Bachelor Degree Project

Feeling Close to Someone:
The Neural Correlates of Social Connection

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Abstract

During the course of human evolution, being a member of a group has been more beneficial for survival than being alone. Food gathering, protection from predators, cooperation, and care for offspring are distributed among group members, increasing the likelihood for survival. It is as if there is an interplay between agent and environment that interprets being socially cooperative as pleasurable and being left out as painful. Studies have been dedicated to examine how our social life is one of the most important aspects of health and well-being, particularly social relationships. Since this link has been demonstrated, it would be interesting to incorporate the field of neuroscience to understand the involvement of the human brain in our social experiences, specifically the experience of social connection. The current state of neuroscience does not allow researchers to examine this kind of subjective experiences, simply because of the lack of proper tools and knowledge. Research in this field has come a long way since the early stages, and studies have indicated on significant results regarding the involved neural regions. The dorsal anterior cingulate cortex (dACC) and the anterior insula (AI) are active when threats to social connection is experienced. They are also active in situations were survival is threatened. An experience of social connection evokes a feeling of (social) safety, in part because it activates regions of the brain associated with physical safety, such as the ventromedial prefrontal cortex (VMPFC). In similar fashion, a sense of social closeness ("warmth") activates the ventral striatum (VS), which is associated with physical warmth and studies have shown that social and physical warmth share overlapping neural activity in VS. Finally, Mu-opioids have been shown to be responsible for social bonding; while using an opioid antagonist such as naltrexone, decreases the feeling of social connection. Studies in this field are few; one should take their results with caution. The field continues to grow, and the studies that have been done to date give exciting hints of the influence of social relationships on physical health and mental well-being.

Keywords: social connection, social bonding, social safety, social warmth, threat, opioids

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1. Introduction

Humans are fundamentally social animals. Social experiences are primary for humans, who rely on social connection to thrive and survive (Inagaki, 2018a). Social species are categorised as creating organisations beyond the individual using psychological, neural, hormonal, cellular, and genetic mechanisms. These mechanisms enable social behaviour to help organisms survive, reproduce, and leave a genetic legacy. Scientific research regarding the brain and biological processes underlying social cognition and behaviours can be traced to the late 19th Century. Early work in the field was mostly fragmented. Trying to understand the biological bases of social processes and behaviours might have been complicated for the field of neuroscience since the human brain is known to be a complex structure. Distinct basic, clinical, and applied disciplines are required to study the complex structure and function of the human brain. Although existing disciplines are interrelated, individual fields focus on different levels such as neuroanatomy, neurobiology, behavioural neuroscience, cognitive neuroscience, and social neuroscience (Cacioppo & Cacioppo, 2013).

In the field of positive psychology, social relationships are considered one of the fundamental areas of life necessary for mental well-being. Seligman (2012, 2018) has defined well-being as five pillars he calls PERMA, where positive relationships are one of the main components. The theoretical underpinnings of positive psychotherapy stem from the proposition that happiness consists of five elements: *positive affect, engagement, relationships, meaning,* and *accomplishment*. These five elements make up the theoretical model of PERMA and they constitute some of the building blocks of well-being, according to Seligman. The relations between social relationships and mental well-being will be addressed later on in this thesis.

There are many studies establishing the correlation between social relationships and physical and mental health. For many years, studies have ben conducted to uncover the neuroscience behind the feeling of social connection. Social connection is defined by Hutcherson, Seppala and Gross (2015) as the subjective feeling of friendship, love, and caring that is felt from and towards others. Studies have shown how the experience of feeling connected to close others has a positive impact on health. It is only in recent years that research has begun to identify the neural regions responsible for experiences of social connection. Various terms are used, such as *social ties,* which is defined as the connection to and contact with other people through membership in primary and secondary groups, where primary groups are smaller in size, informal, intimate, and long-lasting (Thoits, 2011). Members of primary groups are the people one is emotionally tied to and views as important or influential in her life, such as family members, relatives, and friends. Secondary groups are

larger; members' knowledge about one another is less personal; the duration of membership ranges from short to extended; and interactions are formal: guided by rules, regulations, and hierarchies. Examples are work, voluntary and religious groups. A s*ocial bond* is the warm and affiliative feeling one experiences towards intimate others (Inagaki, Ray, Irwin, Way, & Eisenberger, 2016). Social connection, social ties and social bonds will be used interchangeable throughout this thesis.

The aim of this thesis is to focus on the neural correlates of social connection, with special attention to the links between physical pain and physical warmth, on the one hand, and social pain and social warmth on the other. The research question that will be addressed is: What are the relevant neurological processes that underlie the experience of social connection and bonding, particularly concerning social safety and warmth, and what are the effects? I chose to conduct a literature review. In order to collect relevant articles to this thesis, I searched in Web of Science and Google Scholar, using the keywords “social connection”, “neuroscience”+“social connection”, “social ties”, and “social connection”+“health”. Further, articles were chosen based on how relevant they were for the topic. Then, they were sorted into different categories, such as “social connection and mental health studies”, “social connection and physical health studies”, and “social connection and neuroscience studies”, to organise the search process. When assessing the articles, I examined the introduction, what definitions were used, and what the results were.

The structure of the thesis is describes a follows: first, the background section will introduce the key fields of social neuroscience and the social brain. The section on social connection discusses the beneficial health impacts it has. The neuroscience section reviews studies on physical and social pain, and physical and social warmth. Evolutionary explanations for the social brain are introduced, with a special focus on the Social Brain Theory. Since social relationships are among the many aspects that influence well-being, this thesis includes a section discussing them from the perspective of positive psychology. The thesis ends with a discussion on social relationships and social connection, deliberating the results of the studies; the limitations of the present research and possibilities for future research are proposed.

2. Background

2.1. Social Neuroscience

The term social neuroscience was first introduced almost 30 years ago by Cacioppo and Berntson (1992). It addresses fundamental questions regarding the mind and its interactions with the brain and the social world. It can be viewed as an interdisciplinary field that uses a range of measures

within neuroscience to gain an understanding of how biological systems impact social processes and behaviour, and how social structures impact brain and biology (Cacioppo & Berntson, 2002; Ito & Kubota, 2019; McEwen & Akil, 2011).

As the field of neuroscience continues to grow, not only our knowledge of the brain and its relation to the social and physical environment expands, but more so our ignorance about the brain. This is possible thanks to more technical advances making measures of the brain possible and cheaper, as well as the recognition of the importance of neural and physiological information for the understanding of interactions between people, according to Ito and Kubota. Many findings relate to social interactions, especially lack of social interactions with their powerful effects on brain and body. Across social species, heightened sensitivity to social threats is one consequence of social isolation and loneliness; it motivates the renewal of social connections (McEwen & Akil, 2011). Social species create organisations beyond the individual, which in humans can range from pairs to families, groups, civilisations, and cultures. There are neural, hormonal, and genetic mechanisms supporting these emergent organisations because the resulting social behaviours resulted in increased chances for survival for organisms. Social neuroscience focuses on these emergent structures and investigates the mechanisms that make them possible (Norman, Cacioppo, & Berntson, 2010).

2.2. The Social Brain

Researchers in the field of social neuroscience often use the term *social brain* when speaking of the brain and how it functions in a social context. These functions allow humans to engage in social activities and make certain processes possible, such as social cognition and having a theory of mind (i.e., the ability to make inferences about people's mental states, such as desires, attitudes, beliefs, and to appreciate that these may differ from our own (Baron-Cohen, Leslie, & Frith, 1985)). According to Glozman and Krukow (2013), the term “social brain” was introduced to the field of neuropsychology by Gazzaniga (1985) in his studies on the disruption of emotional and social communication due to right hemispheric damage (i.e., referring to the right side of the brain); this term was later used to explain the processing of social information in the human brain and how it regulates the mind as a whole. When it comes to interactions with the world, being able to predict what is going to happen next or what someone will do next is an advantage.

Social cognition refers to processes that enable prosocial behaviour in relation to other individuals from the same species. It especially refers to those higher cognitive processes that enable the extremely complex and diverse social behaviours observed in primates. Social cognition

evolved from the complex interaction of two opposing factors. On one hand, being a member of a group signals a sense of safety for the individual. On the other, mates and food are also available for competitors within the group. Based on these factors, an evolutionary approach to social cognition predicts mechanisms for prosocial behaviour such as cooperativity and altruism. This relates to smaller groups, such as the bond between the mother and infant. It relates to mechanisms for coercion, deception, and manipulation of individuals in larger groups, where complex dominant hierarchies could develop (Cacioppo & Berntson, 2002).

According to Glozman and Krukow (2013), two approaches can be used to explain the organisation of social cognition, one of them is *theory of mind.* It seems clear that people theorise about inner, non-observable mental states that cause observable behaviour. One could argue that theory of mind is dependent on communication and language. Communication requires constant awareness of the recipient's state of mind: her knowledge, intentions, and beliefs. There are cases when people have disturbances of social cognition, such as some would argue arises in individuals with autism. Some cases manifest a lack of theory of mind, where there is a difficulty to understand the feelings of others. The second approach explaining the organisation of social cognition involves *simulation theory*. Simulation theory proposes that it is possible to use imagination and mental states to simulate others mental states. Simulation may be depended on mirror neurons, which are activated by the subject's own movements, but can also get activated by observing another person's movements. They are localised in the premotor ventral cortex and also partly in the parietal lobe (Gallese & Goldman, 1998).

2.3. The Neuroscience Behind the Social Brain

The underlying neural mechanisms of the social brain are complicated to study, but as of right now, some neural regions have been identified as playing a key role in in humans. Primates are incredibly adapted to handle their social environment, especially the most social primate: *Homo sapiens*. Cacioppo and Berntson (2002) hypothesize that humans' phenomenal cognitive skills was beneficial. To support this idea, Cacioppo and Berntson explains the correlation between mean group size and neocortex volume. The same correlation has been found among several other mammals, including bats and toothed whales. What they have in common is that they are included in a complex social structure. The larger the social groups, the larger the brains, relative to body size. Other factors may also correlate with brain size, including dietary, foraging strategy, tool use, and longevity. The correlation of group size and brain size has been called the Social Brain Hypothesis, which I will return to later.

The details of the relationship between social cognition and social behaviour remain largely unknown; they reflect complex functions that are connected to many other processes of the human brain (Glozman & Krukow, 2013). The neurobiological mechanisms of social cognition can be investigated e.g. lesion studies and functional imaging (e.g. how regions on both sides of the brain in fronto-polar prefrontal cortex (FPPC) are activated when subjects have to concentrate on a main goal over a period of time) (Cacioppo & Berntson, 2002). The role of the amygdala, temporal cortex, anterior cingulate cortex, and orbitofrontal cortex to social cognition have all been argued over (Cacioppo & Berntson, 2002; Frith, 2007).

3. Social Connection

Social relationships are highly topical in the field of social neuroscience. One particular interest is the warm, safe, and loving feeling from close others often referred to as social connection. Over the past decades, significant evidence has accumulated regarding social ties and social support, and how they are causally related to physical health and longevity (Thoits, 2011). It is not just the quantity but the perceived quality of the interactions that are significant (Inagaki, 2018a).

Despite all the findings, researchers do not know exactly *how* social ties or social support improve health and well-being, as pointed out by for example Cohen and Janicki-Deverts (2009: 377) and Thoits (2011). Thoits believes that research has focused its attention on establishing beneficial health outcomes, while the intervening mechanisms of social connection have been neglected. Despite of this, research has come a long way of discovering the underlying neural mechanisms in particular and understanding the importance of social relationships from several perspectives.

3.1. The Health Benefits of Social Relationships

As mentioned, research has shown a correlation between social connection and longevity. At the same time, it is important to remember that every individual is different, with her own subjective experience. There exists a broad human variation in the desire for connection. Some individuals tolerate long distance from friends and family better than others. Some will handle exclusion better than others. The interplay of self-regulation and social cognition determines how the person copes. One person will manage to cope until the next opportunity for connection comes along, while another experiences self-destructive thoughts and behaviour, sending them into a downward spiral (see for example Cacioppo & Patrick, 2008).

With or without individual sensitivity, well-being will suffer when one's particular need for connection is not met. Cacioppo and Patrick argue that evolution established the preference for strong human bonds by selecting genes that endorse pleasure in company and produce feelings of distress when one is left involuntarily alone. It tailored not only people experience positive emotions when connected, but to experience a sense of security. It shaped people not only to feel bad in isolation but to experience insecurity when being feeling physically threatened (Cacioppo & Patrick, 2008). People who have few social connections or feel isolated live shorter lives compared to those who report having strong, dependable, meaningful social bonds (Cacioppo & Cacioppo, 2012). Since the link between social relationships and health is established, scientists dedicates themselves to explain how they relate to each other. Social ties influence health in three broad ways: behaviourally. psychosocially, and physiologically (Umberson & Montez, 2010).

3.1.1. Behavioural explanations

Over the years, studies have provided evidence of how social ties influence healthy life choices over the course of a lifetime. Healthy lifestyle choices include exercise and nutritionally balanced diet. Other behaviours weaken health, such as smoking, extreme weight gain, drug abuse, and heavy alcohol consumption according to Umberson and Montez. One study by Berkman and Breslow (1983) showed that more social ties that are formal (e.g., formal organizations) or informal (e.g., relatives and friends) are associated with a greater likelihood of healthy behaviours over a ten-year period. Being married (Waite, 1995) and having children (Denney, 2010) are also associated engagement in healthy behaviours because it encourages self-regulatory behaviour. According to Waite, a spouse may promote a partner’s health by monitoring, inhibiting, or regulating the partner’s behaviours. Denney states that the presence of children could decrease the chances of ill health and early mortality for many adults. Children increase the feeling of social integration within the family and strengthen the sense of purpose and meaning in life. Religious ties impact health behaviour through social control. According to Umberson and Montez, social ties infuse a sense of responsibility and concern for others that can lead individuals to engage in behaviours that promote health for selves and others.

3.1.2. Psychosocial explanations

Psychosocial mechanisms could explain how social ties promote health. Psychosocial mechanisms means social factors, such as social status or social support, that influence mental health. The connections between these mechanisms are complex. Together they can explain the linkage

between social ties and health better than a single mechanism (Thoits, 2011; Umberson & Montez, 2010).

Social support is referred to as functions performed for the individual by significant others, such as family members, friends, and coworkers. People may look out for social support as a coping resource when handling stressors, which refers to any environmental, social, or internal demands that require the individual to change their usual behaviour pattern. The effects of perceived social support have repeatedly been examined, especially the effects of perceived emotional support. Emotional support is defined as the belief that love and caring, sympathy and understanding, and esteem and value are available from significant others. The perception and belief that emotional support is available have stronger influence on mental health than actually *receiving* social support, and usually buffers the damaging mental and physical impacts of negative life events (Thoits, 1995). Social support impacts mental and physical health through the influence it has on emotions, cognition, and behaviour. It helps one regulate one's response to stressful situation and avoid dysfunctional responses. According to Umberson and Montez, social support may trigger physiological sequelae (e.g., reduced blood pressure, heart rate, and stress hormones) that minimise unpleasant arousal and is beneficial for health. It is also associated with lower blood pressure during everyday life. This is an important factor, because studies demonstrate a consistent link between social support and lower ambulatory blood pressure, which could reduce the risk for cardiovascular diseases (Uchino, 2006).

Social control is more active and direct. Studies focusing on physical health outcomes recognise social control as a main factor in which network ties (i.e. the social relationships that surrounds the individuals – specifically the structural features, such as the type and strength of the relationships) affect health and longevity, particularly through its influence on health behaviour (Cohen, 1988; Umberson & Montez, 2010). Social control is applied when social-network members attempt to monitor, encourage, persuade, remind, or pressure an individual to change or adopt behaviours. Naturally, this could be beneficial or harmful depending on the strategies used by others to regulate a person's behaviour (Thoits, 2011). Social control can be beneficial for behaviour changes, but can also backfire if they are perceived as dominating or intrusive, which could create resentment and resistance to behavioural change (Lewis & Rook, 1999).

Personal control is the influence one has over oneself and one's own behaviour. Social support may enhance one's feelings of personal control. The sense of personal control can be generated when role performances are successful. Role obligations make up a variety of tasks that must that must be completed on a regular basis. Many are practical tasks, such as meeting

deadlines, earning money, cleaning the house; others are interactional, such as showing respect, controlling one's feelings, or being sociable. The more frequently one handles the demand of role obligations, the more strongly one will believe that one has control over what happens in their lives in general. Perception of control in turn creates confidence in one's ability to cope with major stressors and challenges and thereby could be associated with lower anxiety, depression, and reduced physiological reactivity to stressors (Taylor & Stanton, 2007).

S*ocial comparison* is when people obtain normative behavioural guidance by comparing themselves to others. Thoits argues that this particular mechanism has often been neglected for its impact on healthy behaviour. Individuals evaluate their attitudes and behaviours in relation to other members of the groups they circulate in, and often change their own to match. Such norms could include the appropriateness of using tobacco, alcohol, other drugs; starting a diet or seeking preventive care or counselling. Again, social comparison can have positive or negative consequences for health, since group members may model risky or healthy behaviours.

Psychological distress and mental disorders are often accompanied by too much or too little sleep, too much or too little appetite, or too much smoking or drinking according to Thoits. Such changes are likely to be noticed by family, friends, and coworkers, who might comment or try to intervene perhaps by encouraging the person to seek out professional treatment. If their efforts are successful, then distress, anxiety, or depression could be prevented or reduced. Alternatively, network members could support the individual in the process of seeking out professional treatment. In short, social influence from members of primary and secondary groups may just be as relevant to mental health as it is for physical health.

Social ties always laden with *symbolic meaning,* which helps to explain why the ties exist. The meaning of health behaviours may vary across social contexts. For example, ethnic identity and sense of connection to an ethnic community influence what food one eats, whether one drinks alcohol and how much, and so on. Obesity is influenced by social norms concerning its identification and acceptability, along with those concerning food consumption and (in)-activity. What matters in any network is not necessarily how geographically close the members are but how socially close. A concept related belonging is “mattering”. Mattering is defined as the belief that one has the attention of someone; one is important to that person; and that person depends on one for the fulfilment of certain needs (Thoits, 2011; Umberson & Montez, 2010).

Belonging is the acceptance shown and inclusion offered by one's primary and secondary groups, according to Thoits. These do not follow automatically from group membership; rather, they must somehow be signalled. With acceptance comes the sense of mutual obligations; in

particular, the assurance that some portion of one's needs will be met by the group. An aftereffect of acceptance and inclusion is companionship, which is defined as when one has others to share social activities with (Uchino, 2004). Companionship produces positive affect, which in turn increases physical and psychological well-being; whereas lack of companionship, often described as loneliness (i.e. when there is a gap between one's desired and actual ties to others), could lead to depression, anxiety, poor health habits, and sickness. In short, physical and mental health could also be impacted through the sense of belonging (Thoits, 2011; Uchino, 2004).

Apart from the psychosocial impacts of social relationships, it is worth to discuss the association between social relationships and mental health as recents studies provide new insights into the links between social connection, social support, and mental health. As mentioned previously in the thesis, social support is considered a psychosocial coping resource that has a positive influence on individual's personal resources such as self-efficacy. For example, one's belief that one has the ability to accomplish tasks, specially our ability to meet the challenges ahead of us, and succeed in specific situations (Bandura, 1994). Bandura proposed that perceived self-efficacy decides what coping behaviour is initiated when stress and challenges are met and self-esteem, and buffers the negative effects of stress. Research examining a variety of populations demonstrate significant associations between social support and mental health (Hefner & Eisenberg, 2010). For instance, individuals suffering from psychological distress are consistently found to be more isolated (Kawachi & Berkman, 2001), and less interaction with friends, lack of partner, or feeling alone are also related to higher levels of psychological distress (Stravynski & Boyer, 2001). Within the concept of social support, researchers distinguish between structural and functional aspects of social support. Structural support, also called social integration, is seen as the existence and quantity of relationships. It refers to the number of social ties and how integrated a person is within ones social network (e.g., family relationships, friends, and membership in clubs or organisations) (Hefner & Eisenberg, 2010). Functional support is referred to as the perceived quality of social relationships. It looks at the specific functions that members in the social network can provide, such as emotional support which is offering empathy, affection, love, trust, acceptance, intimacy, caring, and encouragement; instrumental which encompasses the concrete and direct ways people assist others such as financial assistance, material goods or services; informational which is receiving advice and guidance from someone (Lanford, Bowsher, Maloney, & Lillis, 1997); and companionship which is the type of support that creates a sense of belonging to through for example shared social activities (Uchino, 2004). Both structural and functional support have been associated with mental health. The research on mental health outcomes are showing consistent results

regarding the general protective effects of social integration and the potential risk for psychological distress that result from social isolation or the loss of the loss of important ties. For example, the protective effects include lower risk of depression (Seeman, 1996). Hefner and Eisenberg worry that too many studies focus on a single dimension of social support to the exclusion of all others, thereby failing to address how the different pillars of social support interact.

Beyond the positive health outcomes from social relationships (Berkman & Breslow, 1983; Thoits, 1995; Umberson & Montez, 2010), public health has been interested in how social networks could be used to improve well-being among specific groups. Hefner and Eisenberg claim that the relation between social support and mental health is particularly important among college students. The years in college are seen as a period of emerging adulthood and are characterised by change, exploration, and a period where one's identity is developed (Arnett, 2000). In the beginning of the college years, the students face a completely new social environment where they experience more freedom, homesickness, friend sickness, a sense of isolation, and interpersonal conflicts. Consequences due to mental health are growing on campuses and is thought to happen because of the effects transition during adulthood have on the relation between social support and mental health. Hefner and Eisenberg conducted the first study (to their knowledge) on the relationships between mental health and social support in a large (2,843 students), random sample of university students. In this sample, they found that social support was negatively associated with measures of mental health, particularly for depression. Results indicated that both structural and functional support were independently associated with better mental health. In fact, higher perceived quality of support was strongly related with lower likelihood of depression, anxiety, suicidality, and eating disorders.

Maternal mental health has been a topic of interest among researchers since the relation between social networks and maternal mental health has been established. Research has demonstrated how mothers with more supportive networks experience better mental health outcomes. There is a clear relationship between supportive social networks and mothers' ability to cope with stressful life events and their ability to use adaptive parenting behaviours. Supportive social networks also result in nurturing styles of parenting, positive interactions between mother and child, and it acts as a buffer against negative parenting and stressful life situations (Balaji et al., 2007). These factors influence the parenting environment; it improves the mental health and well-being for mothers which when translates into a positive environment for the children. This information helps understanding that social relationships have a general impact on human beings, but also has an important influence on people in specific situations.

3.1.3. Physiological explanations

Supportive interactions with others benefit the immune, endocrinal (hormones), and cardiovascular systems. They reduce allostatic load: the wear and tear on the body that accumulate when an individual is exposed to repeated or chronic stress. Patterns of behaviour emerge over the course of a lifetime, with cumulative effects on health. Emotionally supportive environments are especially important during childhood for the healthy development of these bodily systems, the metabolism, and the development of the hypothalamic-pituitary-adrenal (HPA) axis (Umberson & Montez, 2010), which controls stress responses and regulates many other body processes.

3.2. The Stress Buffering Model and The Main Effect Model

Two models are presented to provide a alternative view of the relationship between social support and well-being. One is the stress-buffering model (Cohen & Willis, 1985; Cohen, 2004); the other is the main effect model (Kawachi & Berkman, 2001). The stress-buffering model focuses on the impact that social relationships have on the well-being of people under stress. Stress arises when someone evaluates a situation as threatening or demanding and is not equipped with appropriate coping responses. The stressed person often feels helpless and suffers a loss of self-esteem.

Social support acts as a buffer against the stress. A person who has an effective support network may make less self-harmful appraisals of the situation , experience fewer overwhelming negative emotions, and so respond with more suitable behaviours. Studies have shown the impact of such support on physiological responses. In one study, participants were challenged to engage in public speaking. The availability of support decreased cardiovascular reactivity. Note that an occasional stressful event may not put high demands on coping abilities for the majority of people. It is when multiple problems build up, straining the individual's problem-solving capacity, that one has the potential for serious disorders to develop. The main-effect model looks at the beneficial effects of social relationships, regardless of whether the individual is under stress or not. Particular attention is paid to social influence, behaviour regulation, sense of purpose and belonging, and recognition of self-worth. The models are not exclusive; they can each contribute to explaining the influence that different aspects of social relationships have on psychological health.

Besides the stress buffering model and the main effect model, support can influence the perception of a stressful event, or expectations about that event, and any stress response, by decreasing or hindering a stress-appraisal response. Support may create the perception that others

can provide necessary resources to redefine the potential for harm in a situation and reinforce one's ability to cope with demands, preventing a situation from being perceived as highly stressful. Also, support might intervene between the experience of stress and the risk of pathological outcomes by eliminating or reducing the stress reaction or influencing physiological processes. The perception of stress could be reduced by providing a solution to the problem by reducing the perceived importance of the problem, calming the neuroendocrine system so that people get less sensitive to perceived stress, or promoting healthful behaviours.

3.3. Aloneness and Loneliness

The absence of relationships – social isolation – is experienced by many if not most people at some point in their lives. Beyond the objective absence of relationships is the perception of one's social environment. The experience of having one's desired quality and quantity of social connections unfulfilled is called loneliness. Although isolation and loneliness tend to coincide, they can also be experienced independently. It means that isolated individuals do not need to necessarily feel lonely, nor does a good deal of social connection prevent the feeling of loneliness. Although there is an overlap between the experience of isolation and loneliness, they should not be treated as the same experience. It is important to include measures of both constructs and not treat them as interchangeable. Loneliness is a strong risk factor for depression and although its prevalence varies with age, the associations remains stable across the lifespan (Cacioppo et al., 2006). Pinquart and Sorensen (2003) state that about 10% of older adults experience frequent feelings of loneliness, and the known situational factors that contribute to loneliness can be threats to interpersonal relationships such as social exclusion, rejection, or separation are known to increase feelings of loneliness (Boomsma, Willemsen, Dolan, Hawkley, & Cacioppo, 2005). The relation between isolation and loneliness, and between loneliness and depression may be influenced by genetic and environmental factors, which might explain the sometimes co-occurrence of these phenomena. The contribution of the genetic factors has been represented as an evolutionary frame work, where loneliness is interpreted as an adaptive response to social disconnection. This provides motivation to re-integrate with social groups. There are suggestions that social isolation is a situation that rises from the environment, and the individual's response is genetically influenced. However, the genetic influence on both social isolation and loneliness might be similar, which rises the possibility that some of the heritable characteristics might be involved in both experiences (Matthews et al., 2016).

4. The Neuroscience of Social Connection

There is no question that social connection are essential for mental and physical health; more interestingly, for my purpose, is what neural regions are implicated in the experience of social connection, and how. Currently, there is significant evidence suggesting that there are neural regions responsible for the experience of social connection, and this section of the thesis is dedicated to explaining these mechanisms. Firstly, in discussions concerning the brain, it is worth mentioning the role of neurotransmitters on the function of the brain. Neurotransmitters are defined as a chemical messenger that carries, boosts, and balances signals between neurons. These billion neurotransmitter molecules are in constant work to keep our brain functioning both physically and psychologically (Lodish et al., 2000). Where it concerns social connection, the most important chemicals are naturally occurring and artificial opioids, specifically μ(Mu)-opioids (Inagaki, 2018b). The brain opioid theory of social attachment claims that μ-opioids are released when experiencing social bonding and underlie the pleasurable satisfaction that comes from creating close bonds. The theory claims that experience of social loss results in reduced opioid activity, leading to separation distress and feelings of disconnection. The release of opioids increase affiliative behaviour, while inhibiting opioids increase feelings of disconnection. Studies until recently have only focused on the effects opioids have on the social experience of animals; for example, studies where baby chicks' opioid activity was reduced using an opioid antagonist vocalised distress when placed into groups, suggesting that – in the absence of opioids – group placement is inherently discomforting. Although research on non-human animals has provided important insights, it comes with severe limitations. Researchers do not have the ability to ask animals how they feel in social situations and must therefore make their own assumptions based on the animal's behaviour. This makes it harder to translate animal social behaviour, such as huddling, to the highly subjective human social experience of feeling socially connected. By contrast, application of an opioid agonist decreased such vocalisation (Panksepp et al., 1980). In the past, it was not really practical in many cases to study neurotransmitters and the chemicals that mimic them in a controlled fashion, except on non-human subjects. This led some to question the applicability of the results to the human case. In recent years, that has begun to change – a trend that Inagaki reports on in (2018b).

Inagaki et al. conducted a study to test the opioid theory of social attachment using the opioid blocker naltrexone. The aim of the study was to test whether an opioid blocker would reduce feelings of social connections more than they reduced positive affect. Participants took naltrexone

for four days (25mg on days one and two followed by 50mg on days three and four) or placebo for four days. Participants rated their feelings of social connection each evening. On the fourth day, participants underwent scanning. Feelings of social connection were measured in relation to an experimental task. The experimenters contacted people whom participants had identified as being very close and asked them to write loving, personal messages to the participant. Examples of messages included: “you are one of the most amazing people I know”, “I think you are beautiful inside and out” and “you are a gift!”. The study found that the opioid antagonist reduced feelings of social connection. It reduced ratings of positive affect as well, but to a lesser degree. The results support the theory of how opioids are involved in reward processes; opioids could be particularly important for social bonding and affiliation.

The nervous system of most organisms is incredible in regards to its capacity to respond to threats of survival. When experiencing a threat, a set of physiological responses is activated with the aim to increase the chances for survival. Such responses may include activation of the sympathetic nervous system (SNS), which initiates a flight-or-flight response. In connection to the SNS, the hypothalamic-pituitary-adrenal (HPA) axis is involved in marshalling energy resources for ongoing threats. When it gets activated, it impacts the immune system, preparing the body for possible harms or further dangers. SNS activity modulates inflammatory activity to create a defence and protect the body from foreign agents. Adapting to acute stressors has been thought to be the primary cause of the long-term negative health effects of stress (see e.g. Eisenberger, 2013). These include inflammatory diseases, such as diabetes. The result can be a shortened lifespan. Research on social connection has found similar physiological responses to threats to social connection: i.e., they are treated as basic threats to survival. This is why people who lack social connections tend to have shortened lifespans. Studies have been conducted on test subjects exposed to the possibility of being socially rejected or looked down upon while delivering a speech in the presence of an audience. A social evaluative-threat (SET) is a set of experiences where there are possibilities for negative judgements by other. Studies have demonstrated that SET triggers specific psychological and physiological changes. Those responses are activated during social-evaluative stressors (such as delivering a speech in front on an audience) where there is a risk of being rejected. Social-evaluative stressors are likely to evoke the hormone cortisol, making the body interpret the situation as stressful (Dickerson, Gable, Irwin, Aziz & Kemeny, 2009). This has been demonstrated by Kirschbaium, Pirke, and Hellhammer (1993) where subjects had to deliver a speech and perform a mental arithmetic in front of an audience, this is referred to the Trier Social Stress Test. The result of the study showed increase in hormone levels (cortisol, adrenocorticotropin (ACTH), growth

hormones, and also increases in heart rate. Several studies (such as Bosch et. al., 2009; Eisenberger, 2013) have demonstrated the increased activity in SNS and HPA axis when an individual is experiencing a risk of being socially rejected, which are the same responses activated in basic treats to survival. To understand why these links exist, it is fundamental to understand the importance of social ties and the dangers associated with being alone. Since social connection is crucial for any social species, the brain has clearly evolved to interpret threats to social connection as threats to survival.

4.1. Experiencing Threat or Harm: The Neural Regions Involved

Research on fear and pain processing has shed light on the amygdala, dorsal anterior cingulate cortex (dACC), anterior insula (AI), and periacqueductal gray (PAG) being the regions responsible for detecting and processing threats. The amygdala, which is probably the most studied neural region on this subject of threat processing, is involved in processing basic threats such as imminent pain (e.g., shock) and dangerous stimuli (e.g., sharks, threatening faces).

Many of the neural regions mentioned above are also involved in processing threats to social connection (Eisenberger, 2013). One study (Eisenberger, Lieberman, & Williams, 2003) exposed participants to social rejection during a computer-based ball-tossing game (Cyberball), while they were in a functional magnetic resonance imaging (fMRI) scanner; both the dACC and AI showed activation. The scanner uses nuclear magnetic resonance to create images by measuring brain activity when detecting blood flow. This technique is based on the fact that cerebral blood flow and neuronal activation are coupled. When a brain area is in use, the blood flow to that region increases which makes that particular area visible to measure (Glover, 2011). People - especially rejection-sensitive individuals – show increased activity in the dACC and AI simply by viewing rejection-related images. Negative social feedback is likewise associated with activation in the dACC and AI, as well as the dorso-medial prefrontal cortex (DMPFC) (Burklund, Eisenberger, & Lieberman, 2007). That is to say that activity in these regions tracks the subjective experience of social disconnection and correlates with physiological stress responses. People who have stronger feelings of rejection following social exclusion show activity in the dACC and AI. These regions, including the PAG, are also active in individuals who tend to feel socially disconnected in their real-world interactions. Various experiences that are interpreted as threats to social connection can trigger threat-related regions. There have been studies showing how activity in these regions correlate with physiological stress responses. Cognitive performance tasks that involve the possibility of negative social evaluation or rejection increase autonomic activation – e.g., increased heart rate and blood

pressure; pupil dilation – in relation to activation in these regions (including, in some cases, the amygdala), as mentioned earlier. Human neuroimaging studies also show how the VMPFC plays a key role in inhibiting or reducing threat-related physiological responses. Greater activity in the VMPFC and PCC during social stress is associated with reduced SNS, and cardiovascular activity, as well as reduced activity in the dACC and PAG (threat-related neural regions). Activation in the VMPFC and PCC also reduces cortisol responses to social stress (Eisenberger, 2013)

4.2. The Relation Between Social Warmth and Safety

The brain also has a set of neural regions responsible for processing safety and reducing responses to threat. Safety could be described as the near absence of threat, or the presence of stimuli known to be protective from threats. Eisenberger (2013) identifies the regions to cues that signal safety as the ventro-medial prefrontal cortex (VMPFC), often associated with the reward, and the posterior cingulate cortex (PPC). These regions are active in situations where threatening stimuli are farther away from an individual versus closer. Learning that a stimulus that previously predicted a negative outcome (e.g., shock) now predicts safety (no shock) similarly activates these regions.

Some studies have shown that neural regions that detect safety and reduce threats (VMPFC, PCC) are also responsible for the response to the presence of a social support figure during stress. These studies are based on the fact that attachment figures are coupled with a sense of security, which stems from the attachment theory. The theory of attachment has been coined by John Bowlby and Mary Ainsworth (1991) where they formulated the basic ideas of the theory from ethology, information processing, developmental psychology, and psychoanalysis, and invented methods to test the ideas empirically. This shed a light on the ideas about a child's tie to the mother and its disruption through separation and deprivation. Bowlby describes attachment as a “lasting psychological connectedness between human beings” (1964, p. 194). One central assumption of attachment theory is that the attachment bond created between caregiver and child provides a sense of safety and security for the child, who is dependent on the caregiver to survive. Just knowing that the person is present lets the child know that she does not need to fear any danger. The effects of this attachment bond are most obvious during childhood (Bowlby, 1964). Earlier theories suggested that attachment was the result of the connection created between child and the caregiver though feeding, because it provides nourishment for the child. When studying this phenomena, Bowlby (1982) observed how feeding did not decrease the anxiety experienced by children when being separated from their primary caregivers. The characteristics of attachment was found to be clear behavioural and motivation patterns. This means that when children are afraid, they will seek

closeness from their primary caregiver to receive comfort and care.

Studies on maternal-infant bonding in nonhuman primates made by Harlow (1958) involved separating young rhesus monkeys from their mothers and left them to be "raised" by two mother surrogates. One of them were made of soft terrycloth and provided no food while the other was made of wire but provided food from an attached baby bottle. The monkeys had free access to both surrogates. The point of the study was to examine which one of these mothers would be preferred by the monkeys. The experiment demonstrated that the baby monkeys preferred spending significantly more time with their cloth mother who provided comfort than with their mother who were only approached when they needed food. Harlow also demonstrated how young monkeys would turn to the cloth surrogate mother for comfort and security after the feeding time. Other attachment bonds, such as those formed between adult romantic relationship partners, endure through the course of life and could be similarly beneficial during threatful situations according to Eisenberger.

Eisenberger (et al., 2011) investigated whether an attachment figure could signal safety and activate the relevant regions in the brain. They investigated whether viewing a picture of a romantic attachment figure while experiencing threatful stimuli (physical pain) would lead to increased activity in VMPFC, the neural region involved in safety signalling. They also examined whether this experience would reduce the perception of physical pain, and reduce neural activity in the dACC and AI (regions associated with the unpleasantness of pain). Female participants, in committed romantic relationships, received painful heat stimuli while viewing two kinds of pictures while being in a fMRI scanner: one displaying her romantic partner and one displaying a stranger or an object (control image). After each heat stimuli, they were asked to rate their sense of unpleasantness from 0 (neutral) to 20 (very intolerable).

The study found that viewing images of partners while experiencing pain was associated with lower pain ratings compared to control images. Viewing one's partner compared to a stranger led to greater activity in the VMPFC and less activity in the dACC and AI. It seems that the VMPFC decreases experience of unpleasantness by regulating activation in the dACC and AI.

Although many studies address the negative aspects of social rejection and isolation, fewer have addressed the positive aspects of social connection. A sense of social "warmth", often associated with a sense of connectedness, appears to generate similar neural activity to physical warmth – both associated with a sense of safety. The link between social connection and thermoregulation extends further than linguistic terms. In the search for the neural regions responsible for the feeling of social connection, some studies have explored the neural regions

behind thermoregulation (the internal process of maintaining warm body temperature), to examine whether they are similar to the ones regulating feelings of social warmth. Social warmth can be defined as the experience of feeling loved by and connected to others.

Early interactions, such as between infant and caregiver (e.g., being held or rocked to sleep), directly increase the physical warmth of the child, leading the child to associate the attachment figure with warmth in other contexts. This subjective association of physical and social warmth may have roots that are phylogenetic, ontogenetic or – perhaps more likely – both. Although the link between them has frequently been observed and commented on, Inagaki and Eisenberger (2013) note that few studies have investigated the common neural regions. They examined whether experiencing social "warmth" makes one feel physically warmer and vice versa, along with whether the activated neural regions are indeed the same. Participants performed three tasks in an fMRI scanner. The first was a "social warmth" task where participants either read messages from close friends and family (e.g., "I love you more than anything in the world") or neutral messages (e.g., "you have curly hair"). In the second, participants were either caressed on the arm with a soft brush or provided a neutral touch with a wooden stick. In the third, participants held either a warm pack or a room-temperature ball for ten seconds. Afterwards, participants filled out self-reports on how warm they felt while reading the positive versus neutral messages, how connected they felt afterwards, how warm they felt after the third task, and how pleasant each task was.

Imaging results showed greater activity in the bilateral ventral striatum (VS), left middle insula, and left anterior insula when participants held the warm pack compared to the ball. Other regions associated with experiencing heat and sensory stimuli were also active, such as the posterior insula and primary and secondary somatosensory cortices. The social-warmth task activated the VS, anterior and middle insula, and the perigenual anterior cingulate cortex (pACC). The researchers conclude that physical and social warmth activate the same or similar areas in the insula and VS: areas associated both with warmth and reward. Results of self-report ratings showed that reading positive messages from friends and family members increased feelings of warmth compared to the neutral messages. Increased feelings of connection were also reported while holding the warm pack compared to the ball.

5. Why are Social Relationships Important?

Social relationships are important because they have an impact on our well-being. In the field of positive psychology, relationships and social connection are important aspects of life, if not the most important. People thrive when they experience love, authentic connections, intimacy, and

physical and emotional interactions with other individuals (Seligman, 2012; Positive Psychology Program, 2017). As mentioned in the introduction, Seligman (2012, 2018) proposed a theoretical model to understand the elements behind happiness and well-being. This model is called PERMA. One of its elements is relationships (the "R"). Relationships are defined as having enjoyable and supportive relations with others. To study this model further, Diener and Seligman (2002) conducted one of the first-ever studies examining the behavioural and personality correlates of happiness.

Studying unhappy individuals, such as people suffering from anxiety or depression, is common in psychological literature. Investigations of happy people are much more uncommon, almost non-existent. This imbalance probably stems from the history of clinical psychology and its emphasis on pathology. Studying happy individuals could increase understanding of how they live their lives, providing information to help unhappy and average people avoid psychopathology (Diener & Seligman, 2002). Before World War II, psychology was used as treatment for curing mental illness. It was served as an approach to make lives of people more productive, identify and nurture high talent. After the war, the attention was drawn to curing and handling the veterans who were suffering from mental illnesses as a result of the war. The face of psychology had changed. This change brought some benefits, such as understanding of therapy for mental disorders that were previously defiant could now be either cured or relieved. However, the two other purposes of psychology – making lives of people more productive and identifying talent – were neglected. Psychology shifted more towards assessing and curing mental suffering, and the research in the field focused on psychological disorders and negative effects of environmental stressors (Snyder & Lopez, 2015). In 1998 a new light was shed of the neglected roots of psychology when Seligman called out to applied psychologists to not only focus on mental illness, but also making lives of people productive and fulfilling as well as identifying and nurturing talents. This allowed the field of positive psychology to finally cultivate (Seligman, 2012). There are several definitions of positive psychology within the field. Lyubomirsky (2007) defines it as "the psychology of what makes life worth living" (p. 2); Snyder and Lopez (2011) define it as "the scientific and applied approach to uncovering people's strengths and promoting their positive functioning" (p. 3); and Peterson (2006) describes it as "the scientific study of what goes right in life throughout different stages of life" (p. 4).

Diener and Seligman examined factors that could influence happiness: social relationships, personality, and other factors that are related to subjective well-being such as religious experiences and physical exercises. At the start of the study, measures were used on college students to divide

participants into groups of happy and unhappy individuals. Measurements included scales of participant's satisfaction with their lives, how often they experienced positive and negative emotions were measured with affect scales, how informants (refer to the people with close relationships with the participant) perceive the respondent's emotions, and daily affect. The recollection of positive and negative life events, self-descriptions (using adjectives), and indications of whether respondents ever experienced suicidal thoughts were measured. Self-ratings of relationships (e.g., close friends, family, romantic relationships) and daily activities (e.g., mean time spent alone; mean time spent with friends, family, partner) were also measured.

The results showed that happy participants scored high on life satisfaction; their recollection of positive events was higher than negative events; they reported more positive emotions than negative ones on a daily basis; and they had never experienced suicidal thoughts. The unhappy participants rated themselves as dissatisfied; they experienced an equal amount of positive and negative affect on a daily basis; they recalled far fewer memories, and they had experience of suicidal thoughts. The happiest participants differed from the average and unhappy participants in their social lives. The happy group spent less time alone and more time with friends, family, and romantic partner. The unhappy group did report satisfaction with family, friends, romantic partners, and socialisation, although not to the same degree. The findings suggest that happy people have satisfying social relationships and spend less time alone, according to Diener and Seligman.

6. Evolutionary Explanations of the Social Brain: The Social Brain Hypothesis

Dunbar and Shultz (2007) explain how the ability of some mammals to experience pair bonding might reveal itself in the size of the brain. It has long been a mystery trying to understand the evolution of unusually large relative brain size in some animals, particularly primates. It is easy to understand that our primate brains have evolved during the course of evolution; but what is not so understandable is why primate brains have evolved to grow significantly larger than the size required to stay alive.

Early explanations of the evolution for large brains in primates tended to focus on the brain’s role in regards to sensory and technical competence. Relevant skills include foraging skills, innovations and way-finding. Larger brains were suggested to be associated with physiological and life-history traits such as large body size, metabolic rate, and prolonged development. The suggested correlation between physical body size, metabolic rate, and brain size was argued to be

due to the faster metabolic rate of larger-bodied animals, who devote more energy to early fetal brain development, making the evolution of larger brains possible. Larger brains can be seen as a by-product of effective energy use.

Alternative analyses have suggested that the evolution of the primate brain was due to the demands of living in larger, more complex societies. This differentiates primates from other species. Continuing on that path, recent analyses suggest how the evolutionary development of the larger brain might have been triggered due to the demands of more intense forms of pair bonding. This hypothesis was named The Social Brain Hypothesis (SBH) (Dunbar & Shultz, 2007). As time went by, SBH gained support. A series of studies have demonstrated how the relative size of the neocortex, an area disproportionately developed in primates, correlates with many factors related to social complexity. Such factors include social group size, grooming clique size, frequency of coalitions, number of females in the group, mating strategies, frequency of play, and frequency of social learning. The SBH suggests that individuals living in stable social groups, compared to isolated individuals, need to solve problems in a social context that could be seen as cognitively more demanding. To live with group members and maintain group cohesion, it is necessary for individuals to meet their own needs as well as managing their interactions with other members of the group. That entails managing indirect and direct group conflict that might result from sharing the same space: for example, while foraging (Dunbar & Shultz, 2007; Shultz & Dunbar, 2007). Primate sociality is quite different from what can be found in most other birds and mammals (Dunbar & Shultz, 2007), and SBH could contribute to the explanation.

The aim of this thesis is to focus on the neural correlates of social connection, with special attention to the links between physical pain and physical warmth, on the one hand, and social pain and social warmth on the other. The research question that will be addressed is: What are the relevant neurological processes that underlie the experience of social connection and bonding, particularly concerning social safety and warmth, and what are the effects?

7. Discussion

The research question for this thesis asked whether there are neural regions responsible for the feeling of social connection, the interplay between physical and social pain in one end and physical and social warmth in the other, and the physical and mental effects of those experiences. These subjects have been addressed throughout this thesis, with significant results. There are neural regions that get activated while experiencing social connection, and also when lacking it,

demonstrating that the human brain is very much involved in the experience of having social bonds. This thesis demonstrate that there are multiple ways to study the effects of social relationships, and the different areas are important for science to understand the major impact of social relationships on humans. It has been shown how the absence of social connection activates similar physiological responses (SNS and HPA-axis) and neural regions (dACC and AI) as when experiencing threats to survival. Experiencing social connection is interpreted as a safety and is processed by similar neural regions responsible for safety signalling, such as the absence of threats (VMPFC). Overlapping neural activity between experiences of social and physical warmth has been shown, and VS and middle and anterior insula are responsible for both kinds of warmth. Finally, opioids have an impact on social bonding and affiliative behaviour, especially μ-opioids, while blocking it will lead to decreased feelings of social connection.

Having a rich social life impacts our health to the extent that mortality is threatened when individual needs for connection are not met. It is worth knowing the differences between social isolation and loneliness, because they should not be used interchangeably. Social isolation and loneliness can be experienced together, but also individually. A person surrounded by family and friends can still experience loneliness, as someone who has social resources but isolates themselves from experiencing them. According to the study by Matthews et al., social isolation was operationalised as the lower end of a distribution of social support. It has been discussed on what is the best measure of isolation, because some may be more appropriate then others depending on the participants' age group. For example, children might not be experiencing social isolation when living with their parents. Borys and Perlman (1985) explain how males feel on average more isolated and females more depressed, and no differences in loneliness between the genders. But the association between isolation and loneliness is stronger among females. It could depend on the fact that female friendships are characterised by greater amount on emotional sharing than male friendships (Caldwell & Peplau, 1982). Matthews et al. suggest that females are more susceptible to loneliness because they seem to invest more in the emotionally-supportive qualities of social relationships. However, males may experience this to a lesser degree. Further more, the relation between loneliness and depression was equally strong for males and females, which suggest that both genders experience loneliness as distressing. As Hefner and Eisenberg stated, social relationships are specially important for young adults as they enter a new stage in their lives. It would be interesting to conduct longitudinal studies examining how strong the influence of social relationships are during different stages in life. Some ages are known to seek their close bonds for acceptance and security, but it would be interesting to know how much different each “age group”

rely on their social relationships.

The field of social neuroscience tries to understand the human brain in a social context, and social relationships is one subject relevant to this field. The experience of feeling socially connected to someone goes beyond any pleasurable and heartwarming experience. Having strong social relationships in one's life is important: they have an impact on physical health and well-being. It is easy going through life almost oblivious to how much social relationships influence one's life. To comprehend why the social world should be capable of affecting the internal processes that mediate health and diseases. Thanks to research, the importance of social relationships for health has been clarified. Looking at it from a social neuroscience perspective, the brain is equipped with neural circuits that are dedicated to detecting threats and benefits to survival. Since social connection is another essential ingredient for survival, experiences of social disconnection and connection seem to have incorporated this basic harm and reward circuitry. These systems then evoke physiological responses (SNS and HPA), leading experiences of social disconnection and connection to activate the same physiological responses; which results in health consequences. Emotionally supportive environments during early life stages promote a healthy development of regulatory systems such as the immune system. Social disconnection leaves individuals sensitive to physical trauma (e.g., from predators), exposing individuals to trauma-related bacterial infections, leading to increased inflammatory responses (Irwin & Cole, 2011). The immune system may have evolved to get influenced by the neural correlates of social disconnection to prepare the body for the bacterial threats that are likely to occur as a result of the experience.

Since the link between social connection and mortality exist, the physiological responses due to social disconnection become crucial to understand. It is important to have the knowledge that the subjective experience of feeling close to someone is not only a sense of security but also impacts our physical and mental health. Treating individuals suffering from social disconnection might be problematic or even impossible. Someone dealing with isolation could not automatically find or create social bonds with just any individual. Quality of relationships can not be formed out of nowhere. It takes time, effort, and a sense of trust and caring from and towards an individual to experience social connection. Therefore, telling individuals living lonely lives to “find some company” should not be a solution. The experience of social connection is very much subjective, making it difficult to tell people how they should feel more socially connected.

Furthermore, the link between social support, stress responses, and physical health should be considerate in health care. Close social relationships are not only helpful with support to patients, but can influence the recovery from illnesses and injuries. Assistance and support from friends and

family have promoted patient's adherence (involves patient acceptance with treatment recommendations) by encouraging optimism and self-esteem; acting as a buffer of the stressors of being ill; reducing patient depression; improving sick-role behaviour; and providing practical assistance (DiMatteo, 2004). The presence of close others may result in a direct or indirect impact on behaviour that promotes health. This might also be relevant to mentally ill patients. Controversially, a non supportive social network can hinder successful alterations of health habits by limiting the patient's energy for adapting positive health habits, or increasing the risk for stress that can interfere with the attitude and behaviours needed for adherence. The impact of social bonds on mental health patients could possibly be based on how severe the illness is. Furthermore, according to Penninx (1998), social support may not be universally beneficial. Its value could partially depend on the particular situation, such as the severity of the sickness and the complexity of the treatment.

Throughout this thesis, a few studies have been summarised in the hopes of trying to explain the possible neural regions involved in social connection. Previous studies have established the neural basis of the experience of threat and safety. Research has demonstrated how a lack of social connection is interpreted as a threat (Eisenberger, 2013) and how the presence of social connection, like an attachment figure, is interpreted as safety (Eisenberger et al., 2011). The significant evidence of similar neural activation is very interesting and provides the field with important knowledge that there are neural correlates of social connection. The VMPFC seems to regulate the activation in the dACC and the AI caused by pain. It could be seen as a protection from the hurtful feelings associated with social pain. It is similar to how prefrontal cortices regulate amygdala (one of the most relevant brain region regarding fear) activation in fear-induced stimuli. When experiencing fearful stimuli, cortical and subcortical pathways in the brain bring out a fearful response. Information about external stimuli can reach the amygdala in two ways: through the low road (from the sensory thalamus to the amygdala) and the high road (through the cortex and then to the amygdala). Because the high road passes through the cortex it represents the stimuli more accurately. When experiencing a fearful stimulus, the prefrontal cortex (PFC) decreases activation in the amygdala. This results in a more accurate interpretation of the stimulus, and a less fearful reaction (Åhs et al., 2009). With its regulatory functions of PFC, it reminded me of how VMPFC regulates activity in dACC and AI resulting in decreased feelings of pain.

The question is why the brain interprets social disconnection as a survival threat and social connection as a safety? Over the course of evolution, being a member of a group and being socially connected to other individuals must have been very important, since there are brain regions devoted

to detecting when those experiences are lacking. Evolution must have developed physiological and psychological responses to risky social situations as if they were actual threats to survival.

One approach to the neuroscience of social connection has been to compare physical to social warmth. The relationship between these has received increasing attention from empirical research and Inagaki and Eisenberger (2013) conducted a study focusing on the underlying neural mechanisms for both forms of warmth. Their study demonstrated how the brain processes the experience of pleasant, warm stimuli and the feelings associated with social warmth with similar neural regions; supporting the theory that social warmth is built on basic mechanisms involved in perception and regulation. These results might contribute to alternative ways of dealing with social rejection, isolation, and loneliness. Based on studies on physical and social warmth, individuals could seek out physical warmth in situations were social rejection and isolation are experienced. Social connection does have an impact on general well-being and happiness, and studies comparing physical and social warmth might help form interventions to fight feelings of isolation or loneliness using temperature manipulations (Inagaki & Eisenberger, 2013).

In the continued search for the neuroscience of social relationships, studies have been conducted to understand the neurobiological mechanisms responsible for experience of social connection. Naltrexone, an opioid antagonist, was found to reduce feelings of social connection in daily reports (Inagaki et al., 2016). This was the first study to examine an opioid antagonist's influence on social connection, and the first to focus on opioids and their importance to daily social connection in humans. Opioids are also associated with positive affect, and the study shown increased in positive affect but not to the same extent to feelings of connection. Even though the topic is fairly new, there are significant results indicating that opioids are a critical component for social bonding. Social relationships and connection are included in multiple fields, such as psychology, social neuroscience, cognitive neuroscience, and neurobiology; it is important to study the subject from different perspectives for one to acquire a deeper understanding of social connection. Although μ-opioids are known to be released in response to close social contact, it has also been shown to play a role in fear acquisition, fear extinction, and learned safety. This means that blocking endogenous μ-opioids enhances the acquisition of conditioned fear and damages the acquisition of learned safety. The opioids are involved in reducing conditioned fear responses and enhancing learned safety. This finding is interesting because attachment figures have a way of increasing μ-opioid levels and serve as safety stimuli, which reduces conditioned fear responses and enhances learned safety (Eisenberger et al., 2011).

There is significant evidence from both the field of neuroscience and positive psychology

that social relationships have an impact on lives. Diener and Seligman (2002) suggest that happy people do have enjoyable and rich social relationships. However, it is difficult to know whether rich social lives cause happiness or happiness cause rich social lives, or if there is some third variable responsible. It is interesting how having social relationships is necessary for happiness, but will not increase happiness on its own. Social relationships do not guarantee happiness, but happiness cannot occur without them. It is important to understand that happiness is made up out of several important components, because to work on one's mental well-being requires one to work on and fulfil all aspects of life.

7.1. Limitations

Feeling a close bond to someone is a subjective experience experienced differently by different people. It can be quite problematic trying to understand the phenomenon through a scientific perspective. Even though it might take a while until researchers fully know the mechanisms behind the phenomenon, they are on the path for uncovering some of them. The studies reviewed in this thesis (Eisenberger et al., 2011; Eisenberger, 2013; Inagaki & Eisenberger, 2013; Inagaki et al., 2016) have contributed to alternative explanations for the experience of social connection and the neural mechanisms behind it. However, there are limitations to these studies.

According to Eisenberger (2013), the VMPFC is highlighted as a region involved in the process of experiencing safety and social connection. However, this region is also often involved in the process of reward (along with other regions). The review by Eisenberger (2013) and the study by Eisenberger et al. (2011) conclude that the VMPFC is active while experiencing safety, but viewing photos of attachment figures might also be interpreted as a rewarding experience. It might be that the experience of social connection is interpreted as a reward, not as a safety. Although the study concluded that viewing photos of partners led to greater activity in the VMPFC, Eisenberger et al. state the importance of exploring whether the task of viewing a romantic attachment figure activates neural regions more relevant to studies exploring safety signalling or rewarding experiences. One reason why the VMPFC is active during both times of reward and safety might be that the experience of safety can be interpreted as a reward in itself. More work is required to explore the role of reward-related processes and how they connect to the experience of safety. The study by Eisenberger et al. is one of the first studies to investigate the neural regions behind safety induced by an attachment figure; there were only 17 female participants in the study; therefore, the results should be interpreted with caution. The results can not be generalised to a larger populations or both the genders. Their experience of safety could have been influenced by how long they had

been in the committed relationship. Perhaps the longer, the more safety the partner induce? The study does not state how long the partners were together.

The role of opioids in human social bonding has only begun being explored. The study by Inagaki et al., have resulted in significant results demonstrating how opioids have an impact on the experience of social connection. The role of opioids in the experience of social connection and bonding is providing a deeper knowledge of the phenomena. When speaking of the brain function, it is important to involve the reason for why the brain is capable of function as it does. In this case, the neurotransmitter makes it possible for people to at least desire social bonds and close contact, and feeling bad when one is not experiencing it. Even though the study by Inagaki et al. was one of the first ones to examine this correlation, it provides valuable information about how the experience of social bonding is created and why. Consequently, further research is needed to understand the role of opioids in social connection even better.

The study by Inagaki and Eisenberger (2013) used post-scan self-reported ratings to measure the degree of social connection. This could be problematic since the reports were filled in after the scanning procedure, which could influence how the participants answered the questions. The participants might not remember *exactly* how they felt after the experience was over. To get the most accurate answers, the participants should have answered the questions while experiencing the experiments. Diener and Seligman (2002) also used self-report scales to measure positive and negative affect, satisfaction with life, and suicidal thoughts. The questionnaires were handed out at different points over the course of a semester, and there could be extraneous variables (personal events, weather, physical health, experimenter effects) influencing the answers. Although this study provided interesting results, one should take the interpretations with caution since the study was the first of its kind. Studies using self-report measures of social support might not always provide with an accurate result. People experiencing distress might judge their social relationships more negatively. The solution for future research would be to employ measures of support from the perspective of the participants' friends and family members. This could lower the risk for measurement errors.

As introduced earlier in the thesis, there are many features of social relationships. The features are valuable to understand when speaking of social relationships because there are different meanings to them. As researchers have tried to operationalise these features, I am concerned of the existing definitions. Operationalisation is needed for researchers to study abstract phenomena. The definitions provided in the field of social relationships are almost identical to each other. Both social ties and social integration are defined as the connection and general level of involvement in

primary and secondary groups, and social connection and social bonding are used interchangeably by Inagaki et al. (2016). By not having a clear definition of a phenomenon makes the results harder to interpret. Do the researchers study the same phenomenon by using different definitions that explain the same experience and vice versa? In studies regarding social support, it is not possible to determine exactly whether a lack of social support leads to mental health problems, or if people dealing with mental health problems build weaker social support networks due to the symptoms of their disorders or other factors. It is hard to find causality, even from longitudinal studies, because some personality traits could be related with both lack of network connections and the chance for depressive symptoms (Hefner & Eisenberg, 2009).

7.2. Future Directions

Research is beginning to examine ways in which social experiences influence human beings and their health, and why this knowledge is important to understand. More attention is being shed on this topic, and it is growing; many interesting findings have been made. Research could focus on unanswered questions.

It has been shown how chronic negative social experiences, such as social isolation or loneliness, have a negative effect on health. It is important to understand how chronic positive social experiences, such as social connection and social bonding, alter neural and these physiological responses over time because it has such a major impact on mental and physical health. Individuals with close social bonds throughout their entire life, are they less likely to experience the physical outcomes of social disconnection? In that case, social experiences might act as a buffer for many diseases due to increased physiological responses We should not neglect the fact that not all social relationships are beneficial. Additional research could attend to the impact of problematic social ties and their impact on health, specially in high-risk populations (such as low-income populations). Previous research in this area have demonstrated how measures of quality, rather than quantity, of social relationships might be a better indicator of the role of social networks in high-risk populations (Hefner & Eisenberg, 2009). These types of ideas and measures should be included into future social networks studies and the development of interventions. It is also important for neuroimaging research to understand how exposure to positive social experiences over time impacts the brain, and if those experiences can alter neural regions.

Finally, it would be interesting to examine if the lack of close social bonds during a long period of time would impact cognitive functions such as empathy or compassion. As much as you depend on your friends and family members for love and support, in many cases, you are also a

source for love and support for your close relationships. There is a sense of empathy or compassion for your close ones which makes us want to help and support them. I wonder is the lack of these relationships would reduce feelings of empathy or compassion to people, perhaps because one is not used to experiencing those emotions or situations.

8. Conclusion

The research into social connection has come a long way since the early stages. Social relationships and the experience of social connection are seen as important factors for one's physical health and mental well-being. Fields within neuroscience demonstrate significant results that there are connections between social relationships and physical health and mental well-being, and that there exist neural correlates supporting the experience of social connection. This thesis provides explanations regarding how the human brain processes social connection, such as how experiencing safety activate similar neural regions as social connection, demonstrating that the experience of social connection is signalled as a safety; and how social isolation and rejection activate regions involved with threat processing, demonstrating that threats to social relationships are processed as a survival threat. Experiencing social warmth activates similar neural regions to those activated by physical warmth. In the field of neurochemistry, μ-opioids have been linked to social bonding and affiliative behaviour. By using an opioid antagonist, it is possible to decrease the experience of connection and affiliative behaviour. This indicates that opioids have an important influence on social connection. Since the early stages, research has come a long way of understanding how our close bonds influences our lives, and significant results have been discovered. This knowledge may be used to understand how we are influenced by our social relationships, both our personal lives and our professional lives.

9. References

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