappropriateness, and excessive jocularity. Even if all the symptoms were mild or moderate, P7 performance in the stop-distance paradigm shows an alteration of IPS in the direction of a sensible decrease. However, the performance was not significantly different from the control sample. Disinhibition can be similar to utilization behavior typically associated with frontal lobe damage and also to impaired social insight. To summarize, the opposite patterns observed in IPS in the two patients could be explained by the symptomatology: P5 exhibits a behavioral

impairment in terms of apathy, inattention, emotional flatness; on the other hand, P7 shows impulsivity, aggression, utilization behavior. Furthermore, modulation of social space in P5 could be partially explained by the extension of the brain-lesioned areas.

A second aim of the present research was to explore how brain damage affects empathic abilities. I found impairment in empathy due to brain damage. This is in line with the brain areas damaged in the sample size. Indeed, previous neuroimaging findings showed that neural correlates of empathy rely on a network comprising the orbitofrontal cortex as well as, subcortical nucleus as insula and amygdala, and the limbic system (for a review see Fan et al. 2011). The present findings are in line with the previous studies showing that disruption of brain areas of this network entail an impairment of empathic abilities. Indeed, I found impairment in empathy in the brain-damaged group compared with the control group. This alteration in empathic traits seems to be selective for personal distress. Interestingly, further investigation, shed light on the specific deficits for each patient. In particular, only P5 has an impairment on all empathic dimensions. This novel finding is of particular interest because in chapter 3 it was shown that enhanced empathic abilities involving the cognitive dimension of empathy lead to a reduction of social space. Congruently P5 showed an expansion of IPS due to impaired cognitive empathy. This evidence is partly in line with a recent study by Ruggiero and colleagues (2017). They found that empathic concern and personal distress are related to comfort distance. They found an opposite pattern: enhanced empathic concern abilities are associated with shorter IPS, while high levels of personal distress are related to an increase of IPS extension. P5 showed a reduction of empathic concern and subsequently an expansion of IPS; on the other hand, low levels of personal distress do not seem to be associated with shorter IPS. The difference between the two studies can be due to the methodologies. Ruggiero and colleagues used a virtual paradigm to measure interpersonal distance. This environment is less ecologically valid compared to our stop-distance paradigm. Moreover, in the mentioned study they used stimuli with emotional valence, while in the present research the experimenter approached participants maintaining a neutral facial expression. The differences in the paradigms can explain the different findings of the two studies.

Chapter 5

General discussion

General discussion

Human beings are social animals. It is important for our species to engage in healthy and fruitful relationships. Altruism and cooperative behaviors help us to improve these bonding relationships and are helpful for the survival of the species. In this framework, empathy and interpersonal space are two crucial factors for social interactions. On the one hand, individuals with better empathic abilities will have lasting relationships and a predisposition for cooperativeness and altruistic behaviors that are fundamental skills to develop in large groups. On the other hand, the development of maladaptive or dysfunctional personality traits can hinder these processes, leading to impairment in relationships up to social isolation. In recent years, cognitive neuroscience research has significantly helped to further investigate these constructs, shedding light on their neural correlates. Interestingly empathy, social space, and psychopathy seem to rely – at least partially – on a common neural network.

Given these premises, the present work tried to investigate the three above mentioned constructs. In Study 1, I have explored the presence of psychopathic and maladaptive personality traits in the general population. Moreover, I have examined how different levels of dysfunctional personality traits influence social sensitivity, as measured by a test for complex emotion recognition (RMET), and empathy. Results show that specific psychopathic traits predict empathic abilities. Interestingly different facets of psychopathy predict each empathy subcomponent differently: primary psychopathy seems to predict empathic concern and perspective taking, while secondary psychopathy predicts levels of distress that relate to self-oriented feelings of discomfort in tense situations. Furthermore, Study 1 highlights the relationship between psychopathic traits and maladaptive personality traits (specifically those related to disinhibition, impulsivity, and aggression), and between the latter and social sensitivity.

In Study 1, I have tried to disentangle the relationship between empathic abilities, emotion recognition, core personality features and psychopathic traits on a large non-clinical sample. This is the first study that tries to unravel the deep connections between all these domains in a non-clinical population. Moreover, there is no evidence about the relationship between psychopathic traits and the different cognitive and affective components of empathy in a non-institutionalized sample. Previous studies focused only on mentalizing abilities or on the recognition of simple emotions (Dolan and Fullam, 2004; Ali and Chamorro-Premuzic, 2010;

Sandvik et al., 2014) or empathic abilities (Burke et al., 2001) but findings from these studies are controversial. These contrasting results can be due to different methodologies adopted, and different samples. For example, a study by Sandvik and colleagues (2014), considering a group of male inmates, has examined the link between psychopathy and the capacity to infer others' mental states. They found a dissociation in the ability to mentalize: impaired mentalizing abilities in subjects with psychopathic traits are related to antisocial and impulsive behaviors, while intact ToM skills in subjects with psychopathic traits associated to the interpersonal and affective domains of psychopathy. Dolan and Fullam (2004) investigated the recognition of complex emotions in individuals with an antisocial personality disorder (ASD) and psychopathic traits. They found no difficulties in emotion recognition and in a ToM task in ASD. Another study, conducted in a non-clinical sample (Ali and Chamorro-Premuzic, 2010) found that primary psychopathy is associated with deficits in mentalizing abilities. One hypothesis for this impairment in emotions recognition is that psychopathic individuals have scarce attention to emotional stimuli (Medina, Kirilko, Grose-Fifer, 2016). This proposal is in line with the results found by Medina and colleagues (2016), who measured brain responses to emotional stimuli in a college population. They found a reduced neural response in stimuli with emotional valence in subjects with higher psychopathic traits. In this context, Study 1 provides a novel insight into this topic, by showing that higher levels of psychopathic traits are associated with a decrease of empathic concern and perspective taking and a decrease of personal distress. Furthermore, this study highlights a relationship between fantasy scale and ToM, confirming the association between cognitive empathy and mentalizing abilities. Additionally, I have found an impairment in mentalizing skills related to psychopathic traits pertaining to the secondary facet. No previous studies investigated all together the association between these variables in a large non-clinical sample (here, more than 300 participants, previous evidence in less than 90).

Additionally, Study 1 results highlighted an association between different empathic abilities and the primary and secondary subtypes of psychopathy. This relationship is also influenced by participants' age and gender. In details, primary psychopathy seems to predict empathic concern (i.e., feelings of sympathy and concern for others) and perspective taking (i.e., the ability to adopt the point of view of others). This is in line with the construct of primary psychopathy that seems to reflect the tendency to manipulate others, lack of emotion, egocentrism, and deceitfulness. On the other hand, secondary psychopathy refers to antisocial behavior due to difficulties in controlling impulsivity and emotion. Once again this is in line

with its relation to personal distress that relates to self-oriented feelings of discomfort in tense situations. These findings are in line with previous works on forensic population (Burke 2001) that found an impairment of empathic concern and perspective taking in adolescent sexual offenders. Indeed, psychopathy is a broad category, that includes specific behaviors as impulsivity, aggression, manipulativeness, and stimulation seeking associated to specific empathic abilities (i.e., concern for others, perspective taking and discomfort in tense situation).

Regarding mentalizing abilities, I found an association with one of the empathy subcomponents. The ability to attribute mental states is related to one specific empathic ability, namely the cognitive ability of an individual to identify with or imagine experiencing the events of fictitious characters (i.e., "Fantasy"): participants with a higher level of this ability have better ToM skills. In Davis original theorization (1983), Fantasy scale pertains to cognitive empathy and cognitive empathy is usually linked to mentalizing processes (Davis, 1996; Ickes, 2003). Interestingly in this first study, I did not find a direct association between psychopathy and emotions' recognition, at least when measured with RMET. So, it seems that psychopathic traits do not impair the recognition of complex emotions. This is in line with findings from previous studies that found preserved emotions recognition in the psychopathic population, highlighting the role of emotion recognition as a possible tool psychopaths use to manipulate their conspecifics subtly (Book, Quinsey and Langford, 2007; Pham, Ducro and Luminet, 2010; Migdley & Vrouva, 2014). Pham, Ducro and Luminet (2010), for example, found that inmates perceived themselves as better able to recognize other's emotions and to manage emotional states. Book, Quinsey and Langford (2007) studied a forensic population and showed how psychopathic individuals were better in recognizing other's emotion and also emotional vulnerability. These findings seem to suggest that a preserved ability to recognize others emotion can be useful to psychopathic individuals to charm and manipulate their conspecifics.

However, I have also found an indirect link between psychopathic traits and mentalizing abilities: the "Disinhibition" facet of the PID-5 predict participants' performance at the ToM test and Disinhibition is proven to be related to secondary psychopathy (Strickland et al., 2013, Fossati et al., 2013). Disinhibition is a personality feature related to antisocial traits, dysregulated behavior, and poor emotional control. According to Hare's theory (1983), secondary psychopathy is more connected to antisocial personality traits, characterized by antisocial behavior, impulsivity, aggression, behavioral and emotional dysregulation. This is in line with the work by Fossati and colleagues (2013) that found a correlation between

"Disinhibition" domain and secondary psychopathy. So, it seems highly probable that Disinhibition traits pertaining to impulsivity and risk-taking are linked with secondary psychopathy. This evidence is of particular interest because, on the other hand, primary psychopathy dimension does not seem to correlate with impairment of ToM. Primary psychopaths are usually manipulative, insensitive and show a lack of emotion (Karpman, 1948, Hare, 1983). This match the profile of "successful" psychopaths, individuals that save their "normal" appearance and show higher manipulativeness. The present results are in line with the findings of Sandvik and collaborators (2014), who showed, in a forensic sample, a dissociation in mental states recognition: an impairment of this ability in individuals with psychopathic traits on the antisocial domain; preservation in psychopaths with dysfunctions in affective and emotional domain.

Given the results of Study 1, that shows a positive relation between empathic abilities and personality and psychopathic traits in the general population, I have further investigated the relationship between these constructs and IPS. Current scientific literature suggests that psychopathy, social space, and empathic abilities may be intrinsically linked, but the nature of their relationship is still controversial. A first evidence of the common base of these constructs comes from their common neural correlates. By assessing how different degrees of empathy, psychopathic and maladaptive personality features are related to the preferred interpersonal distance (IPS), Study 2 highlights the role of specific personality traits in shaping social space, namely impulsivity, aggressivity, and psychopathic features. Additionally, only one subcomponent of empathic abilities, as originally theorized by Davis (1980; 1983), seem to be related to a reduction of social space. Such findings extend and elucidate previous evidence by showing how the interpersonal distance between us and our confederates correlates with the disposition to embrace the psychological perspective of others. An increased capacity to take others' point of view, as reflected by PT subscale of the IRI, entails a reduction of IPS. This is in line with evidence that suggests that social skills shape the interpersonal distance between us and our conspecifics (Lloyd, 2009). It has been already shown that personal features, like empathy and extraversion, can influence social space, but this is the first study to demonstrate, in a large sample, how empathy (considered from a multi-dimensional perspective) shape social space. The main result from my study is that only the ability to take others' point of view is related to a shorter interpersonal distance. An explanation of this effect could be that increased cognitive empathy abilities facilitate the proximity with other human beings, and on the other side, the closer we are with our conspecifics, the better we can improve the ability to understand

their perspective. On the other hand, I did not find any relation with the affective facet of empathy: it is not the closeness with our conspecifics that help us to develop a better ability to mirror others' feelings. These findings are party different from the results of Ruggiero and colleagues (2016), that found a correlation between empathic concern and personal distress and interpersonal distance. The different findings can be explained by different methodologies employed: first of all, in the previous study, the authors used a virtual reality version of the stop-distance paradigm. Secondly, the approaching stimuli had an emotional valence, since they consisted of virtual confederates with happy, angry and neutral expressions. I, on the other hand, used a more ecologically version of the stop-distance paradigm. Moreover, there was no emotional component in the task, because the experimenter was told to maintain a neutral facial expression. These two differences in the experimental task can account for the different results, at least to some extent. A final remark needs to be made about the sample size of this study that was of 34 participants only. Although caution is needed due to different methodological paradigms, increasing the sample size seems to completely change the perspective on the link between empathy and IPS, highlighting the major importance of the cognitive side of empathy.

Results from Study 2 further enrich this field of investigation by providing novel evidence about the link between personality and IPS extension. Results highlighted the presence of a relationship between maladaptive personality traits linked to impulsivity, irresponsibility, and distractibility – as measured by Disinhibition facet of PID-5 - and social space: higher scores on the Disinhibition scale are associated with a decrease of the comfort distance. These characteristics are usually associated with psychopathy. Indeed, results from Study 2 confirm those from Study 1 demonstrating that Disinhibition predicts psychopathic traits pertaining to the so-called secondary psychopathy. Secondary psychopathy refers to behavioral dysregulation and is usually linked with the propensity to aggression and antisocial behavior (Karpman, 1948; Lykken, 1957; Hare, 1993). On the contrary, no relationship between primary nor secondary psychopathy and interpersonal space were found. So, again secondary psychopathy is indirectly linked with the preferred interpersonal distance.

So far, in the scientific literature, controversy has arisen regarding the relationship between psychopathy, antisocial behavior, and interpersonal space. Studies on forensic and criminal population indicate that individuals with high levels of aggressivity and disposition to assault, two landmarks of the psychopathic behavior, have enhanced sensitivity to personal space

intrusion (Schienle, Wabnegger, Leitneg, Leutgeb, 2017). It seems that an increase of alertness related to space intrusion could be an explanation for their propensity to violent conduct. On the other hand, studies on non-clinical population (Vieira and Marsh, 2014), found that cold-heartedness traits (i.e., lack of sympathy or interested) usually linked with psychopathy, are associated with shorter preferred distance. The present findings confirm the existence of an indirect connection between psychopathy and decrease social space: maladaptive personality traits correlate with a decrease of IPS and at the same time these dysfunctional features predict the presence of psychopathic traits.

Moreover, Von Borries and colleagues (2012) demonstrate how psychopaths have reduced avoidance to threatening social stimuli. Social space, as theorized by Hediger (1955) is compared to animals' *flight-zone*, for this reason, it can be shaped and modulated by social threats or menacing stimuli (Vieira et al., 2017; Ruggiero et al., 2017). For example, Vieira and collaborators (2017), demonstrated how the perception of threat influence IPS: in their study participants maintained a greater distance from angry faces (perceived as threatening) compared to happy faces. Psychopathic features, combined with shorter preferred interpersonal distances, enhanced sensitivity to space intrusion and lack of mechanisms to avoid threats, can explain why these individuals tend to assault others.

In conclusion, Study 2 shed light on some crucial individual factors influencing social space. The interpersonal space is primarily influenced by impulsivity traits and the ability to assume the others point of view. Both of these individual core characteristics seem to be associated with a shorter comfort distance.

Finally, in the last Study 3, I was interested in exploring how brain damages affect IPS and empathic abilities. In Study 2 we saw that behavioral dysregulation seems to be a crucial factor in altering spacing mechanisms. For this reason, Study 3 focused on the investigation of brain-damaged patients with behavioral symptomatology to confirm and explore its influences on the modulation of IPS. Moreover, I wanted also to investigate the effects of brain damage on empathic abilities since IPS and empathy seem to partially share common neural substrates. The findings of the last study, although preliminary given the sample size, did not show any difference in preferred IPS between healthy individuals and brain-damaged patients. Only one patient (P5) had a performance significantly different from the control group: in this patient, there seems to exist an increased extension of social space. These results are in contrast with previous findings. For example, Perry and colleagues (2016) found a reduction of IPS extension

in individuals with orbitofrontal lesions compared to neurologically unimpaired participants; at variance, in the present study, the trend (although not significant) was toward an increase, rather than a reduction, of IPS in BD patients. Again, the different findings can be explained by different inclusion criteria and methodology applied to measure IPS. First of all, the inclusion criteria for the patient group in Perry et al. (2016) was a selective lesion of the prefrontal cortex, while the present study used a symptomatology criterion to select BD individuals: individuals with the dysexecutive syndrome were included independently from the lesion location. Secondly, Perry and colleagues used a slightly different paradigm to assess interpersonal distance: besides comfort distance, they took an additional measure, namely the "uncomfortable distance". In this condition, participants were instructed to go beyond their comfort zone and stop when they felt uncomfortable. They found a difference between patient with orbitofrontal damage and controls in comfortable distance but only a slightly significant trend for uncomfortable distance. Furthermore, the two stop-distance paradigms differ in respect to the starting position between participant and experiment: in the present study the task began with the participants at four meters from the experimenter; in the study by Perry and collaborators the distance was reduced to 2.8 meters.

Certainly, another possible explanation for the lack of evidence of an IPS alteration is the small sample size of the present study. However, some reflections come from the present results.

Concerning the location of brain damage, all the present patients (except one) have lesions involving frontal cortex. This again is in contrast with findings on brain-damaged patients with lesions involving orbitofrontal cortex, showing a reduction of IPS in this population (Perry et al., 2016). However, previous evidence suggests the existence of a brain network for the regulation of IPS. This network involves prefrontal cortex, a parieto-frontal circuit, subcortical-frontal connections and limbic system (in particular, the amygdala). In this case, it is possible that a lesion to only one area of the network is not sufficient to modulate IPS; the preserved areas could supply maintaining unaltered the social space. This is in line with the hypothesis of Machado and colleagues (2009) that found preserved threat avoidance mechanisms in animals with selective lesions to orbitofrontal or hippocampal cortex; the authors hypothesized that other areas of a broader network might compensate for the selective damage and leave intact the interpersonal space mechanisms.

Nevertheless, the comparisons between the performance of each single patient and the control group on the *stop-distance paradigm* highlighted that P5 had an increased extension of IPS

significantly different from the control group. In order to understand the alteration of comfort distance in this specific case compared to the other patients, it is necessary a qualitative discussion of the lesion and symptomatology of P5. P5 is the participant with the most extended brain-damaged area. This could be a possible explanation for the different modulation of IPS. P5 lesion involved frontal-temporal areas and the limbic system, in particular, a portion of the right amygdala. Evidence from animal studies (Machado et al., 2008; 2009) and neurologically impaired patients (Kennedy et al., 2009; Harrison et al., 2015), demonstrate that bilateral damage to the amygdala leads to an alteration of the extension of IPS in the sense of a reduction. P5 showed the opposite alteration, i.e., an abnormal extension of the preferred interpersonal distance (mean 362.50 cm). A possible explanation is that in this case, the lesion involved the amygdala only partially contrary to the complete lesion in the previously mentioned studies on human beings and primates (Machado et al. 2009; Perry et al., 2016).

I also wanted to explore the relationship between patients behavioral and personality changes and interpersonal distance: the findings do not show any association between these two variables. Given Study 2 results that showed that personality traits linked with disinhibition lead to a decrease of IPS extension, I expected that behavioral symptomatology in the sense of dysregulation and disinhibition would show a reduction of comfort-distance. Once again a qualitative discussion of single patients highlighted two different patterns in two different patients: P5 exhibits a behavioral impairment in terms of apathy, inattention, emotional flatness that leads to a sensible increase in IPS; on the other hand, P7 shows impulsivity, aggression, utilization behavior that leads to a decrease in the extension of IPS (even if not statistically significant from control group performance). Although the preliminary nature of the results from Study 3, some novel insights have emerged, which should guide a deeper investigation of the present findings. Increasing the sample size will allow to elucidate these findings and, through lesion mapping, shed light on the anatomical and behavioral correlates of interpersonal space. Moreover, further investigations may confirm the dissociation among behavioral symptomatology, showing that a profile with the prevalence of negative symptoms (i.e., apathy, inattention, and emotional flatness) leads to an increase in IPS extension; while the prevalence of positive symptoms (i.e., aggression, impulsivity) leads to a decrease of preferred interpersonal distance.

Finally, I found impairment in empathic abilities due to brain damage. This is in line with the brain areas damaged in the sample size. Evidence from neuroimaging studies showed the existence of a vast neural network comprising the orbitofrontal cortex as well as, subcortical nucleus as insula and amygdala, and the limbic system (for a review see Fan et al. 2011) subserving empathy. Results of Study 3 are in line with the previous studies showing that disruption of brain areas of this network entails an impairment of empathic abilities. Specifically, patients with dysexecutive syndrome seem to have a selective impairment of empathic abilities compared to a control group. Specifically, I found a decrease only in personal distress (i.e., the sense of discomfort in stressful situations). In particular, only P5 has an impairment on all empathic dimensions. This novel finding is of particular interest because in Study 2 it was shown that enhanced empathic abilities involving the cognitive dimension of empathy lead to a reduction of social space. Congruently P5 showed an expansion of IPS due to impaired cognitive empathy. This evidence is partly in line with a recent study by Ruggiero and colleagues (2016) that investigated empathic abilities and IPS in healthy individuals. They found that empathic concern and personal distress are related to comfort distance, but with an opposite pattern: enhanced empathic concern abilities are associated with shorter IPS, while high levels of personal distress are related to an increase of IPS extension. P5 showed a reduction of empathic concern and subsequently an expansion of IPS; on the other hand, low levels of personal distress do not seem to be associated with shorter IPS. The difference between the two studies can be due to the methodologies, as already pointed out above, that is the use of a less ecological set-up and stimuli with emotional valence for IPS measurement. Crucially, they investigated the preferred interpersonal distance only on healthy participants. This could be another explanation for the differences in results.

In conclusion, the present research project offers original evidence on the complex relations between psychopathic and personality traits, empathic and mentalizing abilities in healthy individuals. Both psychopathy and empathy are multi-facets constructs: the presence of psychopathy traits on the two dimensions predicts different impairments in empathic skills. On the other hand, our evidence suggests that traits related to secondary psychopathy are related to ToM impairment. Also, our evidence seems to suggest a relationship between maladaptive personality domains, secondary psychopathy, and mentalizing abilities. Furthermore, the present findings highlight the role of personality facets associated with impulsivity and secondary psychopathy in shaping social space. Behavioral dysregulation is associated with psychopathic traits and shorter interpersonal distance. The presence of dysfunctional traits in

the normal population and the consequences on social interactions can shed light also on the symptomatology typical of individuals with personality disorders. A reduction of IPS is related, on the one hand, to impulsivity and disinhibition, on the other hand, to preserved cognitive empathic abilities. This could explain why psychopaths show a tendency for antisocial behavior, but also how their preserved mentalizing abilities help them to manipulate other human beings. Finally, preliminary results showed a modulation of the extension of social space due to brain damage and behavioral symptomatology. Additionally, brain damage seems to affect empathic abilities, in particular, the sense of uneasiness in anxious interpersonal context.

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