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SELECTED ASPECTS OF THE NEUROPSYCHOLOGY OF LOVE

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SUMMARY

This article, based on a review of the neuropsychological literature from the last decade, presents some of the neuropsychological issues related, directly or indirectly, to love, such as the impact of genetic similarity on interpersonal attraction and falling in love; the role of evolutionary strategies concerning mate selection and the choice of partner for a long-term relationship in order to transmit genes to the next generations; the specific role of the activity of neuronal structures, processes and concomitant functions, and also changes connected with the neurohormonal system as consequences for the individual of falling in love; the specific changes caused by the influence of these neuro-and hormonal processes and functions on such factors as cognitive information processing, social and interpersonal behavior, perception of familial, social events and other intra- and inter-individual changes in a person falling in love, as well as attachment; the role of the "mirror neuron systems" within processes and states, especially empathy, imitation, self regulation, reading the mind, etc., which are of vital importance non only for falling in love, but even more for the maintenance of love between partners in close interpersonal relationships, such as marriage, for life. In conclusion, I would like to stress the fundamental importance of social neuropsychology for a more adequate understanding not only of various aspects of love within the individual's remembered behavior, but also for happiness and quality of life.

Key words: romantic love, dopamine pathways, neurohormonal system, mirror neurons

INTRODUCTION

The main purpose of this article is an attempt to demonstrate that, despite the abundance of recognized, recorded and even immortalized expressions in literature, from philosophy, theology, essays, treatises, and above all poetry and various forms of art, not to mention scientific research on behavior, the essence of love and its genuine origin nevertheless remain nearly unknown. In general, however, one can say that, in contrast to the greater philosophers, such as Socrates, Plato, and Aristotle, most contemporary philosophers and thinkers avoid any conceptual or holistic consideration of love, preferring analytic and episodic descriptions of how love is experienced by particular individuals (Solomon, 2002).

Nevertheless, especially within the last fifty years or so, the problem of love has become the topic of frequent psychological study, within different conceptual frameworks and research strategies, mainly in the psychology of personality and social psychology. Some psychologists have tried to create a concept of love, but rather in the phenomenological and descriptive or narrative perspectives, on basis of the subjective experiences of partners in love or falling in love. In general, these are founded on results obtained with the use of surveys and subjective self-reported questionnaire research methods, and also processes of abstraction. In this and similar ways different conceptions and approaches to the phenomenon of love have been created, for example J. Lee's typology of six love styles (1977), or R. Sternberg's "triangular theory of love" (1986) and "love stories" (1995, cf. Watts & Stenner, 2005; Duffy, 2009; Jacobs, 1992; Rostowski, 1987).

Nevertheless, it should be emphasized that nearly all previous known views of love in history, despite their differences, pass over the fundamental source of love, connected with the biological, and more precisely the genetic, evolutionary, and finally neurological structure of the human brain. However, these issues, concerning essentially romantic love, still considered in the modular approach, i.e. with many different aspects and components, constitute precisely the main object of this debate.

It is a well known fact that there are many various, and sometimes contradictory definitions of love, and similarly, many conceptions. In this theoretical and factual context one may think it proper to restrict oneself only to the definition, or rather description of love, corresponding with the main content of the present study. However, to begin with, it should be emphasized that in reality there are still very few definitions of love according to the bioneuropsychological approach. The primary reason for this is the very short period of time during which studies on love in this perspective have been in progress.

However, from the scientific point of view, love, especially romantic love, can be defined as "an integrated neurobiochemical process which aims to promote not only reproduction, but also proximity, a sense of security, and

joy, and to reduce feelings of stress or anxiety" (Marazziti, 2005: 331). In a similar way, love may be described as follows: "Intensive romantic love takes place within a modular framework that can be differently activated according to potential fluctuations of love... Intense romantic love can be defined as a complex state involving cognitive, chemical and goal directed components, [and more descriptively] ... intensive romantic love mainly activates brain regions with a high concentration of receptors for dopamine and related agents, norepinephrine, i.e. the chemical messengers closely tied to states of euphoria, craving, addiction, heightened attention or sleeplessness" (Bianchi-Domicheli et al., 2006: 91-92; Aron et al., 2005; also Ortigue et al., 2007). Moreover, it needs to be stressed that intense romantic love probably involves primarily the motivation system, and a specific constellation or range of emotions rather than a specific emotion, because intense ongoing love recruits subcortico-cortical pathways associated essentially with love, mediating reward, emotion and motivation systems. This happens because dopaminergic pathways, especially reward pathways, contribute to general arousal, a principal component of romantic love, and in general the motivation system. In this sense love may be considered like any form of drive, but this "love drive" is distinct from the sex drive, mainly because the love drive changes its contents and forms across the life span, and especially because it is served, in principle, by different neural circuits than the sex drive, and most often can occur independently, although some neural circuits of both these drives overlap. It should be stressed, however, that in a similar neuronal way romantic love also differs from maternal love and friendship. Moreover, romantic love does not simply mean loving someone - it also means being in love (Ortigue et al., 2007; Aron et al., 2005; Fisher et al., 2005; Diamond, 2003; Beauregard et al., 2009; Bartels, Zeki, 2004). In general, love may be conceived as a complex, multilevel phenomenon encompassing a large set of behaviors, attitudes. values and feelings (Berscheid, Meyers, 1996; Troy, 2005; Ben-Ari, et al., 2006)

The preliminary assumptions of the bioneuropsychological approach

Even if there are indeed universal signs of love, the question arises: why do they occur in such a way, and first of all: why do people fall in love and need the love of somebody else in their life? In order to answer this question it is necessary to take into account the fundamental factors or conditions influencing human social behavior, i.e. primarily genetic factors, evolutionary processes, as well as neuronal structures and functions, in the light of the scientific results achieved by the neuroscience, and more precisely by social neuropsychology.

In the beginning it should be stressed that the aim of the examination of the bioneuropsychological basis of love does not consist only in taking into account detailed and specific genetic, evolutionary and neuropsychological processes, mechanisms or regularities regarding the individual in love, but rather, in a modular, yet selective way, the characteristic connections or relations between genetic, evolutionary and neuropsychological processes or mechanisms, as well as the experiences and behaviors of adult individuals in love within close, interpersonal relationships. Moreover, in principle, the object of the examination of these three factors is to indicate that their appropriate constellation may be a fundamental result of the occurrence of different predispositions, preferences, and tendencies, as well as inclinations and susceptibilities to display definite forms of activities and behaviors (not always correct and favorable), which are also related to love within close interpersonal relationships (Harmon-Jones & Winkielman, 2007; Norris & Cacioppo, 2007; Zeki, 2007; Frank, 2006; Hinde, 1993).

It should be added and emphasized at this point that social neuropsychology underlines the importance of cognition and understanding the way in which brain and body functions influence social processes and behavior, and conversely, the way in which social processes and behaviors influence brain and body functions (Harmon-Jones & Winkielman, 2007; Cacioppo et al., 2002; Esch & Stefano, 2005; Gonzaga et al., 2001; Bartels & Zeki, 2000; Diamond, 2003; Hinde, 1993)

Genetic-evolutionary correlates of love

When it comes to behavioral genetics, aside from the details, it should be emphasized that people's genetic structure, or more precisely the genotype influences activity and behavior, more often indirectly through the nervous system, in cooperation with the environment (Strelau, 2006; Hamer, 2002; Carver & Scheier, 2000; Larsen & Buss, 2002)

This principle may be helpful in providing a general explanation of the differences in attitudes towards love, and more specifically, toward preferred different styles or types of love, such as J. Lee's typology of six love styles, or Sternberg's "triangular theory of love" and "theory of love stories," and even more towards the beloved person, as well as the susceptibility to falling in love and becoming infatuated at first sight. It appears that the dynamics of the relationships of partners in love are subordinated to the genetically programmed expectations and purposes of both partners, which may be sometimes rather different, and the difference may sometimes create a potential threat to a relationship initiated by love or infatuation (Fletcher, 2002, Fletcher et al., 2006; Hatfield & Rapson, 2006; Simpson & Tran, 2006; Buck, 2003; Frank et al., 2006).

In this context the importance of the **genetic similarity** between the partners in a close interpersonal relationship, especially with a perspective of their falling in love or becoming infatuated, should be emphasized. In light of the results of studies conducted among others by Rushton, it appears that partners within a well selected, happy, harmoniously functioning close relationship, such as marriage, are well matched on the basis of genetic similarity. This similarity is measured by many factors, but also genetically programmed indicators or biomarkers, e.g., blood group, similar smell of sweat,

defined type of figure, physical attraction, physiognomy, and so forth, as well as many other somatic, physiological, and psychological factors. A very important role is played, when it comes to the psychological aspects of this similarity or matching, first of all by attitudes, values, beliefs, and expectations, as well as some traits of personality. All these factors and many others, which are not necessarily consciously recorded, but are most often unconsciously perceived and subconsciously processed, performed and evaluated. What is more important, a constellation or defined modular pattern of cognitive factors and neural circuits associated with them is also subconsciously created on the basis of these factors. Thus, to be more specific, this pattern, formed on the basis of the perceived and experienced similarities in the other individual, create a sense of propinguity, a bond, a need to be together, and above all a feeling of love. Therefore happy marriages in which the partners are deeply in love are characterized by a larger scope of similarities in comparison to unhappy marriages. The same rule (principle) of genetic similarity also concerns the selection of partners for close relationships, and also other relationships, such as friends, colleagues, acquaintances, and also the tendency to feel affection even for unknown people, or people met by chance, who are genetically similar. It should be stressed that such a possibility or opportunity may play the key role in cases of falling or being in love, and in particular often of infatuation (Rushton, 1989; Larsen & Buss, 2002; Carver & Scheier, 2000; Lundstroem & Jones-Gotman, 2009; Fletcher, 2002; Fletcher et al., 2006; Sundie et al., 2006; Ortigue et al., 2007; Atcitelli, 2001).

The fundamental and universal emotions and feelings, such as love, joy, sadness, fear, surprise, disgust, and anger, also have genetic roots. The individual's tendency to display diversification regarding the frequency and intensity of the occurrence and expression of these feelings is also genetically conditioned. Similarly, the same genetic mechanism also applies to the susceptibility, e.g., to positive or negative affect, optimism or pessimism, happiness or sadness, love or hate, and so on. One should strongly emphasize that the role of these regularities is fundamental for the understanding of the diversification, changeability, and sometimes opposition or contrast of experienced emotions and feelings, especially at the exact initial period of falling in love, and first of all infatuation (Carver & Scheier, 2000; McAdams, 2001; Frank et al., 2006; Rostowski, 2008; Newman, 1997).

In the field of study on the conditions of the occurrence of love a pivotal role is played by universal, so called, "genetic" needs, despite the occurrence of significant cultural differences. First, there is a tendency to select partners with defined traits, qualities for close relationships, but diversified regarding sex, which plays an important role within marriage or other interpersonal relationship based on love. Second, there is a genetic need or requirement to experience and display the feeling of love. Third, there is a genetic need to have offspring, in order to transmit genes to the next generation. Fourth, above all, there is a genetic need to survive and to guarantee life for one's

children. First of all, these genetic needs (but not only) create the ground for the formation of the structure of marriage as a relationship between two persons of the opposite sex, based on love and monogamy, becoming successively the social institution needed to meet all above-mentioned genetic needs, especially the need for love. Simultaneously with realizing these needs, different processes are formed and established, during evolution, also on the basis of genetics. These processes lead to and are concomitant with marriage (or to some extent other close interpersonal relationships), such as selection, choice of partners to marry, with slightly disparate criteria for the selection of women and men, taking in consideration different forms of investment in marriage, and above all in offspring. As a result of such evolutionary processes, women ascribe more value to the following traits of men as partners: first of all health, good genes, faithfulness, loyalty, warmth, kindness, determination, dominance (to some extent), resourcefulness and age, status or resources. In general men are perceived by women as "bearers of success" (strictly for woman as wife and then mother and their offspring). All these gualities of men enable them to eventually provide well-being for their wives, the mothers of their offspring. When it comes to women as partners, men most value the following traits: physical attraction, youth, health, fertility, faithfulness, fidelity, and loyalty. In general women are perceived and valued by men as "objects of sex" (in the general meaning of that term, strictly rather as an opportunity for procreation and investment in healthy offspring; cf. Fletcher, 2002; Buss & Dantley, 2006; Lieberman, 2006; Fletcher et al. 2006; Diamond, 2003).

It is worth mentioning briefly also the evolutionary approach to love proposed by H. Fisher (2000), who distinguished three successive, gradual systems or stages, each with different neural circuits for love, and also with more specific hormones. The first system, called "lust" or "sex drive," includes testosterone and leads to sexual union, eventually with various partners; in the second, attraction system, or romantic love, infatuation is fired by dopamine and norepinephrine, and is focused on single partner courtship; the third, the attachment system or companionate love, is dominated by thehormones oxytocin and vasopressin (Fisher, 2000; Bianchi-Domicheli, 2006). It is also interesting to consider the conception of romantic relationship and falling in love and remaining in love, according to the assumptions of strategic pluralism proposed by Gangestad & Simpson (2000). This conception takes into account the model of two various types of love and relationships, namely the romantic type of long-term, monogamous interpersonal relationship, based on mutual, faithful love, and the casual type, depending more on environmental opportunities, occasions for short-term relations, based on sexual attraction or looking for good genes. Moreover, these two models are connected respectively with two different strategies of choice of partner for procreation and investment in marriage and in offspring (Fisher, 2000; Gangesstad & Simpson, 2000; Buss & Dantley, 2006; Diamond, 2004; Fletcher et al., 2006; Young, Wang & Insel, 2002).

Neuro-hormonal correlates of love

In order to attempt some explanation of the neuronal correlates of intensive romantic love, it is necessary to begin, in general, with emphasizing the activity of the subcortico-cortical reward, motivational and emotional systems; in particular the limbic system, in connection with the hypothalamus, and the connection between the cingulate cortex and the thalamus. Next, one should take into account the more specific cortical neural circuits, structures that are strictly and essentially associated with the display of various, but fundamental expressions and experiences of love in humans. First of all, great importance is ascribed to such structures of the brain as

- · the medial insula, mainly on the left;
- the head of the caudate nucleus and the putamen, both on the left;
- the ventral tegmental area;
- the anterior cingulated cortex bilaterally;
- the posterior hippocampus bilaterally;
- the left anterior frontal gyrus;
- the left middle temporal gyrus;
- the right parietal lobe;
- the cerebellum.

In addition, in cases of a highly subjective feeling of love and positive involvement of partners, activation occurs in the antero-medial caudate nucleus and the septum fornix cortex. However, in instances of partners remaining (being) in love a long time, it appears that their brains display positive (intensive) activations in

- the right mid-insular cortex;
- the right anterior cingulate cortex;
- the posterior cingulate cortices bilaterally;
- the left inferior frontal gyrus;
- the left ventral putamen-pallidum;
- the left middle temporal gyrus;
- the right parietal lobe.

But in cases of partners solely in a short-term relationship. or a declining relationship, their brains manifest activations in the posterior cingulate gyrus and the retrosplenial cortex. Yet in the light of research it appears that the more fundamental regions of the brain, most likely to be involved in romantic love and also in infatuation, are

- the ventromedial prefrontal cortex;
- the anterior cingulate cortex;
- the amygdale;
- the hippocampus;
- the nucleus accubens;
- · the hypothalamus;

• certain regions of the brain stem (Ortigue et al., 2007; Bianchi-Demicheli, 2006; Aron et al., 2005; Marazziti, 2005; Fisher, Aron & Brown, 2005; Fisher, 2000; Bartels, Zeki, 2000).

In this context, it would appear that love occurs within both the subcortical (that is, unconscious or subconscious) and cortical (conscious) neural circuits, thus integrating emotional and reasoning or rational processes; and in this way it is possible to overcome the paradox " that love is blind and also wise." Moreover, these findings demonstrate that intensive romantic love takes place within a modular neural network that can be differentially activated according to the potential fluctuations of the mental states of love and the influences of external, environmental circumstances. Therefore, one might suppose that an intensive romantic love has not only conscious, but also unconscious facilitation effects on cognitive and behavioral performance. It needs to be stressed that this assumption is very important to explain the processes of falling in love, being in love, or infatuation, because it is connected with the subliminal presentation of the beloved person, i.e. with "romantic love priming". Moreover, it appears that the subliminal presentation, according to a genetically outlined program, is started by individuals in early childhood. Gradually, approximately till late adolescence, they develop a "love map," which can also be referred to and conceived as "priming", which is a subconscious, or partly unconscious constellation of traits, behaviors, activities and various physio-somatic details that they will later look for in a mate. Therefore, when in adolescence and later the individual falls in love on the basis of their priming or love map, the person whom they fall in love with, where they falls in love, what they find attractive in a partner and how they court a potential mate, will vary from one society and one partner to the next. But once they find that special person and the actual emotion or feeling occurs, they experience this passion lodged in the modular structure of their brain, i.e. the love map. This evolved to enable individuals, at that time, to conduct a more conscious selection among potential mates and focus their mating energy on the preferred partner, who best fit their genetically programmed and neurologically developed and arranged "love map" or love priming (Fisher, 2000; Bianchi-Demicheli, 2006; Ortigue & Bianchi-Demicheli, 2008;Ortigue et al., 2007; Fishbane, 2007).

When it comes to the subcortical neural network, it plays a very important role in social interpersonal relationships, especially for the early stage processes of mate selection, and above the falling in love of both partners and their mutual attraction and attachment, as well as the neuro-hormonal base for the prospective function of a developing relationship, because, as is well-known, it mediates the emotional, reward and motivational system (Hermans et al., 2001).

Romantic attraction

From the scientific and evolutionary point of view, romantic attraction is a universal experience of mankind, sometimes also called romantic love, passionate love, obsessive love or infatuation. As everybody knows, attraction is essentially associated with an altered mental state. This state, with mood elevation, is characterized by the sensation of being full of energy and strength, feelings of exhilaration, intrusive thoughts about the object of love, and a craving for an emotional union with the partner or potential partner, by being certain that his or her partner is the most unusual (extraordinary) individual in the world or the best available mating partner, and at the same time decreased interest in routine or daily and mundane activities (Fisher, 2000; Marazziti, 2005).

The feeling of romantic attraction is probably associated with a high level of dopamine and norepinephrine, and low levels of serotonin. The most important features of the specific behavior of people in love or infatuated, in addition to those already mentioned, include (for example) a tendency to focus attention on the positive qualities of the beloved and overlook, falsely appraise or show only partial understanding, or misinterpret negative traits, actions or deeds and, on the contrary, what is more important and happens often, to focus on specific events, objects, and so on, yet all related to the beloved person. On a neurological basis, the use of functional imaging of the brain (fMRI) has shown that a high level of dopamine is associated with increasing the demand for a novel environment, for novelty and challenge. In this context there may arise the question: why does this happen? In principle, because novelty and challenge is typically associated with a higher level of arousal, and arousal can promote or facilitate meeting the appropriate person, as well as romantic attraction to this other person. In the case of attraction, arousal would increase attraction to a desirable person, but would decrease attraction to an undesirable one. It is worth adding that the significant influence on the strength and intensity of the experience of romantic attraction may be caused by certain facilitators - not only physical beauty, but also, as well, a sense of self-expansion, enrichment of self-esteem, wellbeing, and so on; and also, on the other hand, a state or feeling of distress, anxiety, danger. Moreover, an overly high general arousal of attraction may be caused by different situational stimuli, or the sex drive, with age and often concomitant social pressure Moreover, the possibility of mutual performance of new and challenging activities, to a larger extent, increases the feeling of love and satisfaction (Lewandowski & Aron, 2004; Aron et al., 2000; McClnahan et al., 2001; Foster et al., 1998; Griffin & Taylor, 1995).

In addition, the high level of dopamine supports the tendency to focus on, remember and cherish specific qualities or traits of the beloved, as well as the tendency to remember, muse on or consider, sometimes obsessively, and imagine or focus on specific moments and experiences associated with the beloved person (Fisher,2000; Kiyatkin, 1995; Lewandowski & Aron, 2004; Griffin & Taylor, 1995)

Norepinephrine also plays a very important role in interpersonal processes, including those connected with love. An increased level of brain norepinephrine is associated, among other things, with increased memory for new stimuli, objects, especially persons, and moreover, with an ability to imprint or form similar, very close, long-lasting and strong relations, not only with beloved or friend, but even with strangers, which above all might take place when the individual is falling in love, and especially in infatuation. However, taking into account this aspect of norepinephrine, it is first of all associated with being in romantic love. Yet it should be emphasized that various levels of dopamine, norepinephrine or serotonin, taken together, create different compositions as a neuro-hormonal base for the functions of some brain areas, and consequently also different mental and emotional-affective states, which are characteristic of individuals falling in love or being infatuated. Therefore they experience altered mental states, from elation, the sensation of being full of energy and strength, to a state of depletion, as well as mood swings, from depression to euphoria, and/or feelings of anxiety or even fear, depending on the partner's response. If the relationship suffers setbacks, the attracted individual may fall into apathy, brooding, and despair. Moreover, the specific behavioral models very characteristic for attraction aim at evoking patterns of reciprocal response or behavior similar to hugging and cuddling or mutual holding, and even to compulsions. This set of symptoms is similar to the opposite phases of a bipolar disorder (manic - depressive), being sometimes an effect of exactly different levels of dopamine, norepinephrine, and partly also a low level of serotonin, and above all oxytocine and vasopressin, which may be responsible for caressing and hugging, and also for intrusive thoughts, often associated with romantic attraction and more often with infatuation. These individuals report feelings of emotional dependency on the relationship with the beloved, and also specific feelings of emotional, reciprocal union, even possessiveness, and especially the powerful attachment that is more valuable than a sexual union; simultaneously, they often report feelings of jealousy and fear of rejection or separation. Nevertheless, in general, smitten individuals feel a powerful sense of empathy toward the beloved one and willingness to sacrifice for their partners, and also a tendency to reorder their daily priorities, habits, and even their clothing, values, attitudes and beliefs in order to become more available to the loved one. On the basis of these processes and in its consequences, there are also deep changes in the scope of emotion and feelings, attitudes, some values, and even personality traits, with a revaluation or reappraisal of the personal genetic kinship toward the non-kin but beloved person, into a more important, significant, constant, psychological love kinship. Moreover, importantly, in times of adversities beloved individuals experience an intensification of their mutual romantic love and concomitant passionate feelings. One should stress that the above mentioned processes are not only very important, but are likely to have strategic significance to overcome new emotional, cognitive, behav-

ioral, and also existential or even material states, arising in the new situation of falling in love or being in love. Such states may concern, first of all, general risks linked to the feeling of separation from the current family environment, fear of the unknown, uncertainty, being unsightly for the stranger, becoming a non-related (without common, genetic kinship), but at the same time a truly beloved partner, and, conversely, one who is recognized as a person with a great likelihood of mutual bonding and faithfulness, and the hope to create a happy future relationship with him or her, and also procreate offspring. It appears that on the basis of and because of these processes, there are also deep changes in the scope of emotion-feelings, attitudes, some values, and even personality traits, with a revaluation or reappraisal of one's own, previous, familial genetic kinship into a more important, significant, constant, psychological love kinship toward a stranger, non-related but very loved person (Marazziti, 2005; Bianchi-Domicheli et al., 2006; Ortigue & Bianchi-Domicheli, 2008; Ortigue et al., 2007; Aron et al., 2005; Fisher, 2000, 2005; Hatfield & Sprecher, 1986; Bailey & Nava, 1989; Rostowski, 1987, 2008; Canli & Lersch, 2007; Depue et al., 2002).

Now it should be emphasized that all these processes can be put into effect for human individuals, above all because the functional cooperation between genetic, evolutionary, neurological and hormonal systems makes it possible for human beings to select a partner, fall in love and create a relationship for procreation, and transmit their genes to future generations (Schaller, Simpson & Kenrick, eds., 2006).

Romantic attachment

Now I would like to return once again to neurohormones in the context of attachment. Omitting a detailed presentation of the early periods (infancy, childhood and early adolescence) and limiting myself only to late adolescence and adulthood regarding attachment. I would to focus only on selected issues concerning falling in love or being in love. Attachment can generally be defined as a social process involving a firm emotional relationship between one individual and another (partner) as the attachment object (target). The understanding of attachment essentially contributes to understanding the nature and functions of romantic love. Men and women who are securely attached experience a feeling of closeness, propinguity, security, peace, social and personal comfort, and also mild euphoria when they are in contact with the beloved partner, and separation anxiety when remaining apart a for a longer period. Attachment is the most substantial component of love, and even, according to some researchers, attachment is equal to love, i.e. love could not exist or could not be spoken of exactly as love without attachment. Bowlby argued for the existence of three basic behavioral systems that bond dyads together in love, namely: attachment, care-giving and sex. Similarly, Shaver is convinced that saying "I love you" can mean any or all of following: love as attachment, love as care giving, and love as sexual

attraction (Hazan & Shaver, 1987; Fitness, Fletcher & Overall, 2007; Mirazziti, 2005; Fisher, 2000; Rostowski, 2003).

Neurological and psychological studies indicate that the hormones oxytocine and vasopressin, released in the brain, are primarily involved in the production of attachment behaviors and the feeling of attachment in the three different styles, i.e. securely attached, avoidant attached, and ambivalent attached. It is necessary to stress that the basis for particular styles of adult attachment also contain to some extent different neural structures and functions connected with them. In the general approach, in the case of secure attachment, the main activated structures are the orbitofrontal and medial prefrontal cortex of the frontal lobe, while in the case of the insecure avoidant/ anxious style it is the anterior temporal pole, the anterior cingulate cortex, and the hippocampus. Similarly, in the case of the insecure ambivalent/anxious style, there is more diversified activation of the cingulate areas (Cacioppo et al., 2007; Hazan et al., 2006; Fletcher, 2002; Carter, 2002; Insel, 2000).

Here I would like to emphasize that the high level of oxytocine within appropriate brain regions contributes to the occurrence of the feelings of joy, happiness, a sense of propinguity, attachment and even euphoria, and, what is most important, to the willingness and ability to perform difficult tasks and even sacrifices on behalf of the relationship with the beloved. Moreover, such processes may become established in the form of a conditioned reflex/response, as if it were a form of addiction. Each recurrence of the primal stimulus (the former cue) that is in accordance with the genetic love map or love priming (who really may be or most often is the beloved partner, or both partners within an interpersonal relationship, such as marriage, one for another, or relations of beloved partners, or sometimes a person perceived as a stranger at first glance), may suddenly initiate or cause active secretion of neurohormones, and more precisely such neurohormonal activity that this stranger becomes a close, familiar and even almost instantly an intensively beloved partner, which very often happens in falling in love, and even more in infatuation. But what is most interesting is that even a merely potential partner who is genetically similar and familial, precisely because on the genetic love map-or love priming they are sometimes perceived as such at first sight, may become a very desired and proper partner to love. Moreover, at the same time as this ongoing perception, such a process may cause the secretion of oxytocine and vasopressin, as well as the sex hormones, and other concomitant hormones, such as dopamine, norepinephrine, and serotonin, causing in this way, on the neuronal level, the beginning of the process of falling in love and remaining in love, and also forming the above mentioned conditioned reflex, or perhaps some kind of imprinting or addiction. But in a more general approach, oxytocine also plays a very important role in the lives and relationships of adult persons, regarding the initiation, growth and maintaining of feelings of kindliness and friendship between siblings, close relatives and friends, but above all the love between beloved partners, most often spouses. The secretion of oxytocine and vasopressin is also an important component of sexual arousal or intercourse, especially in the occurrence of concomitant passionate kisses, caressing, hugging or cuddling, so that oxytocine is sometimes referred to as the "chemical of cuddling" (Carter, 2007, 2002; Taylor & Gonzaga, 2007; Fletcher et al., 2006; Guerrero & Andersen, 2000; Plopa, 2004; Rostowski, 2008; Gonzaga et al., 2001).

Self-regulation in romantic relationships

In the context of recent, more empirical research in social neuropsychology concerning various aspects of love, one should take in account certain aspects of social processes more or less associated with the mirror neuron systems, such as self-regulation, reappraisal, simulation, empathy, and mindreading (or mentalizing). In principle, self-regulation includes the control of the processes of emotion and feelings, needs, drives, impulses, and motivation, or various daily events, such as conflicts, as well as processes of constraint. In the neurological approach, this involves functions of subcortical neural structures and their "bottom up" pathways, as well as more cortical structures and their "top down" pathways. This pertains especially to the three cortical structures associated with the executive functions, namely:

- 1. the ventro-medial prefrontal cortex, together with the orbito-prefrontal cortex;
- 2. the dorsolateral prefrontal cortex;
- 3. the anterior cingulate cortex.

The fundamental functions of self-regulation depend upon the correct functioning of these neural structures, especially (but non only) the anterior cingulate cortex. These functions include aspects of interpersonal relations, also important in love and falling in love, such as monitoring of the decisionmaking process, initiating the selection of a new but appropriate response among many alternatives, monitoring activity and performance results, forecasting the possibilities of making mistakes or evoking conflicts, evaluation of benefits, rewards, costs/expenses, acquiring gains or avoiding losses, or eventually punishing, and also perceiving physical, social and psychological pain. These processes are of pivotal importance not only for relationships already based on love, but especially in situations of falling in love, and above all in states of infatuation, when these processes of self-regulation may be diminished or disturbed as a result of a decrease in the level of functioning or damage of these neuronal structures; in extreme cases this can lead even to depression, deep changes of mood, emotional instability, apathy or compulsive-obsessive disorders (Cacioppo et al., 2007; Decety, 2007; Ochsner, 2007; Knutson & Wimmer, 2007; Sjoberg, 2006; Rostowski, 2008).

Reappraisal in romantic relationships

Next, processes of emotional reappraisal are necessary in order for a close interpersonal relationship to develop and function. These essentially consist

in the reinterpretation of the significance of the same emotional event, but now in unemotional categories, on the level of consciousness. Reappraisal may have favorable or harmful effects on the interpersonal functioning within a relationship between people in love, falling in love, or infatuated. In principle, since the essence of this process consists in cognitive transformation of negative emotions aroused at the subcortical level by unpleasant events, which are then evaluated again, but at the cortical level in other, more objective categories of the real/factual state, whereby they lose their previous aversive, unpleasant character or dimension. In this way the individual becomes liberated from these unpleasant emotions, for example anxiety, uncertainty, nagging doubt, fear, anger, sadness, rejection, jealousy, envy, and so on - the typical emotions or feelings that occur in the state of falling in love, and moreover in the state of infatuation. Thanks to these processes associated with reappraisal, it is possible to overcome the paradox that love is blind and also wise. It should be stressed that the neuronal structures responsible for the process of reappraisal of unpleasant stimuli, as well as emotions and feelings, are the cortical regions associated with mirror neuron systems, mainly:

- 1. lateral prefrontal cortex;
- 2. various areas medial prefrontal cortex;
- 3. anterior regions of cingulate cortex;
- 4. dorsomedial prefrontal cortex.

It should be added that the dorsomedial prefrontal cortex simultaneously participates, on the one hand, in the processes of cognitive control, and on the other, it acts as a brake on the structures responsible for arousing negative emotional reactions at the subcortical level: basically the amygdala, partially the hippocampus, and also partly the medial orbitofrontal cortex. The medial orbitofrontal cortex is responsible, to be exact, for forming reappraisal strategies through the modulation of different systems associated with examining and realizing emotional states (Cacioppo et al., 2007; Decety, 2007; Ochsner, 2007; Lieberman, 2007; Ochsner et al., 2005).

Imitation in romantic relationship

Imitation is more a process than an ability, and is of major significance in the development and mastery of many social skills and competencies, which in turn play a pivotal role in all close, love-based interpersonal relationships, and also in the state of falling in love and infatuation; it consists chiefly in reading other people's facial expressions and gestures, and especially understanding their goals, intentions or desires, and wishes. From the neuronal point of view, the recognition of the emotional expression of another person depends, at least partly, on the same subset of neuronal structures that are engaged in expressing the same emotion in one's own neuronal circuits in the brain, associated or responsible for arousing this emotion. In the process of imitation there is a type of "empathic resonance," which may occur even at the unconscious or subliminal level, and is made possible by the mirror neuron systems (Herberlein & Adophs, 2007; Turner, 2007; Havet-Thomassin et al., 2006; Lizardo, 2007; Jacoboni & Dapretto, 2006; Castelli et al., 2005).

Empathy in romantic relationships

The neuronal process of empathy plays a pivotal role, especially in the various stages of falling in love and being (or remaining) in love, and more generally in all properly functioning close interpersonal relationships. Empathy is a complex form of psychological inference, in which observation, memory, and reasoning are combined to yield insights into the thoughts and feelings of others. At the phenomenological level, empathy can also be defined as a sense of similarity between the feelings that one person experiences and those expressed by others, or as an interaction between any two individuals, with one experiencing and sharing the feeling of the other. But this ability is not always used to act or behave sympathetically; it may be used to be either helpful and supportive or hurtful and even hostile. The social and emotional situations which elicit empathy can be very complex during a mutual interaction, depending on the feelings experienced by the observed individual and the relationship of the target to the observer. In recent times, cooperation between social psychology and social neuropsychology has provided knowledge about the neural processes underlying empathy, so that it has become possible to describe a more adequate conceptual framework of empathy. It is worth noting that only human beings can feel or express empathy for virtually any target; also, the emotions connected with empathy can be put into words, allowing us to express these emotions of empathy, not only in the present, but also in the past, or even in the future (Decety, 2007:246-247; Jacoboni, 2007).

The results of different studies have proven that the most important way of empathizing is an innate ability to read expressions of face and different reactions, and also the attitudes of other people, as well as their mental processes and states of mind. In this neuropsychological approach empathy, as well as imitation, the mirror systems play a fundamental role, mainly because they code not only the external activities or behaviors of other people, but also their unobservable intentional states, connected with such activities as planning, intentions, aims, inferences, feelings, desires, emotional valuations, and even inferring and imagining the mental contents or concepts of other persons (Decety, 2007; Norris & Cacioppo, 2007; Ochsner, 2007; Beer, 2007; Stone, 2007; Saxe & Kanwisher, 2005; Carr et al., 2005).

It is essential to add that the functioning of these mental states connected with empathy, and playing pivotal roles in various states of being in love, are essentially associated or conditioned by the activity of:

- the bilateral temporoparietal junction (R/LTPJ);
- the medial prefrontal cortex (MPFC);
- the orbitofrontal cortex (OFC);
- the posterior cingulate (PC);

- the superior temporal sulcus (STS);
- the inferior frontal gyrus (IFG);
- the temporal poles near the amygdala (A);
- the occipital gyrus (OG);
- the fusiform gyrus (FFG).

As far as the emotional aspects of empathy are concerned, three neural structures (STS, IFG, FFG) play the important role, because they are strongly activated, both when individuals are processing social stimuli and when the perceived social stimuli (in and of themselves) have emotional significance; particular emotions seem to be related to different neural structures (Saxe, 2006; Beer, 2006; Stone, 2006; Carr et al., 2005; Saxe & Kanwisher, 2005; Saxe et al., 2004; Norris & Cacioppo, 2007; Jacoboni, 2007).

Mirror neuron systems and romantic relationships

In the context of the connections between empathy, imitation and reappraisal, it appears that the mirror neuron systems consist in the processes by which a class of neurons (now called mirror neurons) in one individual become active when they perform a particular action or when they observe another individual performing a similar action (Cacioppo & Berntson, 2005). Taking in account this specific activity of the mirror neuron systems, it becomes obvious that these neurons play a very important role, especially in close interpersonal relationships based on love and falling in love, since these neurons enable partners to conduct better mutual decoding, to understand, recognize, and predict their own and above all their partner's social and personal information, intentions, needs, desires, and so on. Moreover, in this way mirror neurons assure perseverance and success in these complex interpersonal relationships, which are indeed responsible for performing different, often complicated or problematic life tasks, and for the implementation of joint undertakings. Obviously it is just such problems that face partners in love, falling in love, and in particular those who are infatuated. This approach suggests that not only are the mirror neuron systems neuronal, but to some extent and in a larger sense they are also a kind of cognitive mechanism for sending information when the activated state of the neuronal network underlying activation in one person is shared with another person, or even many other people present or participating in a concrete situation. This happens as a result of a close connection and transmission between one brain and another brain, or even many other brains, influencing not only the brain, but also the body, by activating in this way different, typical brain structures appropriate to the particular set of stimuli, and above all various kinds of cognition or emotions and feelings, including also physical activity and behavior. Moreover, mirror neurons not only code or decode and analyze perceptual audiovisual information or actions per se, but also conceptual processes connected above all with the goal and meaning of the thoughts and actions of both oneself and others, as well as the perspective one takes on those actions. Similarly, the activity of the mirror neuron systems also include social, neuropsychological, and interpersonal processes, very important for the correct functioning of close relationships based on love, falling in love, or infatuation. These activities of the mirror neuron systems, along with the previously mentioned self-control, reappraisal and especially imitation, empathy, self-awareness, and mindreading, are made possible by taking into consideration th eparticipation and cooperation with the mirror neuron systems of so many different subcortical and – especially – cortical structures of the entire brain (Izardo, 2007; Turner, 2007; Jacoboni, 2007; Jacoboni & Dapretto, 2006; Cacioppo & Berntson, 2005; Castelli et al., 2005).

Considering the role, in general, of neuronal structures, and particularly the role of the mirror neuron systems in the context of the functioning of close interpersonal relationships, and especially the mutual relations of partners in love or falling in love, it is necessary to take into account the difference in meaning between perception and knowledge of persons and perception and knowledge generally, including that of inanimate objects. These differences include a number of potentially important aspects of social, intimate behavior between two persons in love. Most obviously, the attributes ascribed to persons differ substantially from those which pertain to inanimate objects, and even animals or plants. Description and evaluation of another person, the partner, should be considered above all, but non only, in categories of their internal, unobservable attributes, and also their mental and emotional-affective states, i.e. states that cannot be directly observed, but may instead require generalization from one's own internal psychological processes or properties (see above), all of which is included in the concept of "theory of mind." Therefore, normal, intuitive and even semantic application of the knowledge of persons for the proper progress of interactions between interdependent partners in love demands special flexibility and selective forms of evaluation of mutual behaviors and reactions to them, especially in times of trouble, as well as individually or socially important situations, in order to guarantee the favorable continuation of mutual love (Stone, 2007; Mitchell et al., 2005; Haxby et al., 2005; Saxe & Kinwisher, 2005).

As for the neuronal base underlying these psychological processes, an important and modulated role is played by very different brain areas, including:

- the dorsal and ventral areas of the medial prefrontal cortex (MPFC);
- the right intraparietal sulcus (IPS);
- the right fusiform gyrus (FuG);
- the left superior temporal cortex (ST);
- the medial temporal cortex (MT);
- the left motor cortex;
- regions of the occipital cortex bilaterally.

There are some differences among the neural structures more connected with knowledge of persons in comparison with animal or object knowledge. Yet it is a very interesting and important fact that the three neuroanatomical structures with notably high resting metabolic rates are associated with person knowledge: the dorsal and ventral medial prefrontal cortex (MPFC), and the lateral and medial parietal areas, with the inferior parietal sulcus (IPS; cf. Mitchell et al., 2005: 60; Gusnard, 2006; Fishbane, 2007; Gusnard & Raichle, 2001).

This fact is important because neuronal structures with high resting metabolic rates in the brain, associated with mirror neuron systems, may reflect high levels of spontaneous, continuous, active mental processing, taking place even during resting states; and more importantly, these neural structures are consistently associated with social-cognitive processes, such as the imitation of other minds, the perception of socially relevant stimuli, empathy, the flexible use of social and moral knowledge, self-referent memory, and emotional self-regulation. The above-mentioned neuronal regions and related neuronal processes, characterized by high resting metabolic rates, are connected to and underlie the functioning of the mirror neuron systems, which is why the mirror neuron systems within these neuronal regions play such socially or individually important functions, as an early warning system against danger or other surprising events, unexpected but possible to forecast, behavior, information, encounters both good or bad, and so on. In this way they enable people, in the form of some kind of vague feeling, an unclear impression, a (pre)feeling, an intuition or biomarkers, to forecast or interpret such unexpected events and their potential results, and also eventually prepare to react or cope with them. This kind of processing operation first of all may occur spontaneously, at any time, even during the resting state, whereas the following, second reaction, already after a consciously perceived stimulus, produces little or no deviation from the baseline metabolic rate for these typical neuronal regions, because these two processes, the first occurring spontaneously and the second consciously activated by stimuli, very often overlap. Moreover, finally it should be stated that the aforementioned neural, cortical structures continuously functioning at a high metabolic rate are above all and essentially responsible for many pivotal aspects of processes connected with being in love, and also falling in love, especially suddenly, and even more so in states of infatuation, as well as affecting the quality of functioning and satisfaction in close interpersonal relationships based on love (Mitchell et al., 2005; Gusnard, 2006; Beer, 2007; Gusnard & Raichle, 2001; Gusnard et al., 2001; Haxby et al., 2005; Fletcher et al., 2006).

Finally, it should be emphasized that positive functioning of the mirror neuron systems explicitly indicate an occurrence of the general properties and the specific abilities of the human brain that make it possible to repeatedly utilize similarly defined and formed sets of neuronal processes to perform similar goals or tasks. This ability underlines not only self-regulation, reappraisal, imitation, and empathy, but also the various types of imagination, most importantly, thinking, reasoning, understanding others' mental processes, and even volitional states. On the other hand, the possibilities associated with the mir-

ror neuron system may also indirectly affect social, interpersonal cognition in respect to prejudice, misunderstanding, inappropriate attributions, erroneous heuristics, even conflicts. Therefore also in the modular approach, especially in the domain of social cognition and behavior, it is necessary to use the semantic systems as well to analyze social situations. That is to say, these processes are based not only on the neural regions (temporal, parietal, and temporo-parietal junction) associated more directly with the mirror neuron systems, but also on other executive functions of prefrontal cortex, especially the medial prefrontal cortex and the ventro-medial prefrontal cortex, which is primarily responsible for normal, objective, rational, more probably correct processes of control and making responsible decisions. It is necessary to take into account those processes of pivotal importance for normal, appropriate interactions within a close relationship based on love, such as marriage or relations between beloved partners.

Our knowledge of the functions of the mirror neuron systems is still incomplete. Precisely, we are only at the beginning, but one may expect that further systematic investigation of the mirror neuron systems within social neuroscience will certainly discover and explain more completely and satisfactorily this kind of neuronal process, influencing various forms of human activity and social-interpersonal behavior, including love. In order to avoid possible misunderstanding, it should be explained that the mirror neuron systems are only one of the means, though a very important one, to attain correct social understanding and cognition. Yet in order to achieve a more solid, competent social understanding of human love, we should also use the semantic system, based to a greater extent on reasoning, the contents of memory, previous experiences and concomitant context, and so on. Nevertheless, the two systems do not exclude each other, but rather are complementary, within the framework of activity and executive functions of the prefrontal cortex of the frontal lobe (Lizardo, 2007; Turner, 2007, Muthukumaraswany & Johnson, 2007; Fishbane, 2007; Saxer & Kanwisher, 2005).

To sum up, it is worth remembering that both subcortical and cortical structures, associated with subconscious rather unconscious processes, along with conscious processes and functions, are responsible for processes of development, maintenance, maturation and above all expression of love. Moreover, nearby the same module of neuronal structures and functions are responsible for the actual expression of love by different individuals, but individual differences of expression are conditioned by different levels and quality of functional fitness of these neuronal structures, and even hemispheric asymmetry of the brain; that is, if they function normally, correctly, or pathologically, improperly, or even detrimentally. Finally, I would think that the approaches discussed and explained here may be helpful in the cognition of the very important (but often overlooked) bioneurologically programmed individual differences in respect to how love is experienced and expressed love, and may not only contribute to a somewhat better understanding of the bioneuropsychological aspects of the basis of human love, but also, even if indirectly, shed a somewhat new light on the different cognitive, behavioral and cultural approaches to understanding the phenomenon of love.

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