



# Bachelor Degree Project

## **NEURAL CORRELATES OF ROMANTIC LOVE AND ROMANTIC ATTACHMENT**

Bachelor Degree Project in Cognitive Neuroscience

Basic level 15 ECTS

Spring term 2018

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### **Abstract**

In the field of neuroscience, being in love and feeling romantically attached to a partner is described as a dynamic process. Romantic love may be viewed as a motivational system, changing throughout time and place, fluctuating on the interest and motivation of the individual. Early memories and attachment towards a caregiver, lay the foundation for later attachment behavior, also known as attachment styles. In this thesis, an exploratory approach is present. The thesis aims to introduce and describe the neural correlates of romantic love and romantic attachment. Brain regions concerned with reward, emotion and thought processing, such as the reward circuitry network of the brain and the limbic system, are being investigated. So are other brain areas involved in romantic love and romantic attachment. Research findings suggest that brain areas responsible for affection, emotional control, learning, memory and social judgment are all involved in the complex processes of being in love and feeling romantically attached. These findings are represented by the involvement of the frontal lobe, cerebral cortex, limbic system, orbitofrontal cortex, and hippocampus, anterior cingulate cortex (ACC), ventral tegmental area (VTA), caudate tail, including the reward pathways of the brain. Distribution and regulation of neurotransmitters such as; vasopressin, oxytocin, dopamine, corticosterone and serotonin are all present in the state of romantic attachment and romantic love. Overlapping evidence confirms the involvement of the reward circuitry network, together with the limbic system as crucial in the formation and maintenance of a romantic relationship.

*Keywords:* Attachment, the attachment theory, the limbic system, the reward circuitry network, romantic love

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## Introduction

“Brain activity is considered the physical correlate of mental activity. Accordingly, a change of the state of mind implies a change in the state of the brain and vice versa” (Friedrich, Wood, Scherer, & Neuper, 2014, p. 1). What are the neural correlates making us experience love and attachment towards our partner?

A person in love can experience being in a wonderland of thoughts and emotions about and towards their significant other, or in pain or despair of lost love. When it comes to romantic love, obsession and addiction are common experiences. Romantic love can often result in the absence of self-control, loss of reasoning, and a constant longing for the other individual. The abnormal behavior of people reporting being intensely in love is linked to the same behavior present in addicted behavior, also observed in individuals suffering from drug addiction (De Boer, Van Buel, & Ter Horst, 2012). This abnormal behavior is explained as a consequence of elevated or suppressed levels of the brains chemistry, differentiating the process of being in love from not being in love (Fischer H. , 2006a).

Behavior resulting from feelings and actions of caring, adoration, emotion, motivation, enamoredness, worship, amorousness, loyalty and sexual attraction are all found in the circumstance of being intensively in love. Although romantic love in scientific literature is often described mostly as feelings, science has moved away from this assumption (Fischer H. , 2006a). Current research believes that romantic love is not behavior executed from emotional responses but rather categorized as a motivational system, changing throughout time and place fluctuating on the interest and motivation

of the individual. This motivational system involves many emotions as well as thought processes as the result of the wish or action of pursuing and maintaining a romantic relationship (Fischer, Aron, & Brown, 2005). It is characterized both as a state common for everyone in love, with subjective traits making the experience unique for the ones in love.

From an evolutionary perspective, the goal-directed behavior of mating results in a reciprocated action, also described as “push-pull mechanism” experienced by the ones involved. The internal motivation of carrying on one’s genes, combined with the emotional and thought processing of reciprocating actions with one’s partner, confirms that we prefer our partner over other possible fitting individuals (Fischer, Aron, Mashek, Li, & Brown, 2002).

The bond of attachment towards a romantic partner, is not only linked to sexual drive, which can fluctuate in a relationship (Acevedo, Aron, Fischer, & Brown, 2012). Romantic love also involves components of intimacy towards the chosen one and the decision of commitment and investment in the relationship (Sternberg R. J., 1986). Consequently, it is reasonable to include the bond of attachment being central in romantic relationships.

The individual learns to develop and maintain close relationships through interactions with its caretakers. This behavior is suggested to follow the individual throughout their lives (Bowlby, 1988), influencing learned social behavior towards our romantic partner (Shaver, Hazan, & Bradshaw, 1988). Romantic attachment, interaction and behavior are similar to the dynamics found in close relationships with family members, where the sexual component is naturally missing, as we are not sexually attracted to our relatives.

When it comes to behavioral science, attachment is often described from Bowlby and Ainsworth's (1988) perspective resulting in *the attachment theory*. Here attachment styles are suggested to follow the individual in close relationships and encounters, hence romantic relationships. Today the attachment theory is a grounded, respected and frequently used scientific theory. The attachment styles include; *secure, anxious-ambivalent, insecure-avoidant* and *disorganized-disoriented*. The last one is a later contribution from Main and Solomon's research from 1990. When it comes to the neurological view on attachment, and the different attachment styles, they are suggested to be caused by neurological correlates of heightened or lowered activity in brain regions and the involvement of specific neurotransmitters (Carter, 2017; Cozolino, 2014).

### **The present study**

This thesis aims to introduce and describe the neural correlates of romantic love and romantic attachment. It is exploratory in the sense that a lot of attention has been given to the topic – over many years. The discovery of neural correlates is considered necessary in the understanding of romantic love and romantic attachment.

Consequently, the central question in this thesis will be; which neural correlates are involved when we experience love and romantic attachment towards a partner?

Being in love and feeling romantically attached to a partner, often demands a lot of thought and emotional processing, together with being a highly rewarding experience. Taking this into consideration, I want to investigate the reward, emotion and thought processing areas of the brain, namely the reward circuitry network and the limbic system and their involvement when it comes to romantic love and romantic attachment. When it comes to the different attachment styles, it is also suggested that the differences

among the attachment styles can be found in neuroscientific findings as heightened or lowered brain activity, and neurotransmitter release.

The method of approach is to introduce scientific literature of theories on romantic love and attachment, in combination with an investigation of the neural correlates. The layout of the thesis starts with a theoretical explanation of romantic love and attachment. The attachment theory from Bowlby and Ainsworth's (1969/1982) perspective is included with the aim of understanding attachment behavior in romantic relationships. After this an introduction to the neural correlates of romantic love and attachment is presented. Brain areas such as; *the frontal lobe, cerebral cortex, limbic system* (as in *the amygdala, hippocampus, hypothalamus, insula*) together with the *orbitofrontal cortex (OFC), anterior cingulate cortex (ACC), ventral tegmental area (VTA)* and *the caudate tail* are presented separately, and sometimes together, when it comes to the neural correlates of romantic love and attachment.

*The reward circuits of the brain*, together with the neurotransmitters such as *vasopressin, oxytocin, dopamine, corticosterone* and *serotonin* are presented separately, and together, when found necessary in relation to romantic love and attachment. Regarding the different attachment styles and neural correlates, they are included when distinctive findings in neuroscience are present when considering their impact on romantic love and attachment in relationships (Bartels & Zeki, 2000; Fischer et al., 2006; Fischer, et al., 2002; Schore, 2000).

Although romantic love and attachment have previously been defined separately, it becomes more complex when considering the field of neuroscience. Brain areas, neurocircuits, hormones and other neurological compounds are often involved in both

romantic love and attachment, combining the two phenomena (Bartels & Zeki, 2004; Fischer H., 2006; Fischer H. E., 1998; Fischer et al., 2006; Fischer et al., 2002).

The dramatizing of romantic love at the beginning of a romantic relationship, or how romantic love is fantasized about is not pursued in this thesis, rather included as an attempt to explain the different experiences the individual might have of romantic love. The basis of my interpretation will explore scientific literature and research findings on romantic adult heterosexual relationships where the couple engages in a romantic, intimate, sexual, physical and monogamous relationship. Although this, I personally hope and believe that scientific findings from heterosexual monogamous couples can be useful regarding people in other couple constellations as well.

I will not investigate the different perspectives on romantic love between the genders. It is recognized that there can be more differences within genders rather than between the genders, not to mention cultural differences and within nations. Despite these limitations, I hope that my conclusions can also be used in a general manner.

## **Theoretical background**

### **Romantic love and attachment**

What happens in the body and the brain when being in love and attached to another individual? When it comes to the evolutionary and psychosocial aspect of romantic love, it lays within our nature (Fischer et al., 2005). This to say, that we are also acting on instinct, to find the right partner to produce our offspring.

From an early age, children pay attention to love and partnership. Through role-playing and mimicking parental behavior, they show similar non-sexual affection towards the opposite sex. In puberty, romantic love and attachment are more focused on

hormone levels as well as cognitive development that has reached higher levels. The individual then begins exploring their own sexuality together with a wish of participating in a romantic relationship (Feeney & Noller, 1996). As adults, there is a commonly shared understanding in western contemporary society that a romantic partner is preferred, especially when it comes to mating in order to carry on our genes (Buss, 2015).

We might go through different phases in our lifetime, but the longing for someone to share our life with, a partner, romantically or as a friend, is common for many. The wish for someone to love, who loves you back, is a dream for many (Graham, 2011). We have a biological drive to reproduce combined with psychological factors such as the need for belonging, intimacy, and affection (Gonzaga, Turner, Keltner, Campos, & Altemus, 2006). The main question for this thesis now becomes central. What neural correlates are involved when we experience love and romantic attachment towards a partner?

**Theories on romantic love.** When it comes to scientific views on romantic love one of the most grounded in behavioral science is *Sternberg's triangular theory of love* (O'Leary, Acevedo, Aron, Huddy, & Mashek, 2011). Sternberg proposes *intimacy*, *passion* and *decision/commitment* crucial in a romantic relationship. Sternberg explains intimacy as the feeling of connectedness, closeness and bondedness that one experiences in a romantic relationship. Here, attachment might be another word for the same behavior. Sternberg defines passion as the drive that leads to romance; the mental and physical attraction towards the other individual, including the sexual drive (Sternberg R. J., 1986). Lastly, decision/commitment is the component which makes the relationship long term. In the beginning, commitment might be the pursuing and

engagement of a romantic relationship, which later develop into a choice of staying together for long-term purposes (Sternberg R. J., 1986; 1988).

When it comes to romantic love, it seems nearly impossible not to mention *love at first sight*. Hatfield and Walster (1981) define this term as infatuation. Here they propose the active component of being in a state of passionate arousal (Hatfield, 1988), however components of commitment and intimacy are missing. Although it is a nice thought to fall in love with someone at first sight, a relationship cannot alone be based on passion.

When looking at the scientist's different definitions of romantic love and attachment, it is easy to understand that the universally known concept of romantic love is portrayed in many ways. When it comes to a romantic relationship, the individual might be looking for someone who shares qualities of their own in addition to finding a partner who is stable, trustworthy, caring, lovable, and who equally wants to share in a relationship. Maybe they share a similar background, lifestyle, morals and ethical values, or other shared similarities (Fischer et al., 2002).

**Romantic insecurity and loneliness.** Insecurities with relationship satisfaction, relationship fulfillment, mutual love interest, and mutual investment such as home, family, insurance, are additional factors influencing a romantic relationship. This is why, it can be an emotional and irresistible debate as to whether or not the individual should commit to their partner and how long the relationship will last. Ambivalence can also act as a force within the individual, causing them to want to be closer to their partner, for then at the same time push them away (Hazan & Shaver, 1987).

Fear and longing for intimacy might be present at the same time. Jealousy, mistrust, insecurity, and delusions can all be lurking in the background. Romantic rejection is connected to protest and resignation/despair. When being abandoned the individual often feels an intense energy, alertness, and extreme motivation to win back their beloved. Suggested by psychiatrists, this can be linked back to our mammalian response to winning back any social connection we have (Fischer, 2006b).

Many people believe that their loneliness will be cured when they find a matching partner. However, loneliness can be felt as much when indulging in a relationship as when single. Often people feeling lonely are lonely within themselves, something a love interest cannot cure (Shaver & Hazan, 1984). From Weiss (1973) perspective both *emotional loneliness* and *social loneliness* exist. Emotional loneliness is often found in dysfunctional relationships, while social loneliness is found in friendships. Often in a romantic relationship, friendly love and romantic love is present, making both aspects of loneliness possible.

Emotional loneliness is when you lack close and intimate attachment to others. People who have recently broken up, are widowed or involved in a relationship where emotional connection is a missing component might experience this kind of loneliness. Social loneliness comes from lack of family, friends or a social network. People going through major life changes often experience this kind of loneliness as well. This is an intrinsic feeling, depending on the individual's perception of themselves, how they feel and their self-esteem and is not dependent on their partner (Weiss, 1973).

**Research on romantic love.** Research on romantic love comes mainly from qualitative research such as therapy sessions with individuals and couples. Quantitative research is based on international online surveys, university data, in addition to lab

experiments (Graham, 2011). Romantic love questionnaires often investigate attachment to current partner, previous partner and sometimes a fictitious partner (Aron & Aron, 1991). The questionnaires can be *Rubin's loving and liking scales (RLLS)*, *the love attitudes scale (LAS)*, *the passionate love scale (PLS)* and *the triangular love scale (TLS)* (Graham, 2011). For the questionnaire of the TLS, see Appendix A.

Neurological experiments of romantic love and attachment usually involve lab experiments of fMRI (functional magnetic resonance imaging) or EEG (electroencephalography) with the intention of measuring activity and deactivity in specific areas of the brain. The distribution of neurotransmitter involvement is also used to measure love and attachment (Acevedo et al., 2012). Often the individuals are asked to bring pictures of loved ones and friends to the lab and then fill out questionnaires for the scientists to understand the nature of their relationship (Bartels & Zeki, 2004).

### **The attachment theory**

The creation of a relationship between the caregiver and toddler is the beginning of socialization that will impact the individual for the rest of their life (Ainsworth & Wittig, 1969; Ainsworth & Bowlby, 1991; Berger & Luckmann, 1967). During this time, the interaction with caregivers forms a memory and learning process, establishing the formation of socialization patterns. According to Berger and Luckmann (1967), the early memory and learning processes lay the ground for action and reaction patterns. This again is considered to impact the repeating patterns of behavior for the individual throughout its lifetime. This again is affecting the child throughout its life, impacting the chosen direction concerning education, lifestyle and partner preference (Berger & Luckmann, 1967; Cozolino, 2014).

When it comes to romantic love, the attachment theory and attachment styles give us a deeper understanding of couple dynamics. This is an important element in relationship satisfaction, and contributes to the explanation of how a relationship can be healthy or unhealthy, depending on their individual and combined attachment styles (Mikulincer & Shaver, 2016). How the individual behaves is often a repetition of the previous memories linked to similar events (Berger & Luckmann, 1967; Bowlby, 1988).

However, studies show that memory and learning can be learned, re-learned and new-learned (Gazzaniga, Ivry, & Mangun, 2009). The neuroscientific way of explaining this is stimulus, response, and reinforcement, together with the plasticity of the brain (Gazzaniga et al., 2009). Influenced by the right guidance and conscious awareness, the individual may change their perception and how they engage in their environment, hence their attachment style (Belsky, 2002).

The attachment theory was developed in 1950's and is a result of a cooperation between John Bowlby (1907-1991) and Mary Slater Ainsworth (1913- 1999). Based on Bowlby's psychoanalytic thinking, ethology, developmental psychology, information processing, the control systems theory as well as Ainsworth's studies in Uganda (Ainsworth M. D., 1979) it is frequently used in the behavioral sciences. The original theories of attachment names three forms of attachment: *secure*, *insecure-avoidant attachment* and *ambivalent-resistant attachment* (Ainsworth M. D., 1979). These attachment styles are also known as *secure*, *avoidant attachment style* or *avoidant-dismissive* and *anxious-ambivalent*, *ambivalent-preoccupied* or just *anxious attachment*. In this thesis the names insecure-avoidant, anxious-ambivalent and secure attachment will be used.

Presented by Bowlby (1969/1982) *the Internal Working Model* (IWM) is suggested to work automatically (Verschueren, Marcoen, & Schoefs, 1996) and is the response to the environmental influence of the individual's attachment style. The IWM functions as a pre-programmed way of responding, based on the individual's earliest memories and learning from interactions with caregivers. Verschueren et al. (1996), describe the IWM as being the inner representation of the child itself. It is dominated by unconscious interpretations that are a challenge to be aware of, understand and even change.

Mikulincer and Shaver (2003; 2007) suggest attachment as being compromised as a model called *the attachment behavioral system (ABS)*. According to Bowlby's (1969/1982) IWM model, the attachment system gets activated by threats where the individual subconsciously notices the responsiveness and availability of a situation that provides a secure attachment situation (Mikulincer & Shaver, 2003). The ABS provides an automatic response pattern over time, structuring the behavioral and reaction patterns of the individual's attachment style in later romantic and maternal relationships (Mikulincer & Shaver, 2003).

Studies show that when an individual knows and feels they will master the situation, based on implicit or explicit motivation, consciously or subconsciously, they share a secure attachment style. However, if the person constantly feels the need to hyperactivate or deactivate the situation, they have an anxious or avoidant reaction pattern. This is an example that illustrates attachment styles (Main & Solomon, 1990; Mikulincer & Shaver, 2003). Attachment influences the rational functioning and intrapsychic development of the individual. This includes the dynamics occurring in romantic relationships (Allen & Land, 1999).

**Research on attachment.** Originated from Ainsworth's research, the strange situation test (SST) is most commonly used when measuring child attachment in laboratory settings (Ainsworth & Wittig, 1969). Adult attachment is also possible to measure in laboratory settings through couple interaction. Usually, single and couple's attachment style, can be investigated in forms of people discussing matters they already know they disagree on (Youngmee, 2006). When it comes to adult attachment measurements, including adult romantic attachment measurements, there are by now many represented in the field of science. Although the attachment theory is presented as the individual sharing one attachment style, it is not that simple. Today, scholars include the possibility that the individual might have different traits of the different attachment styles, formed into one unique attachment style of the individual.

Hazan and Shaver's (1987) *three-category measure of adult attachment* is one of the first measurements on adult attachment in romantic relationships. This measurement contains one question for each of the three attachment styles; secure, anxious-ambivalent and insecure-avoidant, from a liking scale from one to seven, with strongly disagree to agree strongly. Later Bartholomew and Horowitz's (1991) made a relationship questionnaire (RQ) where the questions were similar Hazan and Shaver's (1987) measure, adding the fourth attachment style disorganized-disoriented attachment, but also changed and worded the questions differently.

The relationship scale questionnaire (RSQ) (Griffin & Bartholomew, 1994) was inspired from the previously mentioned measurement tools, together with Collins and Read's (1990) adult attachment scale (AAS). In the RSQ participants rate each statement on a five-point liking scale, that fits their characteristic attachment style the best when it comes to their feelings, thoughts, reaction patterns and behavior in

romantic relationships. This questionnaire can be found in Appendix B, as an example of one of the adult romantic attachment measurements.

Here the scientists use the names *preoccupied attachment* for anxious-ambivalent attachment, *dismissive* for insecure-avoidant attachment, and *fearful* for disorganized-dismissive attachment. Five statements concern secure and dismissive attachment patterns, and four statements for fearful and preoccupied attachment styles.

The four-category model of attachment is from Griffin and Bartholomew's (1994) survey, may serve as an indicator when calculating the results from the questionnaire. Here the individual can see their own composite attachment ratings on a self/avoidance and other-model/avoidance attachment scale of dimensions as explained in Ognibene & Collins (1998) and later Mikulincer & Shaver (2016). This model can be found in Appendix C1.

This scale includes the individuals own self-image of dependence (positive or negative) and image of others and avoidance (positive or negative). A securely attached individual will have both a positive view of self and others, as well as being comfortable with intimacy and autonomy. Someone who has an anxious-ambivalent attachment style has a high negative dependence, and positive avoidance resulting in a negative effect (Bartholomew & Horowitz, 1991) for the individual.

Insecure-ambivalent attachment style shares a high negative avoidance and high negative dependence resulting in fear of attachment. The last attachment style, disoriented-dismissive attachment shares a high negative avoidance, together with a low positive dependence, resulting in being counter-dependent and having troubles in interactions and relationships with others (Feeney & Noller, 1996; Sternberg & Weis, 2006).

When it comes to Hazan, Mikulincer and Shaver with colleagues, the commonly used adult romantic attachment questionnaire today is the experiences in close relationships (ECR) which was first published by Brennan, Clark and Shaver in 1998. This measure has 36 items and is quite similar to the RSQ in wording and style.

**Attachment styles.** Ainsworth proposes 70% of all infants share secure attachment. Here they have low anxiety and low avoidance patterns. Insecure attachment styles such as insecure – avoidant and anxious-ambivalent attachment represent the remaining 30 % with each style representing 15 %. The insecure-avoidant attachment style has a high avoidance and low anxiety pattern, the anxious-ambivalent attachment has high anxiety and low avoidance pattern (Cozolino, 2014).

Van IJzendoorn's (1995) meta-analysis study on attachment showed a distribution of; 15% as disorganized, while 55% secure, 8% ambivalent and 23% avoidant. Compared to the 1988 study when he together with Kroonenberg found attachment patterns to be 65% secure, 14% ambivalent and 20% avoidant (van IJzendoorn & Kroonenberg, 1988). This shows that the estimated percentages of Ainsworth's attachment styles are still quite precise. These statistics may also be a contributing factor in understanding the attachment style diversity in society, hence being applicable in therapy settings (Cozolino, 2014). When it comes to characteristics of attachment styles, parenting attachment style and resulting adult attachment style, this can be found explained in Appendix D.

Ainsworth believes insecure-avoidant attached individuals have had a caregiver rejecting them, being insensitive to their needs. This results in trust and dependence issues (Ainsworth M. D., 1979). People with insecure-avoidant attachment style are

independent both emotionally and physically. When put under pressure, they choose to handle things themselves, and are not available to help, or receive help from others.

People with a secure attachment style are easy to calm down since their caregiver has been sensitive and trustworthy in meeting their needs. According to Bowlby, a securely attached individual will most likely be the one who is responsive, emotionally and physically available and helpful towards others (Bowlby, 1980).

The anxious-ambivalent attached individual will have conflicting feelings and behavior, as a result of ambivalent caring from their earliest primary caregivers. They will vary with clingy and attention seeking behavior and then push the caregiver away when they eventually get a response to their needs (Ainsworth & Wittig, 1969). Since the child does not develop any physical or emotional response of security from the attachment figure, they will have difficulties with trusting people later in life and may repeat this behavior (Ainsworth M. D., 1979).

Main and Solomon (1990) added an additional attachment style to the original attachment theory, called disorganized-disoriented attachment. This attachment behavior has previously been included in the descriptions of the two insecure attachment styles (Ainsworth M. D., 1979; Main & Solomon, 1990). This attachment style is a form of avoidant attachment, acting from fearful responses motivated by the “conscious fear of anticipated rejection of others” (Bartholomew & Shaver, 1998, p. 27).

The disorganized-disoriented attachment is often a result of the parent not being an appropriate attachment figure mentally, emotionally or physically (Main, 1990). As a result, the individual will have trust and attachment issues, and disorganized attachment as an infant is also believed to be a precursor to later repetitive troubled behavior throughout life (Karlen, 1996; Shemmings & Shemmings, 2011).

Mental disorders are often linked to maltreatment, inappropriate social relating and maladaptive behavior, all covered in the disorganized-disoriented attachment style. A relatively new attachment disorder concerning children, called *reactive attachment disorder (RAD)* is included in the DSM-5 (Cumyn, 2016). This attachment is a more extreme version of the insecure attachment styles, concerning severely inappropriate social behavior in children before five years of age. An individual with the latter disorder, has often suffered severe trauma such as neglect, maladaptive behaviors in caregivers where the caring needs have not been met (Cumyn, 2016).

An individual with an anxious-ambivalent attachment style will need constant confirmation in the relationship, whereas the person who has an insecure-avoidant attachment style would react in the opposite manner (Hazan & Shaver, 1987). Attachment deals with many aspects including; intimacy, fear of intimacy, loss, and jealousy, including the ups and downs an individual might experience in a romantic relationship (Hazan & Shaver, 1987).

Someone who is anxious needs a lot of confirmation, affection, and compliments, knowing that they are wanted and needed in the relationship, and often is dependent on their partner. The fear of someone leaving and abandoning them might impact their behavior and consequent relationships, wavering between wanting to be close and distant at the same time (Bowlby, 1973). An insecure-avoidant attached individual may be reluctant to be close, and claim freedom and independence, suppressing the importance of the relationship or their partner. A disorganized-disoriented attached individual may be dependent on their partner, while causing a lot of turbulence in the relationship due to inner instability.

A person who is driven by emotions and fears, is often overreacting rather than rationalizing the situation (Cozolino, 2014). Anger and avoidant patterns in behavior are predictable. This is a result of the individual struggling with mental and sometimes physical stability, reliability and security (Shemmings & Shemmings, 2011), also affecting romantic relationships.

**Coping strategies and attachment styles.** Dysfunctional coping strategies have been found more in people with insecure attachment styles. People with an insecure-avoidant attachment style have better strategies for ignoring unpleasant thoughts. These participants showed no decrease in blood flow, nor deactivations in concerned prefrontal regions, when participating in lab experiments (Mikulincer & Shaver, 2003). These findings indicate that insecure-avoidant individuals cannot deactivate certain brain regions, as the other two attachment styles, impacting their patterns of behavior (Mikulincer, Birnbaum, Woddis, & Nachmias, 2000).

Anxiously attached individuals have a more negative coping strategy as compared to secure and insecure-avoidant individuals (Davis, Shaver, & Vernon, 2003). People with insecure-avoidant and disorganized-disoriented attachment may also use alcohol and other drugs, in an attempt to lower the negative internal processes. Anxious-ambivalent attachment is also linked to alcohol and drug abuse when coping with rejection and abandonment (Davis et al., 2003).

When it comes to the different attachment styles mindfulness-based stress reduction (MBSR) meditation has shown lower stress levels and might be a healthy contributor with the aim of handling one's attachment style better. In a study on MBSR and attachment styles, the insecure attachment styles had higher stress levels prior to participation with MBSR techniques than securely attached individuals. In post-

participation, the insecure group, had lower stress levels than pre-participation as compared to the secure group (Cordon, Brown, & Gibson, 2009).

Therapy, such as psychotherapy, cognitive behavioral therapy, single and couples counseling have all shown different effects on romantic love, and attachment styles. The most significant effect is found in the insecure attachment styles, revealing that self-awareness of behavior and reaction patterns, may help the individual change their attachment style, and attachment towards their partner or potential partner (Cozolino, 2014). The touch of a healing hand can fix a broken soul, or implied when it comes to attachment styles; by being around a person with a secure attachment, this can make the insecurely attached individual feel more secure about themselves and others.

The use of medication to influence insecure attachment styles is a frequently debated among scientists. The solution of treating attachment styles seems to be complicated. Over 70 % of people, using serotonin-enhancing antidepressants (SSRI), report having a decline in sexual arousal, desire, and orgasm. This is often accompanied by feeling estranged from their chosen partner (Fischer H. , 2006b). A drug designed to lower the negative emotions and thoughts, might decrease positive emotions as well, resulting in the individual feeling detached from their partner.

The ethical and moral issue here is that an attachment style is in itself not necessarily linked to mental illnesses. When it comes to romantic love and attachment behavior, it would be questionable if medication is the right way to go (Haggerty, Hilsenroth, & Vala-Stewart, 2008; Hegtvedt, 2014). Medication can however be found necessary in certain circumstances.

## **Neurological research**

### **Romantic love, romantic attachment and the brain**

Which are the neural correlates involved when we experience love and attachment towards a partner? The emotion-motivation systems in the mammalian brain involve cohabiting, breeding and parenting. This is in turn, motivated by lust, attraction, and attachment (Fischer H. E., 1998). In both sexes the attraction system is characterized by focus of attention and increased energy on a specific mating partner. The human attraction system is often called romantic love, companionate love or passionate love. In this thesis, romantic love is used as the common term for this attraction system.

Signs such as heightened energy, sleeplessness, obsessive following and loss of appetite are normal. Both sexes share an increased focus of attention, affiliated gestures, increased empathy for the other, and intense motivation to develop a relationship with the potential partner (Fischer et al., 2006). Nature and nurture also play an important role in the individuals choice of mate (Buss, 2015).

Specific neurochemicals influence pair bonding formation and may influence the individuals capacity of acting in a monogamous manner or not. The involvement of the libido, reacting from female estrogen and male androgen hormones, is functioning as a motor for mating. Studies on pair bonding formation are often on mammals, more specific microtine-rodents (voles) (Curtis & Wang, 2003).

Romantic love is not only linked to different hormones and neurotransmitters involvement, but also different behavior strategies happening at different stages of the reproduction phase. When it comes to homo sapiens, the primary sex drive has evolved

from motivating the individual to seek sexual union with any possible mate (Fischer et al., 2002). The constellation of neural circuits, and neurotransmitter involvement associated with attraction and romantic attachment, motivates the individual to selectively choose between possible fitting individuals. This enhances the individual's motivation and capacity in finding a suitable mate, investing energy and mating time (Fischer et al., 2002).

Proposed by Fischer' in 1998, the three emotion-motivation systems act as single units, and together, when it comes to romantic love and romantic attachment towards a partner. The independence of the three motivational-emotional systems can be found in humans, as people reporting being in love with someone they have not shared sexual behavior with, people reporting they may have sexual relations with someone they are not in love with, and people reporting being in love with someone they have no sexual desire to be with. This explains that lust, attraction and attachment, can act as a single unit and together, when it comes to romantic love and romantic attachment in homo sapiens (Fischer et al., 2002). Although the three emotion-motivation systems in this thesis often are found acting together in symphony, as the people in the reference literature often are reporting being in love with their partner, sexual desire towards their partner, and feeling romantically attached, it is important to be aware of the complexity of the mating system.

Sexual behavior enhances dopamine, serotonin, and vasopressin production, in addition to lowering the levels of corticosterone for both sexes. Women reports being more attached to their partner after sexual activity than before, especially if they orgasm, explained by oxytocin and serotonin release. The enhanced vasopressin release

in men, can be a possible explanation of why they feel more close and connected to their significant other after sexual behavior (Fischer et al., 2002).

Brain development is defining the human life (Gazzaniga, 2005). By the time the infant is aged 7 to 15 months old, the myelin system is formed (Kinney, Brody, Kloman, & Gilles, 1988). By the age of 15 months, the cerebral cortex is matured (Schore, 2005). This is why, social experiences from infancy, are essential for the development of the nervous system, due to the fact that they develop as reaction and reflexes (Ainsworth M. D., 1979). Bowlby (1988) suggests that attachment behaviors can be linked to threatening conditions such as fear, separation or insecurity experienced in childhood.

Neuropsychiatrists argue that “the social construction of the human brain” (Schore, 2005, p. 205) influences the individual's interaction with their environment, hence forming and maintaining attachment (Schore, 2005). Explained as “the self-organization of the developing brain occurs in the context of a relationship with another self, another brain” (Schore, 1996, p. 60). Schore (2005) claims the emotional processing of attachment is linked to Bowlby’s (1969/1982) model of instinctive behavior, explained as a controlled biological activity in the brain. For an overview of the different brain areas involved in romantic love and attachment, see Appendix E2 (Zeki, 2007).

In this thesis, as mentioned in the present study section, the neural correlates of romantic love and romantic attachment will be investigated, introduced and described. Following is a short introduction to the involved brain areas and their involvement in romantic love and romantic attachment.

**The frontal lobe.** Involved in critical judgment, decision making, planning and higher mental processes (Gazzaniga et al., 2009), and is the largest part of the human

brain. It is located anterior to the central sulcus and dorsal to the Sylvian fissure, and includes the motor and prefrontal cortex. The frontal lobe serves as a significant factor in relationship satisfaction (Zeki, 2007).

**The cerebral cortex.** As the largest region of the cerebrum, consisting of grey matter, the cerebral cortex is located at the most anterior part of the brain (Kandel, Schwartz, & Jessel, 2012). The cerebral cortex involves conscious perception, awareness of sensory stimuli, planning, and execution of movement. Memory, social cognition, thought, attention and language (Gazzaniga et al., 2009), together with romantic love, arousal, and attachment (Fischer et al., 2002) are all linked to the involvement of cerebral cortex.

When deactivations in the frontal lobe, temporal lobe, and precuneus occur, moderation of critical judgment is involved. This area is also connected to romantic love and attachment (Zeki, 2007). The forebrain, which consists of “the cerebral cortex, basal ganglia, and diencephalon” (Gazzaniga et al., 2009, p. 73) is responsible for mentalizing and social judgment, as well as the dynamics of understanding other people’s emotions and intentions (Zeki, 2007) called *the theory of mind* (Gazzaniga et al., 2009). An increase in positive emotions, the favorizing of a partner, and an intense longing to be close and intimate with the chosen one, are common for people in love (Xu et al., 2012).

Deactivation of social judgement networks have been explained by Bartels and Zeki (2004) as “a push-pull mechanism that overcomes social distance by deactivating networks used for critical social assessment and negative emotions, while it bonds individuals through the involvement of reward circuitry, explaining the power of love to motivate and exhilarate” (Bartels & Zeki, 2004, p. 1155). The deactivation helps to

explain why people in love are willing to sometimes sacrifice everything, neglecting the possible worrying aspects of their beloved.

**The limbic system.** Consisting of the amygdala, basal ganglia, and *papez circuit* (the hypothalamus, anterior thalamus, cingulate gyrus and hippocampus) the limbic system serves many functions when it comes to romantic love and attachment. It is located within the cerebrum above the brainstem, and functions as a regulatory system essential in inhibitory control. Key functions are social cognition, memory, learning, arousal and fear responses. When it comes to romantic love and attachment, the entire limbic system is involved (Gazzaniga et al., 2009). Although not included in the limbic system, but in *the paralimbic system* (Gazzaniga et al., 2009), the orbitofrontal cortex (OFC) is found crucially connected to the limbic system, and is also highly involved in romantic love and romantic attachment.

**The amygdala.** Acting as *the alarm center of the brain*, controlling our drives, responses and memories in relation to others (Gazzaniga et al., 2009; Lövblad, Schaller, & Vargas, 2014). The amygdala plays an important role when it comes to romantic love and attachment. The activation of the left amygdala enhances positive states when feeling in love and attached (Lanteaume et al., 2007). Deactivation of the amygdala also causes positive feelings looking at images of an individual's partner, when test subjects reported being intensively in love (Zeki, 2007). The individuals fear responses of their partner and partner's actions is lower when in love, as compared to the fear response of friends and strangers. This makes the person in love, less apprehensive when reacting to their partner's actions, helping us understand why a person can stay in an unhealthy relationship.

The difference in brain alterations and attachment styles can be related to differences in the amygdala formation and hippocampal nuclei. Insecure attachment styles, especially anxious-ambivalent attachment, have an increased amygdala volume in the brain. This is developed during infancy and continues into adulthood (Moutsiana et al., 2015). People who have a fear of being abandoned have an enhanced volume of the amygdala. In particular this is true for the anxious-ambivalent attachment style. When these volumes are enhanced it suggests that their response center being in alarm mode. The same individuals commonly share an intrinsic fear of being abandoned, hurt or rejected by their loved one or a potential partner (Fischer H. , 2006a). Left amygdala response is associated with negative feedback, found positively correlated with anxious-ambivalent attachment. It is noted, people with this attachment style often suffer from anxiety disorders and social phobias (Cozolino, 2014).

People with an insecure-avoidant attachment style, have a decrease in amygdala activation, when measuring love and attachment. This is with regard to both the left and right part of the amygdala. This suggests that the individual has a more distant relationship to rejection and negative feedback (Vrticka, Andersson, Grandjean, Sander, & Vuilleumier, 2008), than is true for lower right activation. The insecure-avoidant individuals do not experience the high levels of positive states as do individuals with activation in the amygdala. Securely attached individuals, on the other hand, have shown a mirror effect in the amygdala, but no other specific correlates were found for the secure attachment style (Vrticka et al., 2008).

People with the anxious-ambivalent attachment style are more vulnerable when it comes to a partner breakup, as compared to the other attachment styles. Increased amygdala activation in anxious-ambivalent attachment is higher, than it is for securely

attached individuals. Regarding abandonment, insecure-avoidant individuals share a decrease in the amygdala, as compared to other attachment styles (Collins & Gillath, 2012).

People with anxious-ambivalent attachment often have problems coping with the breakup and often experience more heightened levels of anxiety and depression. This can be caused by their inner fear, as a result of higher amygdala activation than for the other two attachment styles. The breakup experience might also confirm what they already know about the risk of being in love and feeling attached, namely that they stand a chance of being abandoned, and then will be alone once again (Fischer H. , 2006a).

**The hippocampus.** This brain structure is located in each temporal lobe and it is involved in learning and memory. To be more specific, this area is responsible for spatial memory in mammals and episodic memory in humans (Gazzaniga et al., 2009). When it comes to the creation of hippocampal volumes in early infant attachment, Moutsiana et al. (2015) did not find any results connecting hippocampal volumes to infant attachments. However, people with a fear of being abandoned by their partner, have alterations in the hippocampal nuclei.

People with insecure attachment styles have neglected emotional regulation (Quirin, Gillath, Pruessner, & Eggert, 2010), which can be seen in the hippocampal nuclei. Hippocampal nuclei volume in adults differs with each attachment styles. A reduction in cell concentration in the left hippocampus (Quirin et al., 2010), is linked to insecure attachment styles. Reduced hippocampal cell density is found in people with post-traumatic stress disorder (PTSD) and anxiety, which are linked to attachment insecurity. Reduction in cell-concentration in the left part of the hippocampus, is also found in people with anxious-ambivalent attachment style. Quirin et al. (2010) revealed

insecure-avoidant attachment style to be neurologically demonstrated as a bilateral reduction in the hippocampal nuclei. Being rejected or abandoned show similar reactions in the same areas involved in both physical and emotional pain (Sternberg & Weis, 2006).

**The hypothalamus.** This is a structure located deep within the brain, and is responsible for the release of dopamine, together with vasopressin and oxytocin (Fischer et al., 2002). This structure is highly involved in romantic love and attachment. The hypothalamus functions as a bridge between the endocrine and nervous system. Erotic arousal is enhanced by hypothalamus activation (Arnou et al., 2002).

Nucleus accumbens and the hypothalamus become more active when introducing certain drugs, such as cocaine which is known for inducing a state of euphoria (Breiter & Rosen, 1999). The same brain areas that are shown to be involved in OCD (obsessive-compulsive disorder) are also observed as activated for people in love (De Boer et al., 2012).

**The orbitofrontal cortex (OFC).** Found crucial in relation to *the theory of mind*, also involved in social interaction, memory, learning, and reward the OFC has an important role in romantic love and attachment. It is a structure dealing with multiple sensory information systems, such as the primary olfactory cortex, and primary gustatory cortex, in addition it conveys somatosensory, visual and auditory information (Gazzaniga et al., 2009). Romantic love and attachment involve all the aforementioned behaviors. The smell of a loved one, combined with visual, and auditory stimuli is highly connected to romantic love and attachment, in particular to the aspect of affection and intimacy (Acevedo et al., 2012).

Deactivation of the medial OFC (mOFC) is discovered in long-term relationship satisfaction (Acevedo et al., 2012), suggesting that being in love makes the involved less afraid of one's partner's actions, behaviors or responses, as compared friends and strangers. Higher tolerance to fear of one's partner is also connected to deactivations of the mOFC (Xu et al., 2010). The OFC has also been called the *frustration-aggression area* by Fischer (2006b). The primary rage system has pathways and neural circuits in the OFC, controlling anger. Activations are linked to romantic love and rejection (Panksepp, 1998). People being abandoned, rejected, ignored, or ones that have a fear of these things have higher activations in this area as compared to others who do not share these fears (Fischer H. , 2006b).

The rage and reward pathways of the brain are closely connected, suggesting that romantic love and abandonment can operate in tandem. The individual may experience the rage and frustration of being abandoned, while still expressing love and attachment towards partner leaving the relationship. When comparing rage and hate to love, the same mechanisms as increased focused attention, excessive energy, overthinking are observed (Fischer H. , 2006b). As long as the individual is occupied by thoughts of their previous partner, they will experience conflicting emotions and cravings for reconciliation, or search for explanations as to why they are being abandoned. These findings suggest that the opposite of romantic love is not to hate but rather indifference (Fischer H. , 2006b).

Dozier (2002) explains abandonment rage as maladaptive, where heightened levels of corticosterone are present. The fear of abandonment and its physical manifestation in the body suppresses the immune system, stress the heart and increases blood pressure. This reaction is also present when frustration is caused by someone not

responding to our love. Although the distress of rejection or abandonment might be unpleasant at first, it can have unhealthy implications when prolonged. The aforementioned neural processes are found in people who are not satisfied in their relationships. This implies that feeling pain for a short time when being abandoned is normal (Downey & Michaelis, 1998).

When it comes to attachment styles and the OFC, experiences of rejection and abandonment enhances OFC involvement. People with the anxious-ambivalent attachment style share a need for maintaining a relationship with their ex-partners to ensure that they are not disliked. The fear of being disliked or unwanted is an element common for this attachment style. The anxious-ambivalent individual indulges in self-blame, and self-destructive thoughts, looking at themselves in a more negative light. Negative thoughts such as a breakup, conflict, or the death of a romantic partner are related to activation in the anterior temporal pole, an area linked to emotion regulation and sadness as well as activation of the OFC (Fischer H. , 2006a).

Anxious-ambivalent attached individuals are often more open to reconciliation, as compared to the other attachment styles. Due to the fact that they have challenges feeling closure, combined with an intrinsic need to feel loved by their abandoning partner. These are motivating forces for the individual to seek to reconcile (Collins & Gillath, 2012). This is called *a positive tone* during a breakup. People who experience this mechanism are more likely to take responsibility, and have reservations concerning the breakup. The anxious-ambivalent individual is also more prone to depression post-breakup, than the other attachment styles (Collins & Gillath, 2012).

An individual with an insecure-avoidant attachment style often operates in the opposite manner. This attachment style is more distant and reluctant to feel pain and

anxiety towards the breakup (Schore, 2000). Resentment and anger during a long period often surface at the end, as mental problems and possibly health issues (Smith, 2013). Both insecure attachment styles experience pain and despair when separating from a loved one, but they share a different set of emotions and reaction patterns.

**The insula.** Including several subdivisions (Damasio, 1999), as well as the perception of visceral sensations. The insula is known to influence *the gut feeling* of emotional states. It is an important element contributing to pair bonding formation (Olausson et al., 2002). The medial insula is also involved when regulating affiliative, emotional and hormonal responses as the result of skin to skin contact (Bartels & Zeki, 2004). Ven economico neurons (VENs), found both in the ACC and anterior insula, is responsible for processing complex social information. These neurons are known to dominate the right hemisphere in the processing of emotional and social information. Also found to be involved in the phenomena of reward and attachment (Cozolino, 2014).

**The anterior cingulate cortex (ACC).** The ACC is a connection area for the limbic system and prefrontal cortex (Stevens, Hurley, & Taber, 2011), involved with romantic love and attachment, associated with affect regulation, emotional and social processing (Zeki, 2007). Activation in the dorsal ACC in people with anxious-ambivalent attachment can be connected to physical pain and distress (Gillath, Bunge, Shaver, Wendelken, & Mikulincer, 2005), showing that the affective-emotion regulative areas of the brain act differently in people with anxious-ambivalent attachment.

Abnormalities in the ACC is connected to mood disorders, generalized anxiety disorder (GAD), depression, panic disorder, PTSD and schizophrenia. Autism specter disorder and high-functioning autism are also included (Cozolino, 2014) in this

typology. People with insecure-avoidant attachment also share abnormalities in the ACC as compared to secure individuals.

**The ventral tegmental area (VTA).** This is a structure located in the midbrain, responsible for sending dopaminergic projections to both the cortical regions (mesolimbic and mesocortical circuits) and the limbic system (Hanlon, Dowdle, & Jones, 2016). The VTA is known for regulating the involvement of dopamine, linked to both romantic love and attachment. The region of A10 dopamine cells alter group activations in the right medial and posterodorsal body, where the caudate nucleus functions of sensory signals are inclined to action. Activations of the VTA is associated with focused attention, pleasure, general arousal and motivation to pursue and gain rewards (Fisher et al., 2005; Schultz, 2000).

When it comes to the reward system of the brain, in addition to the VTA involvement, the subcortex and striatum (caudate nucleus, putamen, globus pallidus) have also been linked to both romantic attachments. The stratum accommodates cells that are responsive to both drink and reward and is also found present when sexual arousal in humans and monkeys is detected (Arnou et al., 2002; Bartels & Zeki, 2004). Monetary reward stimuli (Schultz, 2000), and as well as stimuli associated with cocaine usage (Breiter & Rosen, 1999) is also reviewed.

Moreover, Gillath et al.'s (2005) study on participants sharing an insecure-avoidant attachment showed less deactivation in brain areas than securely attached individuals in *the subcallosal cingulate cortex (SCC)* and *the lateral prefrontal cortex (LPFC)*. These areas are often involved in cognition and regulation of emotions, and emotional withdrawal. The SCC, on the other hand, involves avoidance regulation and thought processes.

**The caudate tail.** Brain areas that are associated with romantic feelings, have a high concentration of the neuro-modulators and dopamine-related to desire, euphoric states, reward and addiction (Takahashi et al., 2015). The caudate tail is an area rich with dopamine. People in long-term relationships are shown to have higher dopamine activation than people who have been in a romantic relationship for a short period of time. This result indicates that the caudate tails neural activity plays a role in relationship satisfaction (Bartels & Zeki, 2004). The right medial and posterior-dorsal body, are areas responsible for the release of dopamine (Fisher et al., 2002), and together with the medial caudate nucleus which is accountable for enhancing performance (Fisher et al., 2005) and is highly involved with romantic love and attachment.

### **Romantic love, attachment and the neurotransmitters.**

Studies on microtine-rodent mammal voles show the difference in the presence of neurotransmitters such as *vasopressin*, *oxytocin*, *dopamine*, and *corticosterone*. The distinctive difference in neurotransmitters may be the reason for why the social *pine* and *prairie voles* are being monogamous compared to the promiscuous non-social *meadow* and *montane voles* (Curtis & Wang, 2003; Fischer et al., 2005; 2006).

**Vasopressin.** When it comes to vasopressin, this neurotransmitter has a strong influence on cognition and behavior when released within the brain (Gazzaniga et al., 2009). The presence of vasopressin can cause the sexual dimorphism observed in rodent species (Curtis & Wang, 2003). Sexual dimorphism can impact pair bond formation resulting in stronger attachment in voles. The vasopressin release in the lateral septum of the brain is found in monogamous male voles when introduced to females. This is an

area activated by recognition of faces as well as sexual dimorphism. In this study, the centrally released vasopressin binds to the V1a receptor (Young, Nilsen, Waymire, MacGregor, & Insel, 1999), an action not happening for promiscuous voles. The voles share nearly the same gene sequence for the receptor but have different promoter regions.

These findings might explain the difference between monogamy and non-monogamy involvement (Bamshad, Novak, & De Vries, 1999), especially when it comes to males. When in love, enhanced levels of vasopressin are found, although males share higher alteration contra females. Induced vasopressin in males has a positive impact, while for females too much vasopressin has a negative impact. Scientists suggest these findings indicate a possible explanation to the problem in human males that have issues being faithful and attached to their partner and children (Donaldson & Young, 2008).

**Oxytocin.** When it comes to females, oxytocin has the same impact here as compared to vasopressin in males. Oxytocin has a significant effect on female voles whereas too much oxytocin has a negative impact on males (Insel & Shapiro, 1992). Oxytocin also acts as a component of bonding between the caregiver and offspring. Enhanced pair bonding and attachment is found when inducing oxytocin in the large ventricles of the brain, especially in females. When introducing an antagonist specific to the oxytocin receptor, it barricades for the oxytocin-and mating-induced pair-bonding, only found effectual in monogamous voles (Curtis & Wang, 2003). The differences between the social and non-social voles are in the distribution of oxytocin-containing cells in the oxytocin related brain regions.

Curtis and Wang (2003) question whether the difference in behavior is caused by the different distribution patterns of oxytocin receptors in the brain, similar to findings

regarding vasopressin. When inducing oxytocin in the brain from reporter genes, both pair-bonding and maternal behavior in promiscuous voles is found similar to the monogamous voles. The exception to this assumption is found in the female promiscuous voles when giving birth. Here the oxytocin receptors grow to be similar in size to the social voles (Curtis & Wang, 2003). Scientists suggest the reason for voles to show pair-bonding formations outside maternal care, is because they have copied and activated maternal behavior towards their partners. These findings are present in both sexes (Curtis & Wang, 2003; Fischer, Aron, & Brown, 2006).

Although vasopressin and oxytocin have been represented alone, they are functioning together as in one pathway of the brain (Carter, 2017). The core of attachment is found in the neurobiological systems regulating fight and flight responses, and security and stability responses. Oxytocin might be explained as sharing a more passive role of attachment. Vasopressin, on the other hand, has a more aggressive and possessive side of attachment and is also linked to jealousy (Carter, 2017).

The formation of oxytocin and vasopressin systems is found affected by early life experiences. The loss of an attachment figure, early grief, separation, and other traumas can trigger stress and fear. Resulting in a shutdown behavior in the individual, often found in insecure attachment styles (Cozolino, 2014), as heightened or lowered alterations. In healthy individuals, the interaction between oxytocin and vasopressin regulates the anatomy's nervous system, especially when exposed to stressful situations. The different forms of emotion and emotional regulation can be explained under the influence of neuropeptides. It is important to note, that oxytocin and vasopressin are linked to metabolic and immune system involvement, physical health and well-being, combined with the regulation and affiliation of emotional experiences (Amini-Khoei et

al., 2017; Carter, 2017). Although high oxytocin release is often linked to female experience of romantic love and romantic attachment, it is also found present in men when looking at pictures of their beloved partners (Scheele et al., 2103).

When it comes to attachment styles, romantic attachment is positively linked to attachment anxiety and oxytocin. This to “a statistically significant degree ( $r=0,30$ ,  $p=0.04$ ), that is, the higher the oxytocin levels the higher the score on the scale of the ECR” (Marazziti et al., 2006, p. 1). Here the ECR is the Italian translation of the American questionnaire *Experiences in Close Relationships (ECR)*. This suggests that that high oxytocin release can be linked to human anxiety (Marazziti et al., 2006).

There is a positive correlation between a moderate level of stress and pair bonding in humans. When it comes to romantic relationships, it seems healthy for the individual to have induced oxytocin to a certain degree. Proposing that the role of oxytocin, in this case, is to keep anxiety levels under control, so it is not harmful for the individual (Marazziti et al., 2006). This suggests that the involvement in a romantic relationship is resulting in stress conditions, that act differently depending on the phase of the relationship. Very low concentration levels of oxytocin have also shown a negative effect resulting in pain syndromes, such as abdominal pain and fibromyalgia (Marazziti et al., 2006).

Oxytocin nasal spray is being used today in studies on females who struggle with developing and maintaining attachment to their infant, especially when suffering from postnatal depression (Mah, Van IJzendoorn, Smith, & Bakermans-Kranenburg, 2013). The use of nasal spray has shown to have a significant impact on human cognition, social information processing and behavior. As introduced in Guastella and MacLeod's (2012) research paper, nasal oxytocin spray enhances the appraisal of effect from the

information of social cues from others and improves the individual's strategic levels of processing. It is suggested that this might be a solution for women struggling with attachment towards their romantic partner as well (Guastella & MacLeod, 2012).

**Dopamine.** Dopamine is strongly linked to interaction and execution of behavior, especially attachment and social functioning (Curtis & Wang, 2003). Dopamine release is a part of *the reward system* in the brain, starting at the substantial nigra and ventral tegmental area to the striatum, thalamus and the cerebral cortex to the corpus callosum, through the pons and medulla, and down the spinal cord (Gazzaniga et al., 2009).

Dopamine release is related to motivating and rewarding activities such as exercise, sex, specific food consumption, and consummation of certain drugs (Hanlon et al., 2016), but also mating, pair-bonding, and maintenance of a relationship (Curtis & Wang, 2003). Dopamine release is found in the nucleus accumbens during mating in social voles.

Human disorders that can benefit from this drug are related to people struggling with attachment, such as social phobia and autism, and involuntary movement diseases, such as Parkinson's disease (PD) (Takahashi et al., 2015). Introducing the antagonist apomorphine manually increases pair bonding formation outside mating season. Apomorphine primarily activates the D2 receptors, but can also affect D1 receptors in the nucleus accumbens when given at a high dosage. Activation of the D1 receptors has interestingly shown to decrease pair-bonding formation (Curtis & Wang, 2003).

Apomorphine given at a high dosage is inadequate when it comes to the male population in regard to romantic love and attachment. Specific disposition of the D2, and not D1, may induce pair bonding formation outside the breeding season. Blockage

of the D2 receptor, excluding the D1 receptor, prevent from pair bonding when mating (Curtis & Wang, 2003). The female social voles need a higher dosage of dopamine agonist release, in order to have the same effect as the males. Inducing the dopamine antagonist, haloperidol, destroys the process of pair bond formation and results in promiscuity (Curtis & Wang, 2003).

**Corticosterone.** Explained as a “steroid-based hormone of 21 carbons with adrenal corticosteroids synthesized in the adrenal cortex” (Katsu & Iguchi, 2016, p. 527), corticosterone is a known stress hormone. De Vries and Boyle (1998) found cohabitation happening significantly faster in females when experiencing adrenalectomy, whereas males experience sexual dysmorphia. Females often react hostile to males when levels of corticosterone are manually induced, or with heightened stress levels, whereas males react in the opposite manner (De Vries & Boyle, 1998). From a neurobiological perspective, males are driven by the chase of their partner, whereas the females seek security and commitment.

**Serotonin.** Acting as a neurotransmitter and hormone, called 5-hydroxytryptamine (5-HT), serotonin is found in many tissues, the central nervous system, blood-platelets etc (Gazzaniga et al., 2009). Decreased activity of the neurotransmitter serotonin transporters is often found in blood-platelets of people suffering from OCD and obsessive thinking. A study with three groups; people in love, people with OCD and controls showed the same decreased activity in blood-platelets and central serotonin transporters for the first two groups compared to controls (Fischer H. , 2006a).

Blood levels of serotonin also have a differential effect on the two sexes. Men in love share lower serotonin levels in both plasma and serum serotonin, compared to

women who shared heightened levels in both. In a study detecting serotonin involvement and romantic love, both sexes reported obsessive thinking of their beloved up to 65 % of the day. However, in this study women reported a more intense state and trait of romantic love than men (Langeslang, van der Veen, & Fekkes, 2012).

When it comes to the reward pathways of the brain, people with anxious-ambivalent attachment might have higher dopamine hence corticosterone release in the brain, as compared to the secure and insecure-avoidant attachment styles. This to say, the anxious-ambivalent attached individual get a higher reward for engaging in romantic love, but they are also exposed to higher levels of stress and possible negative obsessive thinking.

While secure attachment is the goal, people with the insecure-avoidant attachment style have lower levels of dopamine and corticosterone release in the brain (Cozolino, 2014), which results in a reluctance to feel as close to their partner as compared to the other two attachment styles. These neurological differences help to explain the different patterns of behavior in people with a specific dominant attachment style.

## **Discussion**

The present study represents a neurological view investigating the complex processes of romantic love and romantic attachment. The thesis started with the question; which neural correlates are involved when we experience love and romantic attachment towards a partner? As proposed at the beginning of this thesis, I aimed to introduce and describe the neural correlates of romantic love and romantic attachment. The thesis approach has been exploratory for the reason that a lot of research have been

given to the topic over the years, although the neuroscientific side of it is quite new. Since being in love and feeling romantically attached involves a lot of reward, thought and emotional processing I found it natural to investigate areas of the brain involved in these cognitive processes, namely the reward circuitry network and the limbic system, including other areas that might be involved. The involvement of specific neurotransmitters might also explain aspects of the individuals experience of being in love. It was also suggested that the differences among the attachment styles were to be found in neuroscientific findings as heightened or lowered brain activity, and neurotransmitter release.

As described in the research findings, romantic love goes deeper, and involves the regulation of more brain areas, than the brain areas involved for mating purposes only. This confirms that sex drive is distinctive from romantic love (Fischer et al., 2005), although there are strong connections to it. This can be seen in the emotion-motivational system with the three drives such as lust, attraction and attachment. For what romantic love and romantic attachment are understood as, all these processes are involved, in a symphony with one and another, and in cooperation with other bodily systems as well (Fischer H. E., 1998). Most important, romantic love is a primary motivation system, fundamental for human survival and focused on the specific reward of mating. Nevertheless, when it comes to romantic love there is something more than lust, sexual attraction and behavior. It is a deep connection, attachment and a wish of committing to the chosen partner (Fischer et al., 2002). It is also a choice, an inspiration and a motivation to continue to be together with the beloved, with investment of time, energy and effort.

In the theoretical background of romantic love and attachment, following romantic attachment, the phenomena seems to go hand in hand, as explained in behavioral science. Despite this, attachment as a central aspect has not always been included in the definition of romantic love, although interpretations of ways of attachment may have been included. Sternberg (1997) directs this, mentioning Shaver et al.'s (1988) perspectives of the attachment theory to be a natural contribution to his own theory, and that it needs to be revised complimenting the aspect of attachment as well.

When it comes to attachment, scholars agree on the importance of the early years of infancy (Schore, 2005). The development of the human brain suggests the first years of life is crucial for later brain functioning, social behavior, and interaction (Belsky, 2002), including attachment formed in romantic relationships (Hazan & Shaver, 1987). Brain areas involved in learning, memory, emotional regulation, social judgment, and reward, are all found involved in both romantic love and attachment (Bartels & Zeki, 2000; Buss, 2015; Fischer et al., 2002).

Bowlby and Ainsworth propose that attachment styles formed in the early years continue to follow into adulthood, influencing social life and close relationships (Bowlby, 1969/1982; 1973; 1980). Children who have an internal representation of themselves as being optimistic and confident, might be more secure in their environments and in close relationships. These individuals are better adjusted and more competent, than children who share a pessimistic view of themselves and a negative interpretation (Verschueren et al., 1996). Main and Solomon (1990) propose that it is possible to improve an individual's exceeding harmful behavior, if the dynamics of the environment cooperate in a positive, encouraging manner, together with the individual's intrinsic wish to change.

When it comes to romantic love, it seems that scientists agree on the different aspects of the universal phenomena. Although there are different definitions of romantic love, they commonly mention intimacy, lust, attraction, bondedness, attachment and commitment as central aspects (Sternberg & Weis, 2006). When it comes to the negative aspects of romantic love and attachment this can be experienced as loneliness, pain, frustration and hatred (Fischer H. , 2006a). Although romantic love has often been romanticized in the fiction literature, it is important not to forget the possible challenging and exhausting aspects of romantic love. This being rejection, abandonment, or other factors that might contribute to a romantic relationship not to begin, continue or forcing it to end.

When it comes to both attachment and romantic love brain areas linked to emotional states, memories, thought processes, behavior, and imagination are all involved, and sometimes they are intertwined as one (Bartels & Zeki, 2004). Concluded by Fischer (2006b) and Cozolino (2014), childhood, adolescence and later adulthood play a significant role when it comes to romantic love and attachment behavior. Important to notice, that there are subjective differences in the capability to fall and remain in love and attached.

Neurological evidence on romantic love and attachment, address brain areas responsible for learning, memory, motivation, and reward. Brain areas that are activated include the cerebral cortex, limbic system; amygdala, OFC, hippocampus, hypothalamus, ACC, VTA, frontal lobe, the caudate tail and the reward circuitry network, together with the right medial and posterior-dorsal body (Fischer et al., 2002).

Deactivations of certain brain areas are found crucial in understanding behavior related to romantic love and attachment (Zeki, 2007), such as the frontal lobe, and parts

of the amygdala (Schoore, 2000). Differences in oxytocin, serotonin, dopamine and corticosterone, together with the reward circuitry network differentiates the subjective experience of being in love and feeling attached.

Women often share elevated levels of serotonin, oxytocin and dopamine when being in love and attached to a partner. Males on the other hand shares heightened levels of vasopressin, corticosterone, and dopamine (Fisher et al., 2005). Serotonin release is found during intimacy and sexual behavior together with feeling mentally close to one's partner, in both sexes. When it comes to being in love, men have lower levels in blood-platelets compared to females. Whereas both share obsessive thinking of their beloved, which is a result of differing levels of serotonin (Langeslang et al., 2012).

Presented research findings detect the ability to reveal neurological differences in the brain, such as in the formation of the limbic system, especially the amygdala and hippocampus. Fear of one's partner decreases when in love, this found to be true for all attachment styles. People with an anxious-ambivalent attachment style have a greater amygdala volume and hippocampus volume, compared to securely attached individuals. They are also more afraid of being abandoned or rejected than other attachment styles (Fischer H. , 2006a).

A person with an insecure-avoidant attachment style might have a decreased amygdala and bilateral reduction in hippocampus volume. They also do not share deactivations in the prefrontal regions, nor decrease in blood flow (Quirin et al., 2010). The social judgmental network of the brain is less deactivated here compared to the other attachment styles. Here these persons might be reluctant to be and feel close, and are not able to favor their partner as much as the other attachment styles. Stating that

people with a greater neurotransmitter release, have a greater possibility of feeling in love and attached, than others who do not share the same ability.

Disorganized-disoriented attachment is often included in neuroscience within the insecure attachment styles. Yet, this attachment style is difficult to categorize and detect in neuroscience, since people with this attachment style may be suffering from mental disorders or neurological differences, distinctive from the proposed attachment style characteristics (Main, 1990).

People tend to repeat behavior which gives a pleasurable outcome, avoiding painful behavior. Relationship outcomes experienced painful for the individual can be suggested to influence the individual desire to change their relation to romantic relationships and attachment behavior. By attending therapy, being aware of one's own attachment behavior it is possible to change and modify behavior (Sternberg & Weis, 2006). Couples counseling, single therapy, CBT, psychotherapy and even meditation are believed to be effective strategies in coping with attachment in relation to self and others (Cozolino, 2014).

### **Further research and limitations**

The reigning theory of attachment, and attachment styles, in behavioral science is the attachment theory. Since much of behavioral research, including neurological research, is based on the attachment theory, it is important for science that this theory is being updated to fit recent scientific findings, theories and believes (Slater, 2007). Since there is a wide range of measurements of attachment, it is crucial when it comes to romantic attachment that it measures just that, and not other aspects of attachment which is not included in the research from the beginning. It is also essential that

measurements are being adapted to the times of change, not relying on merely old research (Mikulincer & Shaver, 2016; Slater, 2007).

Scholars in the field of romantic love and attachment are often replicating their own studies, or referring to colleges representing similar findings. This results in a small group of neuroscientists using and re-using the same findings. Therefore, it would be disconcerting if the method is later found to be incorrect (Slater, 2007). During the later years, it has been questioned whether attachment and influence from parents from childhood consequently have as strong of an impact as the aspect of attachment assumes.

Most of the surveys involving romantic love and attachment are based on students who are in college or mature adults who have been married for a long period of time. When it comes to the different attachment styles, there is also a lack of self-reports on the subject (Slater, 2007). Questionnaires can be criticized to be biased, because data is often based on subjective opinions of those involved. Lack of participants and concentrated groups of participants such as students at the universities makes the presented data narrow in a lack of diversity (Gazzaniga, 2005). However, with the internet and constant presence of smart devices, it is easier for the public to be engaged in surveys online, enlarging the group of possible participants.

Lab experiments have often researched attachment in children on caregiver-infant attachment, not including father attachment, or attachment between other caregivers and infant. With regards to neuroscience, it is limited what EEG measures and fMRI measures can show on the physical impact of romantic love and attachment (Damasio, 1999). Mental processes occurring at the testing point can result in

conflicting results (Gazzaniga, 2005), further questioning if romantic love and attachment has been successfully measured or not.

There is a lack of research today on people's attachment styles as children following into adulthood. A solution to this might be to investigate people's attachment styles from an early age following adulthood, and see if the results can be related to each other. Including this, it would be interesting to see the individual's ability to change after utilizing proposed assessments, such as therapy, meditation or in some cases the use of medication, in order to identify the effects of change in the individual.

Prescription of drugs known to enhance neurotransmitter releases in the brain, such as dopamine, serotonin, vasopressin, and oxytocin have been a topic of medical science for years. However, inducing drugs or stimulants, to understand the neural correlates of romantic love and attachment would be inappropriate.

In "*the ethical brain*", Gazzaniga (2005) explains the complex and controversial aspects of cognitive neuroscience. There are advantages in genetics, brain training, and drug development we need to be aware of when measuring the human brain. The law serves as a guideline for the domain that is a person's private life and what is not (Gazzaniga, 2005), making the investigation on romantic love and attachment limited in neuroscience, since this type of study is on such an intimate and subjective level (Damasio, 1999).

When it comes neuroscience there are fundamental questions that need to be answered in regard to embracing pair bonding and attachment. There is still little knowledge regarding the cellular levels in the brain involved in both phenomena. One thing is that the neural correlates are discovered; another aspect is the individual's

subjective, conscious and unconscious, experience and interpretation of romantic love and attachment.

### **Conclusion**

“Brain activity is considered the physical correlate of mental activity. Accordingly, a change of the state of mind implies a change in the state of the brain and vice versa” (Friedrich et al., 2014, p. 1).

Mental processes are based on the individual's own interpretation and interactions of their environment. The mental processes are forming the action and reaction pattern of the individual (Gazzaniga et al., 2009). Participants who are anxious-ambivalent may have higher activations in related brain areas, compared to secure and insecure-avoidant attachment individuals. Participants with insecure-avoidant attachment often have suppressed levels in brain alterations (Gillath et al., 2005).

People can, however, change their attachment styles with conscious awareness, hence making their child attachment different from the one they have later in life (Cozolino, 2014). It is important to understand, that opposed to the individual's own attachment style, there is often a specific couple-dynamics attachment style (Gillath et al., 2005). Gazzaniga (2005) addresses questions such as ethics and morals, the law and the bias of focusing on specific brain activity and areas conflicting with research findings.

As proposed in the beginning of this thesis, I aimed to introduce and describe the neural correlates of romantic love and romantic attachment, as an exploratory approach. The complicated aspects of romantic love and the bond of attachment

towards a romantic partner as well as the discovery of neural correlates are considered necessary in the unit understanding of romantic love and attachment.

As described earlier, being in love and feeling romantically attached to a partner, often demands a lot of thought and emotional processing, together with being a highly rewarding experience. Taking this into consideration, I wanted to investigate the reward, emotion and thought processing areas of the brain, namely the reward circuitry network and the limbic system, together with other brain areas that might be involved when it comes to romantic love and romantic attachment. When it comes to the different attachment styles, it was also suggested that the differences among the attachment styles could be found in neuroscientific findings as heightened or lowered brain activity, and neurotransmitter release.

Proposed neurological research findings, derived from scholars in the field of romantic love and romantic attachment, confirms the involvement of the reward circuitry network and the limbic system as crucial, with contributing regions involved in learning, memory, social behavior and interaction. Neuroscientific findings confirming behavior scientific theories are essential, especially when it comes to an understanding of what happens in our body and brain when being in love and feeling romantically attached. Also, in addition to the basic neural correlates appearing, there are certain neural correlates confirming that there are some differences when it comes to attachment styles and romantic attachment, especially in the activation or de-activation of specific brain areas and neurotransmitter release.

The human's ability to alter memory, and the processes of learning, re-learning and new-learning give us the possibility to alter the effect the brain has on our actions and decisions, hence in romantic relationships and our attachment styles. The plasticity

of the human brain shows that we also have the capability and ability to impact and change our social behavior concerning our intrinsic and extrinsic impression of ourselves and others and in the relationship with self and others (Cozolino, 2014).

Even though secure attachment is the most favorable, there are still highly functioning people who share the insecure attachment styles. In a diverse world, it is beneficial to have people with different characteristics and methods of coping (Cozolino, 2014). Although attachment styles are still being used in the science of romantic love and as relationship preference, prediction, and satisfaction, it is challenging to simplify such complex phenomena such as romantic love and attachment (Acevedo et al., 2012).

A person might have a combination of attachment styles, fluctuating within the dynamics of different interactions as proposed in *the new psychology of love* (Sternberg & Weis, 2006). People, who have their individual attachment style as secure attachment, do not always need their partner to share the same attachment type. There are well-functioning people sharing other attachment styles and experiencing flourishing and healthy relationships.

It would be interesting to know, the changes in neural correlates apparent in people consciously changing their attachment style. As explained in Cozolino (2014) it is possible for people with insecure attachment styles to change towards a more secure attachment style. It is known that people with insecure attachment styles might struggle with mental disorders, and medication might be a possible addition to handling one's own attachment style and reaction pattern in a romantic relationship.

As Fischer (2006b) states, fMRI studies can tell us what happens in the brain when falling in love, continue to be in love and feeling attached to our partner. Despite this, neuroscience still remains to explore and explain the elemental question of why we

fall in love with some people and not others. Nature and nurture play a significant role. Biological factors such as smell, voice, movements, or having an opposite immune system than ourselves might enhance the possibility of finding the opposite sex attractive. Possible factors can be that the other person reminds us of our caretakers hopefully in a positive way. However, many people choose partners sharing the same destructive pattern as caretakers.

When looking at factors other than mentioned above, there are many reasons more for falling in love and feeling attached to someone, making science leaving many questions unanswered (Fischer H. , 2006b). Regarding romantic love and romantic attachment, I assume science will continue to probe deeper into consciousness studies, and investigate why people favor a possible mating partner over other equally fit mating partners.

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## Appendix A

### Sternberg's (1997) triangular theory of love scale (TLS)

Sternberg's triangular theory of love scale is commonly used when measuring romantic love. Answers are scored on a 9-point Likert scale from "Not at all," to "Moderately," to "Extremely." The participants is advised to fill in the blank spaces with the name of one person they care or love for deeply.

#### Intimacy

1. I am actively supportive of \_\_\_\_\_'s well-being.
2. I have a warm relationship with \_\_\_\_\_.
3. I am able to count on \_\_\_\_\_ in times of need.
4. \_\_\_\_\_ is able to count on me in times of need.
5. I am willing to share myself and my possessions with \_\_\_\_\_.
6. I receive considerable emotional support from \_\_\_\_\_.
7. I give considerable emotional support to \_\_\_\_\_.
8. I communicate well with \_\_\_\_\_.
9. I value \_\_\_\_\_ greatly in my life.
10. I feel close to \_\_\_\_\_.
11. I have a comfortable relationship with \_\_\_\_\_.
12. I feel that I really understand \_\_\_\_\_.
13. I feel that \_\_\_\_\_ really understands me.
14. I feel that I can really trust \_\_\_\_\_.
15. I share deeply personal information about myself with \_\_\_\_\_.

#### Passion

16. Just seeing \_\_\_\_\_ excites me.
17. I find myself thinking about \_\_\_\_\_ frequently during the day.
18. My relationship with \_\_\_\_\_ is very romantic.
19. I find \_\_\_\_\_ to be very personally attractive.
20. I idealize \_\_\_\_\_.
21. I cannot imagine another person making me as happy as \_\_\_\_\_ does.
22. I would rather be with \_\_\_\_\_ than with anyone else.
23. There is nothing more important to me than my relationship with \_\_\_\_\_.
24. I especially like physical contact with \_\_\_\_\_.
25. There is something almost "magical" about my relationship with \_\_\_\_\_.
26. I adore \_\_\_\_\_.
27. I cannot imagine life without \_\_\_\_\_.
28. My relationship with \_\_\_\_\_ is passionate.

29. When I see romantic movies or read romantic books I think of \_\_\_\_\_.
30. I fantasize about \_\_\_\_\_.

### **Commitment**

31. I know that I care about \_\_\_\_\_.
32. I am committed to maintaining my relationship with \_\_\_\_\_.
33. Because of my commitment to \_\_\_\_\_, I would not let other people come between us.
34. I have confidence in the stability of my relationship with \_\_\_\_\_.
35. I could not let anything get in the way of my commitment to \_\_\_\_\_.
36. I expect my love for \_\_\_\_\_ to last for the rest of my life.
37. I will always have a strong responsibility for \_\_\_\_\_.
38. I view my commitment to \_\_\_\_\_ as a solid one.
39. I cannot imagine ending my relationship with \_\_\_\_\_.
40. I am certain of my love for \_\_\_\_\_.
41. I view my relationship with \_\_\_\_\_ as permanent.
42. I view my relationship with \_\_\_\_\_ as a good decision.
43. I feel a sense of responsibility toward \_\_\_\_\_.
44. I plan to continue in my relationship with \_\_\_\_\_.
45. Even when \_\_\_\_\_ is hard to deal with, I remain committed to our relationship.

If the participant has high scores on all the three components this would indicate consummate love. However, the nature of a relationship may change over time, not saying that low scores on the three proposed scales represents a weak romantic relationship.

Note: The questions are from "The Triangular Love Scale" from *The Triangle of Love: Intimacy, Passion, Commitment*, by R. Sternberg.

## Appendix B

### Relationship scales questionnaire (RSQ)

#### RSQ

Please read each of the following statements and rate the extent to which you believe each statement best describes your feelings about close relationships.

	Not at all like me		Somewhat like me		Very much like me
1. I find it difficult to depend on other people.	1	2	3	4	5
2. It is very important to me to feel independent.	1	2	3	4	5
3. I find it easy to get emotionally close to others.	1	2	3	4	5
4. I want to merge completely with another person.	1	2	3	4	5
5. I worry that I will be hurt if I allows myself to become too close to others.	1	2	3	4	5
6. I am comfortable without close emotional relationships.	1	2	3	4	5
7. I am not sure that I can always depend on others to be there when I need them.	1	2	3	4	5
8. I want to be completely emotionally intimate with others.	1	2	3	4	5
9. I worry about being alone.	1	2	3	4	5
10. I am comfortable depending on other people.	1	2	3	4	5
11. I often worry that romantic partners don't really love me.	1	2	3	4	5
12. I find it difficult to trust others completely.	1	2	3	4	5
13. I worry about others getting too close to me.	1	2	3	4	5
14. I want emotionally close relationships.	1	2	3	4	5
15. I am comfortable having other people depend on me.	1	2	3	4	5
16. I worry that others don't value me as much as I value them.	1	2	3	4	5
17. People are never there when you need them.	1	2	3	4	5
18. My desire to merge completely sometimes scares people away.	1	2	3	4	5
19. It is very important to me to feel self-sufficient.	1	2	3	4	5

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	Not at all like me	2	Somewhat like me	4	Very much like me
20. I am nervous when anyone gets too close to me.	1	2	3	4	5
21. I often worry that romantic partners won't want to stay with me.	1	2	3	4	5
22. I prefer not to have other people depend on me.	1	2	3	4	5
23. I worry about being abandoned.	1	2	3	4	5
24. I am somewhat uncomfortable being close to others.	1	2	3	4	5
25. I find that others are reluctant to get as close as I would like.	1	2	3	4	5
26. I prefer not to depend on others.	1	2	3	4	5
27. I know that others will be there when I need them.	1	2	3	4	5
28. I worry about having others not accept me.	1	2	3	4	5
29. Romantic partners often want me to be closer than I feel comfortable being.	1	2	3	4	5
30. I find it relatively easy to get close to others.	1	2	3	4	5

The questionnaire originates from Griffin & Bartholomew's (1994) original study, and is a commonly used questionnaire when measuring adult romantic relationship and adult romantic attachment.

*Note.* [Table] Found in "Self-report attachment measures" by Bartholomews Research Lab, n.d., *Simon Fraser University: Department of Psychology Members*. Copyright (2018) by "Simon Fraser University". Retrieved July 27, 2018, from [http://members.psyc.sfu.ca/labs/kim\\_bartholomew/attachment/self](http://members.psyc.sfu.ca/labs/kim_bartholomew/attachment/self). Reprinted with permission from K. Bartholomew.

## Appendix C

### The four-category model of adult attachment

		MODEL OF SELF (Dependence)	
		Positive (Low)	Negative (High)
MODEL OF OTHER (Avoidance)	Positive (Low)	<b>CELL I</b>  <b>SECURE</b> Comfortable with intimacy and autonomy	<b>CELL II</b>  <b>PREOCCUPIED</b> Preoccupied with relationships
	Negative (High)	<b>CELL IV</b>  <b>DISMISSING</b> Dismissing of intimacy Counter-dependent	<b>CELL III</b>  <b>FEARFUL</b> Fearful of intimacy Socially avoidant

Figure 1. Model of adult attachment found in Bartholomew & Horowitz (1991).

Here the terminology of the anxious-ambivalent attachment is called *preoccupied*, insecure-avoidant attachment is called *dismissing* and *fearful* is the known disorganized-disoriented attachment style.

Note. [Table] Found in "Attachment styles among young adults: A test of a four-category model," by K. Bartholomew & L. M. Horowitz, 1991, *Journal of Personality and Social Psychology*, 2, pp. 229. Copyright (1991) by "The American Psychological Association". Retrieved June 12, 2018, from <http://psycnet.apa.org/buy/1991-33075-001>. Reprinted with permission from the authors.

## Appendix D

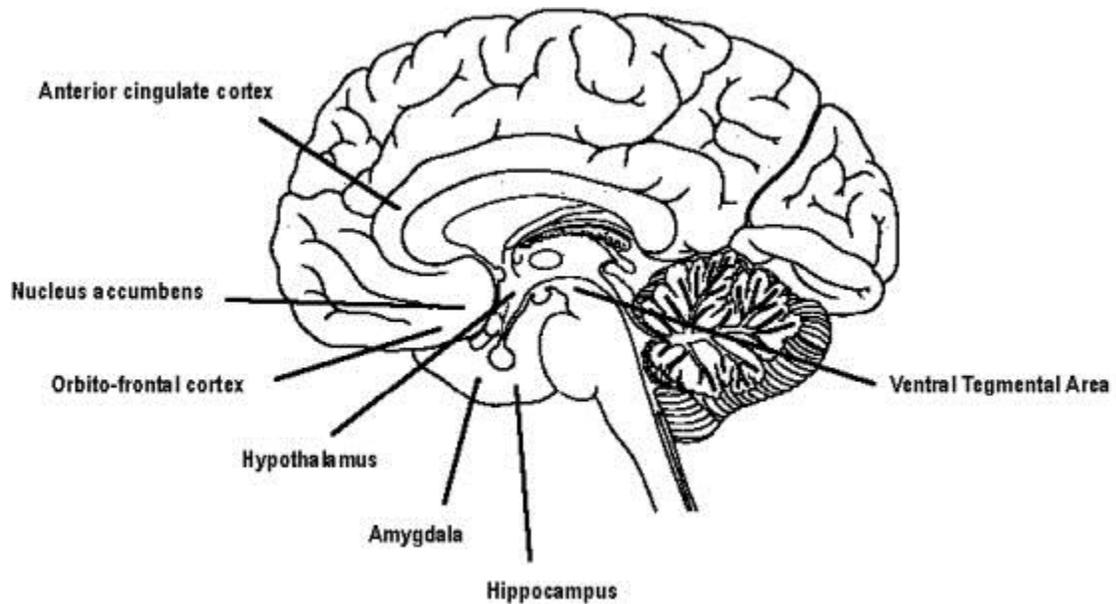
### Attachment styles

The different attachment styles, parental behavior style resulting in adult attachment characteristics of the individual (Cozolino, 2014) proposed by Ainsworth and Bowlby (1991):

- ❖ **Secure attachment style:** The parent has been aligned with the child, and in tune with the child's emotions and needs. This results in adult characteristics as being able to create meaningful relationships later in life. The person will be emphatic and able to set boundaries for itself.
- ❖ **Insecure/avoidant attachment style:** The parent has been unavailable and/or rejecting in their behavior. This results in adult characteristics as avoidant of emotional connection and closeness. The person may behave critical, intolerant, disconnected or rigid in their personal relationships.
- ❖ **Ambivalent/anxious attachment style:** The parent has been inconsistent and intrusive in their communication with the child. This results in adult characteristics of the individual as being insecure and anxious, and may behave as controlling, unpredictable, blaming, erratic and sometimes charming in personal relationships.
- ❖ **Disorganized/disoriented attachment style:** The parent has been ignorant/negligent of the child's needs and parenting behavior might have been frightening or traumatizing for the child. This results in adult characteristics as being chaotic and insensitive, explosive and sometimes abusive. The person is often untrusting while they at the same time craves security, comfort and intimacy.

## Appendix E

### Brain areas involved in romantic love and romantic attachment



*Figure 2.* This figure shows some of the brain areas involved in romantic love and romantic attachment. Some structures cannot be seen from this angle.

*Note.* [Figure] Found in the “The neurobiology of love “ by S. Zeki, 2007, *Federation of European Biochemical Societies Letters*, 581, 2575-2579. Reprinted with permission from the author.