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CICLO XXXI

NEURAL AND PERIPHERAL CORRELATES OF ROMANTIC LOVE: EVIDENCE FROM EEG AND FLIR STUDIES

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Who, being loved, is poor?

-Oscar Wilde

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ABBREVIATIONS LIST

AIM	Affect intensity measure
ANOVA	Analyses of Variance
ANS	Autonomic nervous system
BP	Blood pressure
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CG	Control group
CLS	Companionate love scale
CO	Cardiac output
dACC	Dorsal anterior cingulate cortex
DAT	Dopamine transporter
DWLS	Diagonally weighted least squares
EEG	Electroencephalography
ELG	Ended-love
EQ	Explicit question
ERP	Event-related potential
ESW	Early slow wave
FBLS	Friendship-based love scale
FC	Functional connectivity
fITI	Functional infrared thermal imaging
FLIR	Forward looking infrared
fMRI	Functional magnetic resonance imaging
GSR	Galvanic skin response
HR	Heart rate
HRV	Heart rate variability
ICA	Independent components analysis
IOS	Inclusion of Other in the Self Scale
KMO	Kaiser-meyer-olkin
LAS	Love attitude scale
LG	Love group
LIT	Love induction task
LPP	Late positive potential
LSW	Late slow wave
M	Average

MEVOL	Multidimensional Evaluation of Love
ML	Maximum likelihood
MQ	Mutilation questionnaire
NNFI	Non-normed fit index
OCD	Obsessive–compulsive disorder
PAF	Principal axis factoring analysis
PAIR	Personal Assessment of Intimacy in Relationships Scale
PANRAT	Pasat auditory number reading task
PEP	Pre-ejection period
PET	Positron emission tomography
PLS	Passionate love scale
PLS	Passionate love scale
PLS-FR	Passionate love scale (French version)
PLS-R	Passionate love scale (short version)
PLS-R-IT	Passionate love scale (short Italian version)
PSD	Power spectral density
PT	Perspective taking
PT-positive	Positive perspective taking
ReHo	Regional homogeneity
RMSEA	Root mean square error of approximation
SAM	Self-assessment manikin
SCL	Skin conductance level
SCRs	Skin conductance responses
SD	Standard deviation
SG	Single group
SRMR	Standardized root mean square residual
TLI	Tucker-Lewis index
TPR	Total peripheral resistance
USA	United States of America
VTA	Ventral tegmental area

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SYNOPSIS

The present thesis consists of three main parts: one theoretical and two experimental. The first part, composed of three chapters, will introduce several definitions of romantic love (chapter 1), the paradigms that are currently adopted in the literature to study it (chapter 2) and will provide a neuroscientific framework of the construct (chapter 3).

The second and third part comprises four different chapters that represent experimental research that I have conducted during the three years of Ph.D. Specifically, in the second part, I report two validation studies that had the objective of validating (chapter 4) and designing (chapter 5) two questionnaires that would evaluate romantic love in the Italian context. Moreover, the third part will introduce the neuroscientific studies that aimed to explore the neural (chapter 6) and autonomic (chapter 7) correlates of romantic love through the use of a promising, encouraging and innovative paradigm.

PART I - Theoretical background

Chapter 1: Romantic love and its shades

There are many disciplines that tried to study romantic love and its darker and elusive sides but there are still many things that remain unexplored. Social and personality psychologists have considered love as people's individual styles (Lee, 1977; Hendrick & Hendrick, 1986), or divided it into different types of love (Hatfield, 1984). More recently theories coming from the field of neuroscience have conceived love as a complex sentiment involving cognitive, erotic, emotional and goal-directed components that are difficult to separate (Aron et al., 2005; Bartels & Zeki, 2000, 2004; Mashek, Aron, & Fisher, 2000). However, there are three categorizations of love that are widely shared among scientists. Specifically, *being in love*, *passionate love* and *companionate love.* The first is characterized by high levels of passion, intimacy and commitment (Garcia, 1998) and is

usually present in the early stages of the relationship. The second is also characterized by intense feelings, sexual attraction and physical attraction that lead to romance (Sternberg, 1997). The third, it is determined by deep information about each other; because the couple share a deep intimate relationship. In this stage of a romantic relationship, passion dissolves as physical attraction diminishes and is substituted by a long-term and deeply felt commitment (for a full review, see Aron, Fisher, & Strong, 2006; Sternberg, 1987).

Chapter 2: Paradigms used to study romantic love

There are several paradigms in the literature that have been used to study love. However, the most widely used of all is the visual paradigm, which consists of showing photos of the partner to elicit feelings of love. Another procedure involving the use of auditory and imaginative stimuli was introduced by Mashek and collaborators in 2000. The Authors demonstrated that this paradigm was capable of eliciting intense and positive feelings of love. However, the latter has not received much attention from researchers and its neural and autonomic correlates have never been explored.

Chapter 3: Neuroscience of romantic love

In recent years romantic love has received much attention from neuroscientists. With the first fMRI study, Bartels and Zeki (2000) have tried to map the brain areas involved in romantic love. The findings were surprising as it was discovered that during visual paradigms subjects activated a peculiar neural network that included cortical and subcortical areas associated also with the reward system. In addition to the use of fMRI, other tools were also used. For example, through the use of the EEG some authors have explored the brain electrical activity of people in love. In this regard, it has recently been shown that people in love display higher amplitude of the delta waveband (Başar, Schmiedt-Fehr, Öniz, & Başar-Eroğlu, 2008) when viewing their partner's photos compared to those of an unknown person. These results seem to suggest attention towards love-stimuli is enhanced (Bradley, 2009; Liu et al., 2012). In addition to central measures, other research aimed to

investigate both peripheral indexes and biological processes (e.g. neuroendocrine mechanisms). However, there are few studies concerning the peripheral indexes of romantic love. Recently, some Authors have found that faces of romantic partners elicited higher physiological (skin conductance and zygomatic activity) and subjective (emotional arousal) responses than parents, siblings, or friends (Vico et al, 2010). With regard to the studies that took into account the endocrine correlates associated with love, the literature is divided between studies made on animals and on humans. Among the most important studies in the literature is that of Marazziti and collaborators (1999, 2004) where they show that some hormones (e.g. serotonin, dopamine and testosterone) play an essential role in falling in love.

PART II - Validation studies assessing romantic love in the Italian context

Chapter 4: Assessing passionate love: Italian validation of the PLS (reduced version)

The Passionate Love Scale (PLS) has been shown in previous research to measure a general dimension of passionate love. Due to the increase of its administration in neuroscientific studies, there is a need for a validated Italian version of the scale. The aim of this study was to validate the unidimensional structure of the reduced version of the PLS (PLS-R) in a group of Italians adults. A cross-validation approach was used on a sample of 784 participants. The diagonal weighted least squares method was implemented, which represents a useful option for Likert scales.

The results were consistent with previous studies from other cultures and suggest that the Italian translation of the PLS-R (PLS-R-IT) is a valid instrument to assess passionate love among the Italian population.

Chapter 5: The Multidimensional Evaluation of Love (MEVOL): development and preliminary validation

Recent research has conceptualized love as a complex sentiment that leads to multiple emotions rather than a single, pure emotion (Bartels & Zeki, 2000). However, many authors have continued to measure love as a unidimensional construct. The present study introduces the Multidimensional Evaluation of Love (MEVOL) which measures several novel aspects of love. Study 1 showed a seven-dimension structure of MEVOL through a confirmatory factor analysis. Study 2 replicated these results and found preliminary validity, as compared with the Passionate Love Scale (Hatfield & Sprecher, 1986), the 7-item Companionate Love Scale (Sprecher & Regan, 1998; Sternberg, 1986) and the 3-item Personal Assessment of Intimacy in Relationships Scale (Schaefer & Olson, 1981). Overall, the results allowed for the creation of a quick and easy-to-administer questionnaire comprising a 21-item measure and two explicit questions; this questionnaire can be used to assess the various dimensions of love.

PART III - Central and autonomic measure of LIT and its effects on emotion elaboration

Chapter 6: The love induction task interferes with emotional processing: an EEG/ERP study

In recent years, most studies on the biological basis of romantic love have been based on the use of visual paradigms, and only a few have instead investigated the effects of using other paradigms. The aim of present study was threefold. Firstly, the neural correlates of an auditory paradigm called Love Induction Task (LIT), were explored. Secondly, the impact of LIT on emotional processing (through the picture viewing task) was examined. Finally, we also verified that the LIT, as previous studies has shown (Mashek et al., 2000), is able to induce intense positive feelings. The electrical activity during the two tasks were recorded in two groups of participants: people in love (Love Group, LG) and people not in love (Control Group (CG). Results of the LIT showed that when compared to CG, LG displayed higher alpha activity in occipital-right electrodes. Moreover, the LG

displayed greater positive feelings compared to the CG. ERPs analysis of the picture viewing task revealed that when compared to CG, LG showed larger N1 amplitude in response to unpleasant pictures and more negative late activity in frontal sites in all conditions. Overall, the results suggest that LG in response to LIT (a) shows a posterior alpha activity that could be associated with internal focused attention (Cooper et al., 2003), (b) demonstrates interference in emotional processing and (c) displays positive and intense feelings of romantic love.

Chapter 7: The colors of love: facial thermal reactions of people thinking about their lovers

Romantic love involves peculiar psychological and neural processes that are closely connected with autonomic-visceral changes. The present study aims at investigating the thermal response associated to the paradigm of auditory love induction. We recorded the facial thermal imprints of 44 people who were in love and in romantic relationships at the time of the experiment. Thermal signals were extracted from six regions of interest (ROIs), positioned on the tip of the nose, the upper nose and the perioral areas. The experimental protocol is composed of two conditions, randomized among the subjects: love and control conditions. In the first one, participants were initially asked to think about their partners, then to keep continuing to think about their partners while listening to a song related to their relationships; in the second one, they were asked to think about someone else's relationship, then keep continuing to think about that person's relationship while listening to positive-content song, unknown to the specific participant.

The results showed that, when experiencing the love condition, the temperature of the nasal tip of the subjects increased, compared to the control condition. Moreover, the data showed that music induced a far more intense autonomic response. Thinking about their partners whilst listening to the love song caused higher autonomic (nose temperature) and subjective responses than with the unknown happy song, which suggests that love induction task activates peculiar patterns that go beyond mere positive feelings.

SINOSSI

Il presente lavoro è composto da tre parti principali: una teorica e due sperimentali. La prima parte, composta da tre capitoli, introduce le definizioni dell'amore romantico (capitolo 1), i paradigmi che sono attualmente adottati in letteratura per studiarlo (capitolo 2) e un quadro neuroscientifico del costrutto (capitolo 3). La seconda e terza parte comprendono quattro diversi capitoli che rappresentano le ricerche sperimentali che ho condotto durante i tre anni di dottorato. In particolare, nella seconda parte riporto due studi che hanno l'obiettivo di validare (capitolo 4) e progettare (capitolo 5) due questionari per valutare l'amore romantico nel contesto italiano. Inoltre, la terza parte introdurrà gli studi neuroscientifici che mirano ad esplorare i correlati neurali (capitolo 6) e autonomici (capitolo 7) dell'amore romantico attraverso l'uso di un paradigma promettente, incoraggiante ed innovativo.

PARTE I – Background teorico

Capitolo 1: L'amore romantico e le sue sfumature

Ci sono molte discipline che hanno cercato di studiare l'amore romantico e i suoi lati più oscuri e sfuggenti, ma molti aspetti rimangono inesplorati. Gli psicologi sociali e della personalità hanno considerato l'amore come stile individuale delle persone (Lee, 1977; Hendrick & Hendrick, 1986), o lo hanno diviso in diversi tipi di amore (Hatfield, 1984). Recentemente le teorie provenienti dal campo delle neuroscienze hanno concepito l'amore come un sentimento complesso che coinvolge componenti cognitive, erotiche, emotive e meta-direzionali difficili da districare (Aron et al., 2005; Bartels & Zeki, 2000, 2004; Mashek, Aron, & Fisher, 2000). Tuttavia, ci sono tre categorie di amore che sono ampiamente condivise tra gli scienziati. In particolare, *l'essere innamorati*, *l'amore passionale* e *l'amore di compagnia*. La prima è caratterizzata da alti livelli di passione, intimità e

impegno (Garcia, 1998) ed è solitamente presente nelle prime fasi della relazione. Il secondo, è caratterizzato da sentimenti intensi, attrazione sessuale e attrazione fisica che portano al romanticismo (Sternberg, 1997). Il terzo, è determinato da informazioni profonde l'uno sull'altro, perché la coppia condivide una profonda relazione intima. In questa fase della relazione romantica, la passione si dissolve quando l'attrazione fisica diminuisce e viene sostituita da un impegno a lungo termine e profondamente sentito (per una rassegna completa, vedi Aron, Fisher, & Strong, 2006; Sternberg, 1987).

Capitolo 2: I paradigmi utilizzati per studiare l'amore romantico

Ci sono diversi paradigmi nella letteratura che sono stati usati per studiare l'amore. Tuttavia, il più utilizzato è il paradigma visivo, che consiste nel mostrare le foto del partner per suscitare sentimenti d'amore. Un'altra procedura che prevede l'uso di stimoli uditivi e immaginativi è stata introdotta da Mashek e collaboratori nel 2000. Gli Autori hanno dimostrato che questo paradigma è in grado di suscitare sentimenti d'amore intensi e positivi. Tuttavia, quest'ultimo non ha ricevuto molta attenzione da parte dei ricercatori e i suoi correlati neurali e autonomici non sono mai stati oggetto di indagine scientifica.

Capitolo 3: Neuroscienze dell'amore romantico

Negli ultimi anni l'amore romantico ha ricevuto molta attenzione da parte dei neuroscienziati. Con il primo studio fMRI, Bartels e Zeki (2000) hanno cercato di mappare le aree cerebrali coinvolte nell'amore romantico. I risultati sono stati sorprendenti in quanto si è scoperto che durante i paradigmi visivi i soggetti attivavano una particolare rete neurale che comprendeva aree corticali e sottocorticali associate anche al sistema di ricompensa. Oltre all'uso della fMRI, sono stati utilizzati anche altri strumenti. Ad esempio, attraverso l'uso dell'EEG alcuni autori hanno esplorato l'attività elettrica cerebrale di persone innamorate. A questo proposito, è stato recentemente dimostrato che

le persone innamorate mostrano un'ampiezza maggiore della banda delta (Başar, Schmiedt-Fehr, Öniz, & Başar-Eroğlu, 2008) quando guardano le foto del proprio partner rispetto a quelle di una persona sconosciuta. Questi risultati sembrano suggerire che l'attenzione verso gli stimoli amorosi è potenziata (Bradley, 2009; Liu et al., 2012). Oltre alle misure centrali, altre ricerche mirano ad indagare sia gli indici periferici che i processi biologici (es. meccanismi neuroendocrini). Tuttavia, ci sono pochi studi sugli indici periferici dell'amore romantico. Recentemente, alcuni Autori hanno scoperto che i volti dei partner romantici suscitavano risposte fisiologiche (conduttanza cutanea e attività zigomatica) e soggettive (eccitazione emotiva) superiori a quelle di genitori, fratelli o amici (Vico et al, 2010). Per quanto riguarda gli studi che hanno preso in considerazione i correlati endocrini associati all'amore, la letteratura si divide tra studi sugli animali e sull'uomo. Tra gli studi più importanti troviamo quello di Marazziti e collaboratori (1999, 2004) in cui si evidenzia che alcuni ormoni (ad es. serotonina, dopamina e testosterone) giocano un ruolo essenziale nell'innamoramento.

PARTE II - Studi di validazione per la valutazione dell'amore romantico nel contesto italiano

Capitolo 4: Valutazione dell'amore passionale: validazione italiana della PLS (versione ridotta)

La Scala dell'amore passionale (PLS) misura una dimensione generale dell'amore passionale. A causa dell'aumento della sua somministrazione negli studi neuroscientifici, c'è bisogno di una versione italiana della scala. Lo scopo di questo studio era quello di convalidare la struttura unidimensionale della versione ridotta della PLS (PLS-R) in un gruppo di adulti italiani. Un approccio di validazione incrociata è stato utilizzato su un campione di 784 partecipanti. È stato implementato il metodo dei minimi quadrati ponderati diagonalmente, che rappresenta un'opzione ottima da applicare alle scale Likert. I risultati sono coerenti con gli studi precedenti di altre culture

e suggeriscono che la traduzione italiana della PLS-R (PLS-R-IT) è un valido strumento per valutare l'amore passionale nella popolazione italiana.

Capitolo 5: La valutazione multidimensionale dell'amore (MEVOL): sviluppo e validazione preliminare

Ricerche recenti hanno concettualizzato l'amore come un sentimento complesso che porta a molteplici emozioni piuttosto che a un'unica, pura emozione (Bartels & Zeki, 2000). Tuttavia, molti autori hanno continuato a misurare l'amore come costrutto unidimensionale. Il presente studio introduce la Valutazione Multidimensionale dell'Amore (MEVOL) che ha l'obiettivo di misurare diversi aspetti dell'amore. Nello studio 1 è stata evidenziata una struttura a sette dimensioni di MEVOL attraverso un'analisi fattoriale confermativa. Nello studio 2 sono stati replicati i risultati dello studio 1 ed' è stata testata la validità preliminare, rispetto alla Scala dell'Amore passionale (Hatfield & Sprecher, 1986), alla Scala dell'Amore di compagnia (7 items) (Sprecher & Regan, 1998; Sternberg, 1986) e alla Valutazione personale dell'intimità nella Scala delle relazioni (Schaefer & Olson, 1981). Nel complesso, i risultati hanno permesso la creazione di un questionario rapido e facile da amministrare che comprende una misura di 21 item e due domande esplicite; questo questionario può essere utilizzato per valutare le varie dimensioni dell'amore.

PARTE III - Misure centrali e autonomiche della LIT e i suoi effetti sull'elaborazione delle emozioni

Capitolo 6: Il compito dell'induzione dell'amore interferisce con l'elaborazione emotiva: uno studio EEG/ERP.

Negli ultimi anni gli studi sull'amore romantico si sono basati sull'uso di paradigmi visivi, solo pochi hanno invece indagato gli effetti di altri paradigmi. Lo scopo del presente studio era triplice.

In primo luogo, sono stati esplorati i correlati neurali del paradigma uditivo chiamato *Love Induction Task* (LIT). In secondo luogo, è stato esaminato l'impatto della LIT sull'elaborazione emotiva (attraverso la *picture viewing task*). Infine, abbiamo anche verificato che la LIT, come hanno dimostrato studi precedenti (Mashek et al., 2000), è in grado di indurre intense sensazioni positive di amore. Le attività elettriche durante i due compiti sono state registrate in due gruppi di partecipanti: persone innamorate (Love Group, LG) e persone non innamorate (Control Group (CG). I risultati della LIT hanno mostrato che, rispetto al GC, il LG ha mostrato una maggiore attività alfa negli elettrodi occipitali di destra. Inoltre, il LG ha mostrato maggiori sensazioni positive rispetto al CG. L'analisi ERPs sul compito di *picture viewing task* ha rivelato che rispetto al CG, LG ha mostrato una maggiore ampiezza nell' N1 in risposta alle immagini spiacevoli e un'attività tardiva più negativa nei siti frontali in tutte le condizioni. Nel complesso, i risultati suggeriscono che il LG in risposta alla LIT (a) mostra un'attività alfa posteriore che potrebbe essere associata all'attenzione focalizzata interna (Cooper et al., 2003), (b) mostra interferenze nell'elaborazione emotiva e (c) mostra sentimenti positivi e intensi di amore romantico.

Capitolo 7: I colori dell'amore: le reazioni termiche facciali mentre le persone pensano al proprio partner

L'amore romantico coinvolge particolari processi psicologici e neurali che sono strettamente connessi con i cambiamenti autonomico-viscerali. Il presente studio ha lo scopo di indagare la risposta termica associata al paradigma dell'induzione amorosa uditiva. Abbiamo registrato le impronte termiche facciali di 44 persone che erano innamorate e in relazioni romantiche al momento dell'esperimento. I segnali termici sono stati estratti da sei regioni di interesse (ROI), posizionate sulla punta del naso, sul naso superiore e sulle aree periorali. Il protocollo sperimentale si compone di due condizioni, randomizzate tra i soggetti: condizioni d'amore e condizioni di controllo. Nella prima, ai partecipanti è stato chiesto inizialmente di pensare al proprio partner, poi

di continuare a pensare al proprio partner ascoltando una canzone legata alla propria relazione; nella seconda, è stato chiesto loro di pensare alla relazione altrui, poi di continuare a pensare alla relazione di quella persona ascoltando una canzone a contenuto positivo, sconosciuta al partecipante specifico.

I risultati hanno mostrato che, nella condizione amore, la temperatura della punta del naso dei soggetti è aumentata rispetto alla condizione di controllo. Inoltre, i dati hanno dimostrato che la musica ha indotto una risposta autonomica molto più intensa. Pensare ai propri partner durante l'ascolto della canzone d'amore ha causato risposte autonomiche (temperatura del naso) e soggettive più elevate rispetto alla canzone felice sconosciuta, il che suggerisce che il compito di induzione dell'amore attiva schemi particolari che vanno oltre i semplici sentimenti positivi.

PART I

THEORETICAL BACKGROUND

CHAPTER 1

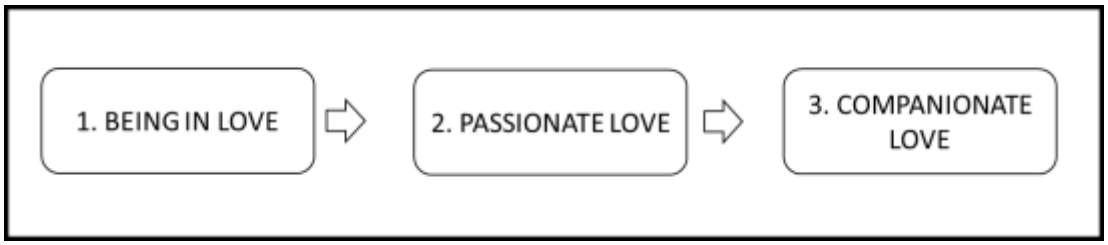
ROMANTIC LOVE AND ITS SHADES

Everywhere in the world people love, fight for love, sing for love, write for love, look for love, live for love and kill for love. Some researchers said that romantic love is one of the most powerful, beautiful expression of human behavior (Bartles and Zeki, 2010). Although most people have been in love in their life, its complexity makes it a mystery to lay people but also to scientists. For many years the researchers, coming from different disciplines, tried to discover something more about love and to define the construct in order to analyze it with accuracy. But how does science define love? One of the first psychologists who dedicate his careers to the study of love was Zick Rubin, who through the use of a scientific method has tried to delineate and define the construct of love (Rubin, 1970). The author speculates that although, at the time, many social psychologists were focused on the study of interpersonal attraction, no one had considered love as an independent entity. Indeed, some (e.g. Heider, 2013) associated the feeling of love with those of mere pleasure as if the two constructs coincided. Thus the research of Rubin (1970) was based on the assumption that love had to be conceptualized and measured as a unique and independent construct. Initially, Rubin conceptualized love as an attitude of a person towards another particular person, which involves predispositions to thinking, feeling and behaving in a certain way towards that person (Rubin, 1970, pp.265). Furthermore, the author specified that the research was restricted to romantic love defined as love between unmarried opposite-sex peers.

Following Rubin's research many other theories have been developed mainly in social and personality psychology and a variety of love classification exist and several types of love have been proposed (for a review, see Hendrick & Hendrick, 1992). Of these, *being in love*, *passionate love* and *companionate love* (see Figure 1.1) are those that obtained the largest attention from

psychologists and neuroscientists (Bartles & Zeki, 2000; Garcia, 1998; Hatifield & Sprecher, 1986; Hatfield & Rapson, 1993; Sprecher & Regan, 1998).

Figure 1.1 The course of a relationship according to the literature.



1.1 BEING IN LOVE

One of the first stages of love is defined by psychologists as "Being in Love". This is determined by a high level of passion, intimacy and commitment (Garcia, 1998). The duration of this phase is still to be determined but some authors suggest that it lasts 6 months (Boer et al, 2012). Many studies, especially in the field of endocrinology, showed that love during this phase is characterized by strong excitement but also by stress (Berscheid, 2010; Marazziti et al, 1999; Starka, 2007). The stress levels, in fact, correlate it with the increase of hormones such as cortisol which will be discussed in the following chapters.

1.2 PASSIONATE LOVE

Passionate love has been defined as “a state of intense longing for union with another” (Hatfield & Rapson, 1993,p. 5). Is characterized by intense feelings, sexual attraction and physical attraction that lead to romance (Sternberg, 1997). Some authors affirmed that this type of love first appears at puberty (Hatfield & Sprecher, 1986), others instead assumed that passionate love is driven by adolescent hormonal changes and therefore appears after puberty (Gadpaille, 1975; Kaplan, 1979; Liebowitz, 1983). Passionate love, therefore, represents a sentiment which is linked to a variety of strong emotion, either positive and negative (Hatfield & Rapson, 1987).

People who feel this kind of love tend to be obsessively focused on the partner and generally consider their attraction uncontrollable. If someone would ask them how much time they about the beloved, passionate lovers will possibly declare that they spend 90%, or all the time, thinking about their beloved (Fisher, 2004).

In 2014 Feybesse and Hatfield have tried to define the traits that are common among passionate lovers, such as: intense sexual attraction to the beloved; strong desire to be with the beloved; intense thinking about the beloved; desire for exclusivity and closeness; idealization of the beloved and the relationship; powerful sense of empathy and concern with the beloved's well-being.

Although passionate love is characterized by a strong sexual drive, many authors are interested in emphasizing that the two constructs go together but are not the same thing. For example, Helen Fisher (2004) stated that desire is regulated by the system of sexual mating, the purpose of which is sexual union for the goal of reproduction. Romantic love, though, is regulated by the system of attachment or pair-bonding (Diamond; 2003). The couple bond sought by passionate lovers goes beyond the desire for reproduction, as there are many factors why mankind has sex. According to other authors, passionate love can be divided into two distinct components (Acevedo & Aron, 2009; Graham, 2011). One component labelled as "romantic obsession" that includes elements such as obsessive aspects of passion love (such as intrusive thinking, uncertainty and mood fluctuations: Acevedo & Aron, 2009). This component of love brings the person to be addicted to the relationship; showing an apprehensive attachment. Romantic obsession would be most commonly placed in the early stages of romantic relationships and uncertain relationships (Graham, 2011) or in relationships where the couple is uncertain about the course of their current romantic relationship (Graham & Christiansen, 2009). The second component of passionate love proposed by these authors has been defined as "romantic love" which corresponds to intense feelings of love, attachment and strong sexual desire without having obsessive features. In contrast to obsessive love,

romantic love can last for a long time and can be found in new or older relationships. This type of love preserves energy, intimacy and friendship in older romantic couples (Acevedo & Aron, 2009).

1.3 COMPANIONATE LOVE

Scholars have argued that when lay people are asked what "love" means, they seem to discriminate between "being in love" and "loving" (Myers & Berscheid, 1997). Passionate love is generally associated with passion, sexual desire, excitement and a variety of other intense emotions, such as desire, jealousy, anxiety and so on (see Aron, Fisher, and Strong, 2006; Sternberg, 1997). Companionate love has been defined as “the affection and tenderness we feel for those with whom our lives are deeply entwined” (Hatfield & Rapson; 1993;p. 9). It is determined by deep information about each other; because the couple shares a deep intimate relationship. In this stage of a romantic relationship, passion dissolves as physical attraction diminishes and is substituted by a long-term and deeply felt commitment (for a full review, see Aron, Fisher, & Strong, 2006; Sternberg, 1987).

Some authors have analyzed how time could affect the endurance of love (Hatfield, Pillemer, O'Brien, & Le, 2008). This research was divided into two studies with the aim of understanding how time interfered in passionate and companionate love. The authors discuss the fact that most theorists assumed that the passage of time has a very different impact on passionate and companionate love. For study 1 53 married couples were interviewed immediately after their marriage and again after a year. Instead, for study 2, 24 women who had been married for a very long time were interviewed. The results of Study 1 showed that although newly married men and women loved with equal passion, women tended to love their partner more amicably than they were loved in return. The results of study 2 were more complex. However, the authors conclude that in both study 1 and study 2, time has had a corrosive effect on both passionate and companionate love.

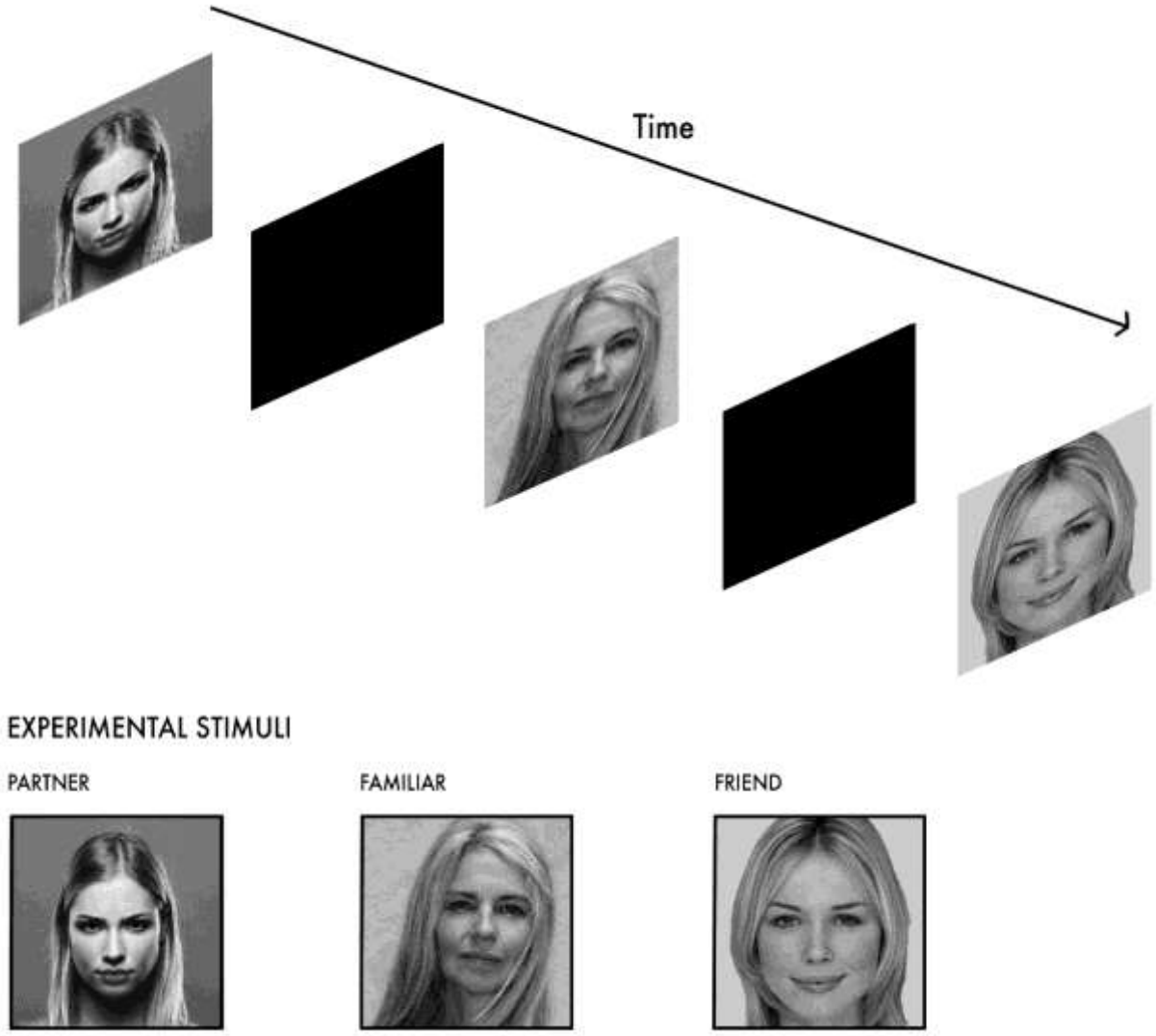
CHAPTER 2

PARADIGMS USED TO STUDY ROMANTIC LOVE

2.1 VISUAL PARADIGM

This type of paradigm is among the most used in the study of romantic love. Almost all neuroscientific studies have used this paradigm to investigate the aspects involved in love (e.g. Bratels & Zeki, 2000; Acevedo et al., 2012). Specifically, this paradigm consists in presenting participants with visual stimuli (usually pictures) that portray their partner (love condition). Generally this condition is then compared to pictures of familiar people, strangers or famous people (control condition). As seen in figure 2.1(example of women partner) the paradigm is made up of various blocks, and each block corresponds to a stimulus. In this case three conditions are compared in order to avoid confounding. In one condition we find partner-related stimuli, in the second condition we find an unknown person with characteristics similar to the partner (sex and age), and in the third a known person (e.g. friend or family) also with characteristics similar to the partner. This last condition is necessary, in fact if we compare only the effect during partner-related stimuli exposure with those of an unknown person, the effect detected could simply reflect the known person (partner) vs unknown person and would be not possible make inference on romantic love. Instead, by introducing the condition of known-person we go to exclude all those areas that are activated during the mere recognition of familiar people. This paradigm is very effective for studying responses to partner-related stimuli but has limits for the study of romantic love in other contexts. For example, if we wanted to study the effects of romantic love during another task (e.g. emotional or cognitive task) the visual paradigm could interfere with the task itself.

Figure 2.1 Example of visual love paradigm.



2.2 LOVE INDUCTION TASK

Another paradigm that is used, though less frequently than the visual one, is the induction of love by Mashek et al. (2000). This paradigm is born with the idea of intensifying the feeling through experimental induction in order to study the mechanism of romantic love. The authors' idea was to reproduce a paradigm that could be similar to that of Gottman and Levenson (1985) who demonstrated that the use of online measurements to study negative emotions were highly reliable

and able to produced coherent psychophysiological responses. Therefore, Mashek and collaborators wanted to repeat this method in the study of positive emotions and specifically of romantic love. The author's proposed procedure consisted of two sessions. In the first session the participants completed a semi-structured interview with the aim of assessing which stimuli were more recurrent while thinking about their relationship. The results of this first phase revealed that the most recurrent stimuli were: songs, smells, photos, places and written items. Subsequently, the experimenters asked the participants to attribute to each stimulus a level of intensity and give it a label between love/not-love. Therefore, at the end of this session each subject was assigned a series of items (e.g. the smell of the partner's shampoo) considered capable of eliciting intense feelings of romantic love. In the second session, participants were asked to bring the stimuli that had been selected in the previous phase and by using a computer task the intensity of each stimulus was evaluated. The results showed that the stimuli that elicit the highest intense feeling were: photography, thinking back, and songs.

Based on this experiment, other authors have proposed a modified version of Mashek's induction and collaborators (van Steenbergen, Langeslag, Band, & Hommel, 2014). Specifically, the task consisted of listening for 10 minutes with earphones a song that the participants had brought with them and that they considered to be relationship-related. This procedure was used to study the effects of romantic love on a task that was administered immediately after induction.

CHAPTER 3

NEUROSCIENCE OF ROMANTIC LOVE

3.1 fMRI STUDIES

The fMRI measures brain activity produced in response to the presentation of a broad variety of stimuli (e.g. pictures, videos and audio) by detecting changes associated with blood flow and oxygenation. Its application in the studies of romantic love has taken over the last 18 years. The aim of this study was to detect blood flow and metabolic changes associated with romantic love paradigms.

The first fMRI study that tried to discover the brain activity of people in love was carried out by Bartels and Zeki (2000). They put 17 people, who self-identified as being truly in love, into a brain scanner and measured their brain activity while viewing colored pictures of four people on a neutral context: their beloved (love condition) and three friends (control condition) of the same sex as their love partner. The subject was instructed to look at the pictures in a screen and think about the person showed. Moreover, by another experiment conducted before or after the scanner, all the photographs were evaluated from a psychophysiological point of view, using GSR. In this way the authors were able to differentiate an emotional response elicited by the partner's photo compared to that of friends. The results showed that there is an exclusive network of brain areas which are activated during the love condition. Specifically, the Author find two cortical activations (see Figure 3.1) restricted into middle insula (mainly on the left side), anterior cingulate and posterior hippocampus. Moreover, they found also a subcortical activation restricted to the caudate nucleus, putamen (both mainly on the left side) and cerebellum. Furthermore, the authors found also some deactivations (see Figure 3.2) which played an important role during the interpretation of the data. These deactivations were restricted cortically to: the prefrontal, parietal, and middle temporal cortex

(all on the right side), and in the medial prefrontal cortex and posterior cingulate gyrus, subcortically to: the posterior amygdaloid region.

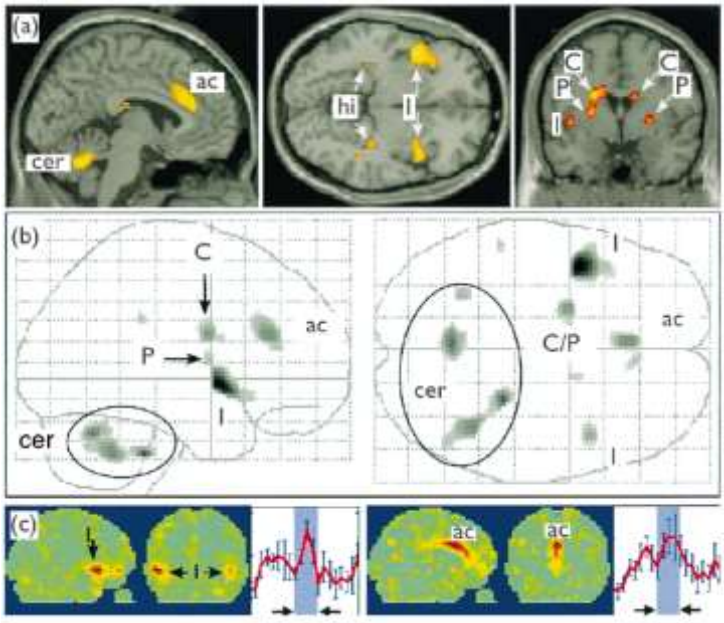


Figure 3.1 "Activity elicited when subjects viewed pictures of their loved partner compared to that produced when they viewed pictures of their friends. The activity, restricted to only a few areas, is shown in sagittal (xˆ=4 mm), transverse (zˆ=6 mm), and coronal sections (y= 0 mm) superimposed on slices taken through a template brain in **(a)** and in glassbrain projections in **(b).** ac, anterior cingulate; cer, cerebellum; I, insula; hi, posterior hippocampus and the coronal section activity in caudate nucleus (C) and putamen (P). Data are from a SPM random effects group analysis of 17 subjects (glassbrains: $p < 0.001$ (Zˆ3.69), sections: p,0.005 (Zˆ2.92), both uncorrected with an extent threshold of 6 voxels. **(c)** An independent component analysis applied to single subjects isolated activity in the insula and the anterior cingulate cortex separately, and in 9 of 11 the components did not involve any other regions. Shown are two independent components from a single subject, in which the one containing the insula included also a more frontal region. The associated activity timecourses are stimulus triggered averages, averaged for all nine repeats and time-locked around the 'love' condition (blue bar: 17.4 s). Error bars=s.e." (figure and caption' s copy rights belong to Bartles & Zeki, 2000).

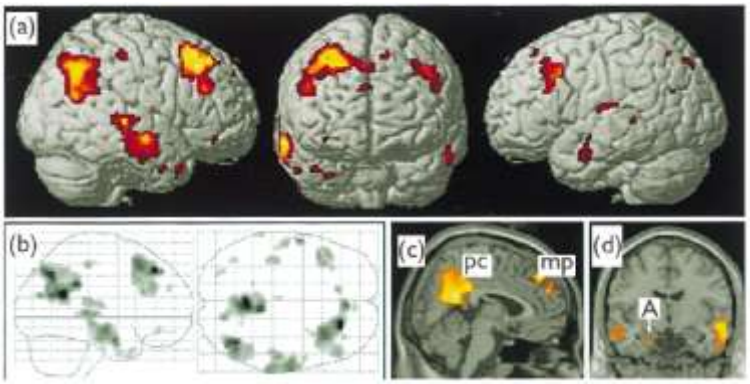


Figure 3.2 Deactivations revealed by a comparison of brain activity elicited when subjects viewed pictures of their friends with that produced when they viewed pictures of their loved partner. Cortically, deactivations were right-lateralized within the prefrontal cortex, the middle temporal gyrus and the parietal cortex, as is apparent **(a)** in the projections onto the cortical surfaces in side and front views of a template brain and **(b)** in glassbrain projections. **(c)** The sagittal section (x= 4 mm) shows deactivations in the posterior cingulate gyrus (pc) and in the medial prefrontal cortex (mp). (d) The coronal section (y= - 8 mm) shows deactivation in the left amygdaloid region (A) (figure and caption' s copy rights belong to Bartles & Zeki, 2000).

Together, these results suggest that passionate love actives specific brain areas related to the euphoria and reward (e.g. putamen and caudate nucleus), but also to areas linked to emotion mediation, reward (e.g. insula and anterior cingulate cortex) and with memory (e.g. hippocampus). Furthermore, results also suggest that some brain areas related to fear, sadness and aggression (e.g. posterior cingulate gyrus and posterior amygdala) are deactivated.

In a further study, Aron et al., (2005) basing on the fact that romantic love include emotional response such as obsessive thinking about the partner, euphoria, craving for union and increased energy (Fisher, 2004; Gonzaga et al., 2006; Hatfield & Sprecher, 1986), the Authors hypothesized the involvement of the brain areas linked to the reward and motivation system. The structure of the experiment was practically similar to the previous (Bartels & Zeki, 2000), participants were asked to see pictures of their partners and think about the pleasing event with them (not sexual related). The sample was made of people extremely in love and in the early stage of the relationship, in other terms in the state of passionate love (Hatfield & Sprecher, 1986) or limerance (Tennov, 1979). The results of this study fully supported the Author's hypothesis and confirm that passionate love is associated with subcortical regions rich of dopamine associated with reward, pleasure, focused attention, general arousal and motivation (Delgado et al., 2000; Elliot et al., 2003; Schultz; 2000). Specifically, the Authors found activations in VTA, dorsal caudate body and caudate tail.

Basing on the latter study, Fisher, Aron and Brown (2005) suggested that romantic love is primarily a motivation system which leads to several emotions rather than pure emotion.

Neuroscientists have explored a lot of passionate love and its neural mechanisms, however, in 2012 another group of scientists focused their study on the long-term intense romantic love (Acevedo, Aron, Fisher & Brown, 2012). The paradigm was similar to previous fMRI studies consisting on facial color photographs of the partner, close friends, high-familiar neutral (a neutral acquaintance less close that the friend) and low-familiar neutral (a person known the fewer year and less close of all the other stimuli). Participants also completed a series of questionnaires including the PLS, the

Eros subscale of LAS, IOS and FBLS. Results of this study showed that intense long-term romantic love is associated with the activation of mesolimbic, dopamine-rich areas which are involved in reward and motivation processes. The authors also find that in particular long-term and early-stage romantic love share the right VTA and caudate.

Recently, Song and collaborators have tried to investigate the effect of romantic love during resting state activity (Song et al., 2015). This study consisted in a scanning of one hundred participants who were divided into three groups: (1) people in "love" (LG), (2) people who just "ended-love" (ELG) and not currently in love, and (3) "single" (SG) that never have been in love. Participants, after PLS administration, were instructed to lie into the scanner with closed eyes and while thinking about nothing. The aim of this study was to compare the ReHo and the FC across the three groups. Results showed that the ReHo of the left dACC was (a) significantly higher in the LG in comparison with the other two groups (b) positively correlates with the length of the time in love. Moreover, the Authors find that (c) the FC in motivation, reward, emotion regulation and social cognition network significantly increased in the LG compare to ELG and SG, and FC (d) positively correlates with the duration of love in LG.

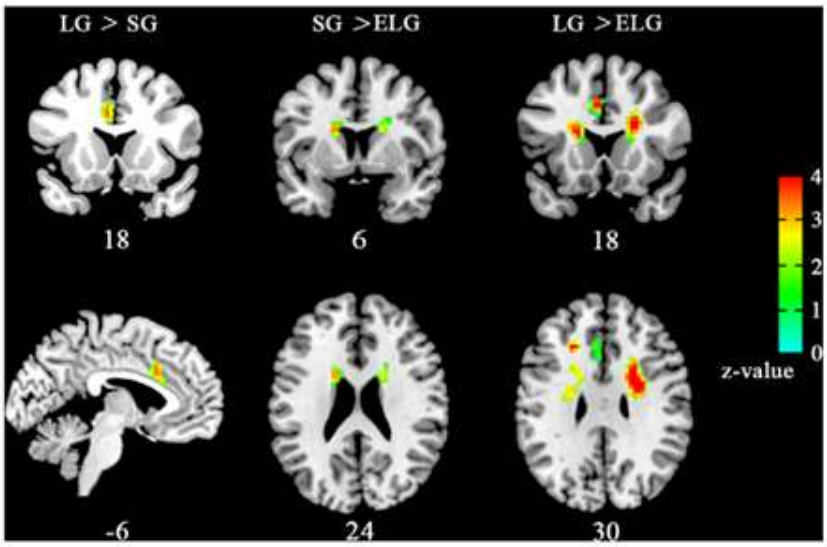


Figure 3.3 Brain areas with altered ReHo the in-love group (LG) and ended-love group (ELG). Significantly increased regional homogeneity (ReHo) was found in the left dorsal anterior cingulate cortex (dACC; −6,18,33) in the LG (LG > SG), but reduced ReHo was found in the left caudate nucleus [ELG < SG, (−15,9,21); ELG < LG, (−18,9,24)] and the right caudate nucleus [ELG < SG, (18,9,2); ELG < LG, (18,12,18)] in the ELG. All resultants were corrected by FDR correction ($P < 0.05$) (figure and caption' s copy rights belong to Song et al., 2015).

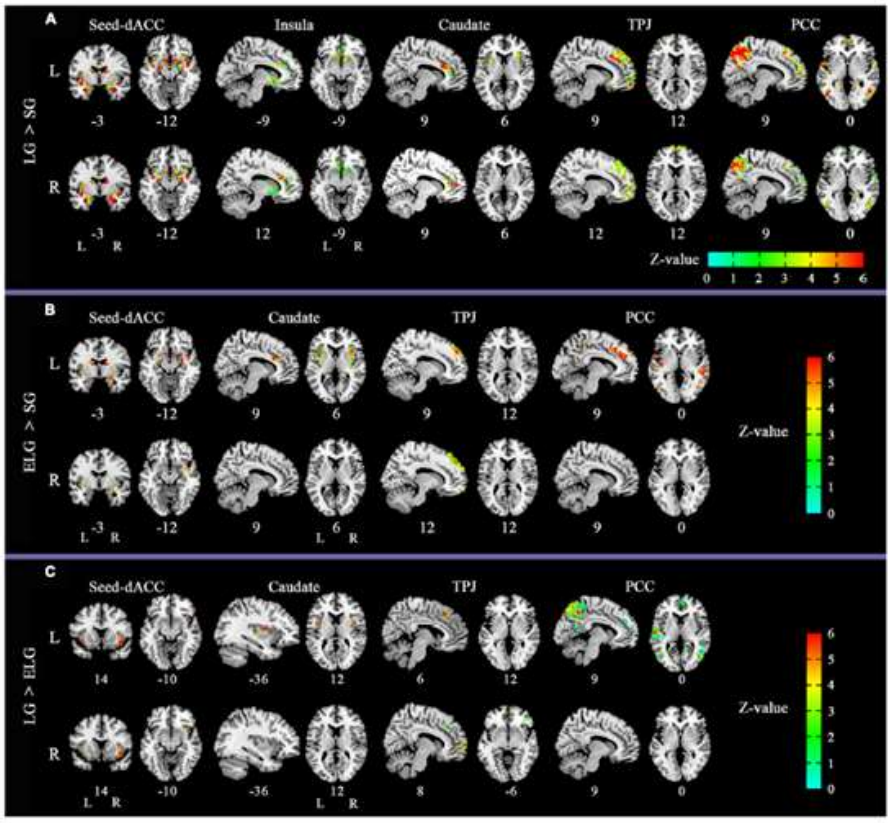


Figure 3.4 Altered functional connectivity (FC) pattern in comparison across the three groups. Images of FC demonstrates differences in resting-state FC between groups (A) LG > SG, (B) ELG > SG, (C) LG > ELG. For each comparison, the top row shows the FC pattern of the left hemisphere and the bottom row shows the right hemisphere. L, left; R, right (figure and caption' s copy rights belong to Song et al., 2015).

As we have seen, there are many studies that have investigated the neural processes that underlie romantic love. Most of the Authors agree on the results and today we have a clear perspective in order to evaluate love from a neuroimaging point of view. Table 3.1 summarizes the studies previously described and compared with other fMRI studies that focused on love in different stages.

Table 3.1 Brain areas activation and deactivation on romantic love (fMRI) studies.

Area	Laterality	Actv/Deactv	Function	Authors
Insula	Medial Mainly on the left	Activation	Romantic love	Bartles and Zeki (2000)
	Posterior part	Activation	Sexual desire No love	Cacioppo (2012)
	Anterior part	Activation Deactivation	Romantic love Unhappy love	Cacioppo (2012) Stoessel et al. (2011)
Cingulate	Anterior	Activation Deactivation	Romantic love Unhappy love – depression - sadness	Bartles and Zeki (2000) Stoessel et al. (2011)
	Posterior	Activation	Retrieval of autobiographical memories	Stoessel et al. (2011)
	Bilaterally	Activation	Sexual Arousal in men	Arnow et al. (2002)
	Gyrus Posterior	Deactivation	Romantic love	Bartles and Zeki (2000)
	Gyrus	Activation	Rejection in love	Fisher et al (2010)
Caudate Nucleus	Mainly on the left	Activation	Romantic love Sexual arousal in men	Bartles and Zeki (2000) Arnow et al. (2002)
		Activation	Long-term romantic love	Acevedo et al. (2012)
Putamen	Mainly on the left	Activation	Romantic love Sexual arousal in male Rejection in love	Bartles and Zeki (2000) Arnow et al. (2002) Fisher et al (2010)
Hippocampus cortex		Activation	Romantic love	Zeki (2007)
Striatum	Medial	Activation	Rejection in love	Zeki (2007)
	Ventral	Activation	Sexual desire Rejection in love	Cacioppo (2012) Fisher et al (2010)
	Dorsal	Activation	Romantic Love	Cacioppo (2012)
Nucleus Accumbens	Right	Activation	Rejection in love	Zeki (2007)
	Right	Activation Activation	Rejection in love The vision of beauty faces	Fisher et al (2010) Wald (2015)

Area	Laterality	Actv/Deactv	Function	Authors
Hypothalamus		Activation	Romantic love - sexual arousal	Zeki (2007)
		Deactivation	Maternal love	
Orbito-frontal cortex		Activation	Beauty or vision of beautiful faces	Zeki (2007)
			Sexual desire	Martin Loeches (2014)
			Rejection in love	Fisher et al (2010)
	Not the middle one	Activation	Unattractiveness	Wald (2015)
	Middle part	Activation	Attractiveness of beauty face	Wald (2015)
			Reward system	
Pallidum		Activation	Rejection in love	Fisher et al (2010)
Ventral Tegmental Area	Bilaterally	Activation	Reward system	Fisher et al (2010)
			Rejection in love	
	Right	activation	Long-term romantic love	Acevedo et al. (2012)
Pre-frontal cortex	Medial	Activation	Rejection in love	Fisher et al (2010)
		Deactivation	Maternal attachment	Zeki (2007)
			Depression - unhappy love	Stoessel et al. (2011)
Occipital medial gyrus	Right	Activation	Sexual Arousal in men	Arnow et al. (2002)
Temporal medial gyrus	Right	Activation	Sexual Arousal in men	Arnow et al. (2002)
Sensomotor area	Right	Activation	Sexual Arousal in men	Arnow et al. (2002)
Premotor area	Right	Activation	Sexual Arousal in men	Arnow et al. (2002)

Area	Laterality	Actv/Deactv	Function	Authors
Claustrum	Right	Activation	Sexual Arousal in men	Arnow et al. (2002)
Amygdala	Bilaterally	Deactivation	Romantic love	Bartles and Zeki (2000)
Frontal Cortex	Right	Deactivation	Romantic love	Bartles and Zeki (2000)
Parietal Cortex	Right	Deactivation	Romantic love	Bartles and Zeki (2000)
	Right	Deactivation	Less judgments	Zeki (2007)
Temporal middle Cortex	Right	Deactivation	Romantic love	Bartles and Zeki (2000)
		Deactivation	Less judgments	Zeki (2007)
Parieto-temporal junction		Deactivation	Less judgments	Zeki (2007)
			Romantic love	Bartles and Zeki (2000)

3.2 EEG STUDIES

The EEG measures the electrical waves of activity that occur in the brain, and across its surface. This electrical activity is present at all times in every human being and is typically used in research to study cognitive and emotional processes. The EEG has obvious limitations regarding the topographic localization of the source, however, it provides excellent temporal resolution. Its application in the study of love dates back to 1993 and represents one of the first studies in neuroscience on this topic. The first neuroscientists who devoted their research to the study of love were Birbaumer and his colleagues (Birbaumer, Lutzenberger, Elbert, Flor, & Rockstroh ,1993). During their experiment, they compared the electrical activity of the cortex, recorded with EEG, of 10 people who were passionately in love with a control group of 10 people who were not in love. Participants had to imagine a happy and jealousy scenes with their partners and a neutral scene. Results showed that passionate imagery involved more complex and more widespread areas and the authors concluded that passionate love could be defined as “mental chaos”.

With the advent of neuroimaging techniques, such as fMRI, the use of EEG in the study of love has been put aside. In fact, for many years few authors have deepened the work of Birbaumer and collaborators. However, in 2007 a group of researchers tried to explore the electrical activity of people in love while watching love-related facial stimuli (Langeslag, Jansma, Franken, & Strien, 2007). For this experiment, eighteen students who were currently in love with a person of the opposite sex have been recruited. The paradigm proposed in this experiment was very similar to the one used previously in experiments with fMRI. Participants were asked to watch at gray-scale photographs of the faces of their partner, friends or of an unknown attractive person while their EEG activity was recorded. The participants also were asked to fill-up the PLS and the AIM. The aim of this study was to investigate the LPP, which is assumed to reflect motivation attention, during a visual love paradigm. Results showed that LPP (from 400 ms after stimulus) significantly rises for the face of the partner on the frontal, central and parietal sites compared to the others stimuli (Figure 3.5). This strongly confirmed previous studies which assumed that there is a special neural network that responds to beloved faces.

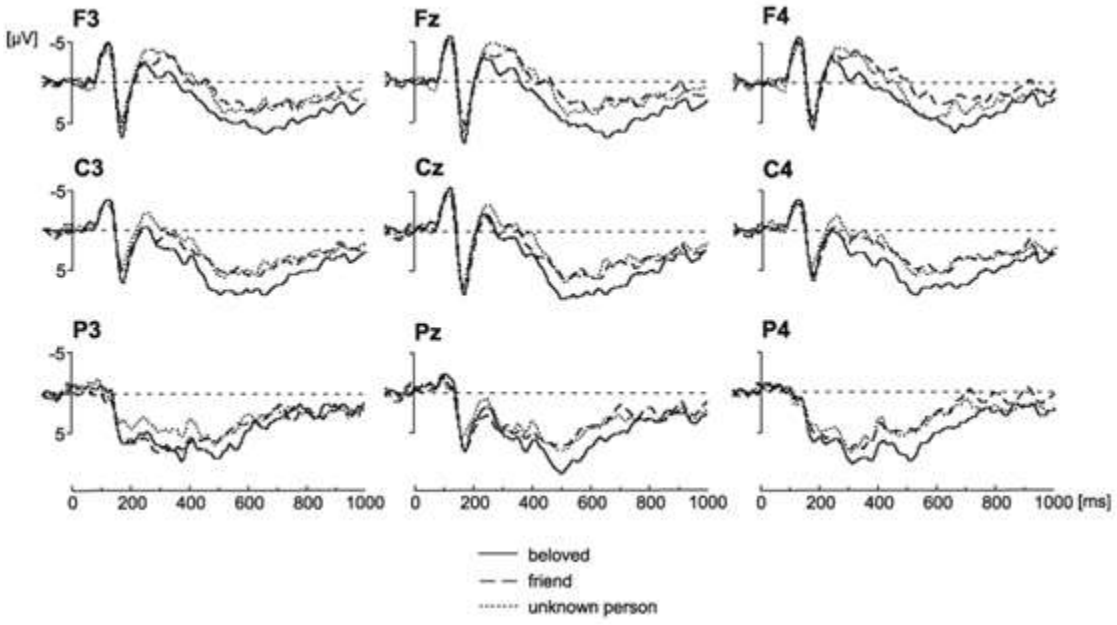


Figure 3.5 Grand-average ERPs of the beloved (solid line), friend (dashed line), and I unknown person (dotted line), positive down (figure and caption' s copy rights belong to Langeslag et al., 2007).

Another study by Basar and collaborators tried to investigate the feelings of love while viewing the face of the beloved by applying the concept of oscillatory brain dynamics (for details see Basar, Schmiedt-Fehr, Oniz, & Basar-Eroglu 2008). This study consisted of EEG recording while running a visual paradigm using stimuli such as pictures of a loved person, known and appreciated person, unknown person and light stimulation. A total of 20 participants who professed to be happily in love with their partner were recruited for this study. Results showed that there was a main significant difference in the amplitude delta band between the picture of the loved person (higher amplitude) compared to those of unknown and appreciated person. The interpretation of these results is discussed in light of the event-related oscillations (Başar et al., 2001). The Authors argue with the fact that in known in the previous literature that delta response in occipital sites plays an important role in face recognition and facial expression processing. However, in this study Basar et al., (2008) have found that the recognition of the beloved's picture seems to have a main effect on the frontal delta response. This could suggest that the frontal lobes may respond to the peculiar type of facial stimuli. Moreover, this study suggests that the electrical activity of the brain while viewing the face of the beloved is strongly associated with the frontal cortex and delta frequency range.

3.3 PERIPHERAL INDEXES STUDIES

Another way to study cognitive and emotional processes is to evaluate and observe indexed of peripheral measures. These reflect the activity of the autonomic nervous system (ANS) which is the general system that is responsible for regulating involuntary body functions such as heartbeat, blood flow, breathing, temperature and digestion.

This system consists of sympathetic and parasympathetic divisions, which are generally associated with activation and relaxation, respectively. The most commonly assessed indices of ANS activation are based on electrodermal (i.e., sweat gland) or cardiovascular (i.e., blood circulatory system) responses. Electrodermal responding is typically quantified in terms of skin conductance

level (SCL) or short-duration skin conductance responses (SCRs). The most commonly used cardiovascular measures include heart rate (HR), blood pressure (BP), total peripheral resistance (TPR), cardiac output (CO), pre-ejection period (PEP), and heart rate variability (HRV). Each of these measures varies in terms of whether it primarily reflects sympathetic activity, parasympathetic activity, or both. For example, SCL and PEP predominantly reflect sympathetic activity, HR and BP reflect a combination of sympathetic and parasympathetic activity, and HRV has been closely linked to parasympathetic activity (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000).

The sympathetic and parasympathetic divisions of the autonomic nervous system represent the principal channels of interaction between the brain and bodily organs and have complementary roles in the achievement of homeostasis and the regulation of physiological responses to emotional stimuli (Critchley, 2009; Janig, 2008). It is therefore plausible that love, which generally referred to several brain activation, also embodies a direct sharing of changes in body physiology between the involved individuals (Critchley, 2009; Preston & De Waal, 2002; Damasio, 1999).

The neural mechanisms of people who are in love are well known but few studies have concentrated their focus on the peripheral measures. In 2010 Vico and collaborators have found that faces of romantic partners elicited higher physiological (skin conductance and zygomatic activity) and subjective (emotional arousal) responses than parents, siblings, or friends, suggesting that looking at the image of someone we love evokes strong positive affect and emotional/cognitive arousal that go beyond a feeling of familiarity or simple recognition. However, there are no other studies that have investigated the peripheral aspects of love.

3.4 NEUROENDOCRINOLOGY STUDIES

Neuroendocrinology is the field of biology that focuses on the interaction between the nervous system and the endocrine system and as a result, how the brain regulates hormonal activity in the body. The nervous and endocrine systems usually operate in conjunction in a process called

neuroendocrine integration, to regulate the physiological functions of the human body. Thanks to the studies in neuroendocrinology initiated in the first decades of the last century by various figures of scientists, the fantastic world of chemical communication between the brain and endocrine glands has emerged. As outlined before, romantic love is governed by precise and peculiar neural mechanisms (Aron et al., 2005; Bartels & Zeki, 2000); however, also important endocrine factors regulate this powerful sentiment (De Boer et al, 2012). One of the earliest biological hypotheses about falling in love assumed that the latter was due to increased levels of phenylethylamine, based on similarities between the chemical structures of this neurotransmitter and that of amphetamines that cause mood changes that are similar to mood changes those typical of the initial phase of a love story. However, there is no scientific evidence to support this theory (Liebowitz, 1983). Over the past twenty years many studies have been performed in the field of the neuroendocrinology of love and many elements have been identified as essential, such as serotonin (Emanuele et al., 2007; Marazziti et al., 1999), dopamine (Takahashi et al., 2015; Marazziti et al.,2017), oxytocin (Algoe, Kurtz, & Grewen, 2017; Schneiderman et al., 2011; Ulmer-yaniv et al., 2016), vasopressin (Lim & Young, 2006), cortisol (Marazziti & Canale, 2004), nerve growth factor (Emanuele et al., 2006) and testosterone (Marazziti & Canale, 2004).

***Serotonin*.** In 1999 some Authors have highlighted the main role of the serotonin (5-HT) transporter in romantic love (Marazziti et al., 1999). This neurotransmitter is also known to be linked to both neuroticism and sexual behavior as well as to obsessive–compulsive disorder (OCD). The Authors selected three groups of participants: people in love, people with OCD and normal controls. Their findings suggested that subjects in the first romantic phase of a love affair were no different from OCD patients in terms of 5-HT platelet transporter density, which proved significantly lower than with normal controls.

Oxytocin and vasopressin. Many scientists have tried to figure out the role of oxytocin and vasopressin in romantic love (Algoe, Kurtz, & Grewen, 2017; Zeki, 2007). However, most of the works that investigated the role of these hormones are based on animal models. Oxytocin is a hormone related to affiliative bonding in mammals (Insel, 2010) and regulate social behavior, pair-bonding, and parental attachment across a different species (Carter, 1998). Many studies have shown that after the experimental administration of dopamine (e.g. intranasal) bonding behaviors increased such as looking into the eyes (Guastella et al., 2008), trust and empathy (Hurlemann et al., 2010; Kosfeld et al., 2005) and social cognition (Kirsch et al., 2005). A recent study evaluated the level of oxytocin in two groups of participants: new lovers vs non-attached singles (Schneiderman et al., 2011). Results demonstrated that the level of oxytocin was significantly higher in new lovers compared with singles. Regarding the role of vasopressin, studies demonstrated its receptors are present in many parts of the brain that are associated with love (Bartels & Zeki, 2004; Zeki, 2007). Although oxytocin and vasopressin have similar roles in mating, there are some differences in their effects, including sex differences and differences in amygdalide output (Lim & Young, 2006). Animal studies have shown that induction of vasopressin in the ventral pallidum increases the partner's chance of preference, while deactivation blocks the partner's preference (Young & Wang, 2004; Wang et al., 1994; Insel, Winslow, Wang, & Young, 1998).

Dopamine. As previously mentioned fMRI studies showed that when people looked at the photos of their beloved there is an increased activity in the dopaminergic-related brain areas associated with euphoria and reward in both early-stage (Bartels & Zeki, 2000; Aron et al., 2005; Xu et al., 2011; for a review, see Ortigue et al., 2010) and long-term relationship (Acevedo et al., 2012). Studies conducted on animal models have shown that the release of dopamine in the accumbens areas increases the generation of monogamous bonds (Aragona et al., 2003). A recent study, conducted on humans, investigated the role of dopamine in romantic love (Marazziti et al., 2017). Two groups

were selected for this study: one of the people in love and the other of people not in love. The aim of this study was to explore the concentration of dopamine in synaptic cleft by detecting the dopamine transporter (DAT). The results of this study showed that the presence of high levels of dopamine in the group of lovers, and not in the control group, could explain some behaviors that are characteristic of the feeling of love.

***Cortisol*.** The adrenal hormone cortisol has basically become how stress is defined. Animal studies demonstrated that stress and corticosterone are related to pair bonding formation in different species (DeVries et al., 1995, 1996; Hennessy, 1997; Levine et al., 1997; Mendoza & Mason, 1997). In 2004 Marazziti and collaborators selected two groups of participants: one composed of 24 people who declared that had recently fallen in love and another composed of 24 people not in love (control group). The purpose of this study was to evaluate the levels of hormones (pituitary, adrenal and gonadal) in people in love. Results showed that compared with the control group, people in love displayed a higher level of cortisol. This study showed for the first time that despite the positive meanings that are commonly attributed to romantic love, it is also accompanied by higher levels of stress and insecurity about the beginning of the relationship (Marazziti & Canale, 2004). The Authors have advanced the hypothesis that high levels of cortisol are necessary to overcome the initial neophobia.

***Nerve growth factor*.** This molecule, which is part of the neurotrophins family, has generally been associated with the regulation of synaptic plasticity and neural survival during childhood or adulthood (Pardridge, 2002). However, in recent years she has been recognized as a mediator in emotional processes and behavioral changes (Aloe et al., 1994; Hadjiconstantinou et al., 2001; Branchi et al., 2004). In 2006 Emanuele and collaborators have examined whether the early stage of love affair could be associated with alterations in circulating levels of neurotrophins. Plasma levels

of nerve growth factor were measured among three groups of participants (early-stage-love vs long-lasting-love vs no-love). Results of this study showed that nerve growth factor level was significantly higher in the subjects in love than in either the subjects with a long-lasting relationship or the subjects with no relationship. The authors have hypothesized that the specificity of the increase in nerve growth factor during the initial phase of love seems to suggest that this molecule could be particularly involved in the formation of new bonds.

***Testosterone*.** This is a steroid hormone, which is secreted by the testicles of males and the ovaries of females. Testosterone is involved in several processes, including the development of the male reproductive system and secondary sexual characteristics (Mooradian et al., 1987; Eisenegger et al., 2011). In recent years its role in romantic relationships and pair-bonding has also been studied. Marazziti and Canale (2004) in the experiment mentioned above demonstrated that the role of testosterone in romantic love is not the same between males and females. In fact, the research shows that while in men there is a reduction in testosterone levels during falling in love in women there is a revers pattern. These differences disappear after 12–24 months, indicating that testosterone is involved in the early stage of romantic love.

AIMS AND HYPOTHESIS

The objectives of this work are manifold. First of all, in the Italian context there are no validated scales that can evaluate the feeling of love. Therefore, the first aim is to validate a scale that could then be used for future studies in the field of love. Secondly, as we have seen, neurosciences and also psychology studies demonstrate that the concept of love is multidimensional. Therefore, the construction of a new questionnaire that would be able to evaluate various aspects that intervene in relationships is our second objective. However, the imprint of this study is rooted in neuroscience studies. As we have seen, there are two main paradigms that have been used in literature to study love, but with this work we intend to provide new literature on the use of an auditory and imaginative paradigm called *Love Induction Task*. Therefore, another objective is to explore the correlates both from a neural (through the EEG) and peripheral (through the FLIR) point of view. In addition, we wanted to test the effects that this paradigm has on the processing of emotions. This research question stems from the fact that previous studies of fMRI have shown that some areas of the brain closely related to the processing of emotions (e.g. amygdala, cingulate bark and nucleus caudate) play an important role in love. Then through the use of a classic task of emotional processing and the EEG was explored the response of subjects in love during the processing of negative, positive and neutral images.

PART II

VALIDATION STUDIES ASSESSING ROMANTIC LOVE IN THE ITALIAN CONTEXT

CHAPTER 4

ASSESSING PASSIONATE LOVE: ITALIAN VALIDATION OF THE PLS (REDUCED VERSION)[1]

4.1 Introduction

According to Hatfield and Sprecher (1986), passionate love combines cognitive, emotional and behavioral components. Specifically, cognitive components include intrusive thoughts about the partner, idealization of the other or the relationship and the desire to know the other and be known. Emotional components consist of positive feelings, sexual attraction, a desire for reciprocity and union and physiological arousal. Behavioral components are reflected by a variety of behaviors, such as being of service to the other and actions to determine the other's feelings.

In order to assess a general value of passionate love, the Passionate Love Scale (PLS; Hatfield & Sprecher, 1986) was developed. The full version of the PLS is a 30-item scale, which is more appropriate to investigate the specific components of passionate love (i.e., cognitive, emotional and behavioral), while a shorter version of 15 items (PLS-R) has been adopted for most neuroscientific and experimental investigations about love (Aron et al., 2005; Cacioppo, Bianchi-Demicheli, Frum, Pfaus, & Lewis, 2012; Langeslag, Jansma, Franken, & Van Strien, 2007; Mashek, Aron, & Fisher, 2000; Tiedt, Beier, Lueschow, Pauls, & Weber, 2014). Aron and colleagues (2005) have even found a strong positive correlation between the PLS and the brain areas associated with romantic love in participants who have declared to be deeply in love.

The PLS has shown to be reliable since the publication of the original article. Posterior analyses provided more compelling evidence about the validity of the scale (Hendrick & Hendrick, 1989; Masuda, 2003). More recently, Graham and Christiansen (2009) obtained a "very good" score

[1] *Published: Cannas Aghedu, F., Veneziani, C. A., Manari, T., Feybesse, C., & Bisiacchi, P. S. (2018). Assessing passionate love: Italian validation of the PLS (reduced version). Sexual and Relationship Therapy, 1-11.*

reliability across several studies (p. 59) for the 30-item PLS and an "acceptable" and "relatively stable" score reliability for the 15-item PLS (p. 59).

Many psychometric studies with the PLS were conducted outside the USA. Today, it is possible to find several publications testing the instrument around the globe. The PLS was successfully translated into Turkish (Yildirim, Hablemitoglu, & Barnett, 2014), Japanese (Kito, 2005), Portuguese in Brazil and Portugal (Feybesse, Neto, & Hatfield, 2011; Feybesse, 2015; Hernandez, 2015) and many other languages (Landis, & O'Shea, 2000). Even though the PLS was not validated in the Italian language, it has already been used in several Italian studies (e.g., Ardone, 2002; Emanuele et al., 2006). The PLS-R-IT can be considered the first Italian questionnaire that assesses love as a unidimensional construct. The present study aims to contribute to testing the psychometric properties of the Italian reduced version of the PLS-R-IT.

4.2 Methods

4.2.1 Participants

A total of 784 Italian volunteers (F = 504, M = 280), with a mean age of 27.40 years old (*SD* = 8.83), took part in this experiment. They were recruited either from the Department of Psychology at the University of Padova or via online notices and social networks. The sample consisted of individuals with different sexual orientations (92% heterosexuals, 4% homosexuals and 4% bisexuals). 30% of the participants had a bachelor degree or higher level of education, 63% had a high school diploma and only 7% had a middle school diploma. Of the respondents, 50% were engaged at the time of the study, 14% of which were living together; 8% were dating; 7% were married; 8% were occasionally dating; 2% had a sexual relationship and the remaining 25% were single. The average length of time the participants had been in the relationship with their partners was 13.72 months for those who were dating regularly, 34.02 months for those engaged, 156.14 months for those who were married, 5.64 months for those infatuated and 11.12 months for those

having only sexual relationships. 57% of the sample had declared that they were actually in love, 20% were not in love and 23% were unsure.

4.2.2 Materials

The study was administered online using the web-based LimeSurvey through the Multimedia and Digital Learning Service of xxx University. In order to have an exhaustive profile, participants had to complete three surveys, which included (i) demographic information (age, gender, sexual orientation, education level and religious background); (ii) relationship status at the time of the study (type of relationship: married, engaged, single, infatuated or dating regularly; partner's name and cohabitation status); and (iii) the PLS-R-IT (see Appendix for all items in Italian and English), composed of 15 statements to rate on a 1 to 9 Likert-type scale (1 = *Not true at all*, 9 = *Definitely true*). To ensure language validity, the original PLS-R was translated following the back-translation recommendations. Furthermore, an explicit question ("*Do you love___? If so, how much from 1 to 10 would you rate your love for___?*") was asked to participants about their relationship status in order to have a measure of their self-perception about their feelings.

4.2.3 Procedure

LimeSurvey, which is an open-source tool to create online forms, was implemented for this study. Participants had to be over 18 years old and had to sign a consent form, approved by the Ethics Committee of the Department of General Psychology of the University of xxx, which informed them of their rights, including the right to stop the experiment whenever they wanted. A web link was created via LimeSurvey and submitted to each participant, who had to fill out the survey online. Participants were recruited by online announcements, such as e-mails or via social networks. In order to ensure security and privacy, collected data were saved in a protected server of the University of xxx through the Telematic Service. We also obtained permission to use the PLS in this study from Elaine Hatfield, one of the authors of the scale (Hatfield & Sprecher, 1986).

4.2.4 Data analysis strategy

Data were analyzed by employing R statistical software (R Core Team, 2014) using the Lavaan package (Rosseel, 2012) and the Statistical Package for Social Sciences (SPSS) (Version 21; SPSS Inc., Chicago, USA). For this study, a cross-validation approach (Cudeck & Browne, 1983) was carried out. Therefore, the original sample was randomly split into two independent subsamples, the calibration sample, which included $N_c = 392$ subjects, and the validation sample, which included another $N_v = 392$ subjects. The original version of the PLS by Hatfield and Sprecher (1986) presents good reliability and a one-dimensional factorial structure. Moreover, its scores are not influenced by participants' gender. We expected to find these characteristics in the Italian version too. First, to assess the factorial structure of the scale, we performed both principal axis factoring analysis (PAF) and confirmatory factor analysis (CFA) in the calibration group. Then, in order to confirm the model advanced by Hatfield and Sprecher (1986), another CFA was performed on the validation sample. As thresholds for an acceptable fit, we considered a root mean square error of approximation (RMSEA) smaller than or equal to 0.08; a comparative fit index (CFI), non-normed fit index (NNFI) and Tucker-Lewis index (TLI) higher than 0.95; and a standardized root mean square residual (SRMR) smaller than 0.10 (Hu & Bentler, 1999; Schermelleh-Engel, Moosbrugger, & Müller, 2003).To evaluate the reliability of the PLS-R-IT, the Cronbach alpha was calculated, and a value equal to 0.7 or higher indicated good internal consistency (Nunnally & Bernstein, 1994).

4.2.5 Item distribution

Before analyzing the data, we ensured the basic statistical assumptions for exploratory and confirmatory factor analysis, such as normal distribution and multivariate normality. In both subsamples, calibration and validation, the items' normality was excluded by both the Shapiro-Wilk test ($0.624 < W < 0.937$, $p < .001$ for all of the 15 items) and Mardia's test. Therefore, as suggested

by Lionetti, Keijsers, Dellagiulia and Pastore (2016), we took into account the ordered nature of the Likert scale as a way of obtaining more reliable results. To accomplish this analysis, the items were treated as ordinal, and we implemented all the subsequent CFAs with the diagonally weighted least squares (DWLS), an estimator specifically designed for ordinal items and Likert-scale data (Flora & Curran, 2004) that provides more accurate estimates than maximum likelihood (ML) methods in cases of non-normality (Li, 2016).

4.3 Results

4.3.1 Descriptive statistics of the sample

The whole sample was divided into three categories: who was in love (Yes), who wasn't (No) and who was unsure (Unsure). Because of a non-normal distribution, the difference between the three groups in terms of PLS-R-IT scores was analyzed using a Mann-Whitney U test of variance involving nonparametric variables with a non-normal distribution. For the effect size, Grisson and Kim (2012) have suggested that for a two-group independent sample design, one can obtain the Mann-Whitney U statistics and then divide the number by the product of the two sample sizes. Results showed a significant difference between the Yes (M = 103.83, SD = 17.68) and No (M = 75.26, SD = 31.24) groups (U = 16383, $p < .001$, $\eta^2 = 0.22$), between the Yes and Unsure (M = 90.81, SD = 20.79) groups (U = 24855, $p < .001$, $\eta^2 = 0.31$) and between the No and Unsure groups (U = 10319, $p < .001$, $\eta^2 = 0.36$). Gender difference was calculated among people who declared to be in love, and the U test showed a slight difference between males and females (M males = 101.69, SD = 18.62; M females = 105.04, SD = 17.03; U = 20367, $p = .044$, $\eta^2 = 0.44$).

4.3.2 Factorial analysis

A PAF was conducted to explore the factorial structure of the PLS-R-IT on the calibration sample. In order to check the suitability of the factorial analysis, several significant criteria were performed. The Kaiser-Meyer-Olkin measure showed that the adequacy of the sample was excellent (KMO =

.92), and Bartlett's test of sphericity was significant ($\chi 2$ (105) = 3056.661, $p < .001$). The diagonals of the anti-image correlation matrix were also all over .5, as recommended by Dziuban and Shirkey (1974). The PAF yielded a one-factor structure that explained 46% of the variance. This result was also supported by the leveling off of the scree plot. As shown in Table 4.1, all items had factor loadings above .40 except item 9, which was .26. In order to decide whether to keep or not keep item 9, we took into account the internal consistency, using Cronbach's coefficient alpha, of the PLS-R-IT without item 9 (14 items; α = .914) and including all items (15 items; α = .914). As there were no differences between the two versions, we decided to keep the original scale with all items. These results also show that the PLS-R-IT had adequate internal reliability as compared to the original version of the scale. An initial CFA was conducted on the calibration group, and the fit indexes were below the thresholds (CFI = 0.97, NNFI = 0.97, TLI = 0.97, RMSEA = 0.06, SRMR = 0.08). Then, in order to support the factorial structure of the PLS-R-IT, another CFA was retested on the validation group, and the fit indexes were even better than those of the calibration group (CFI = 0.98, NNFI = 0.98, TLI = 0.98, RMSEA = 0.04, SRMR = 0.08). In **Table 4.1** are the reported factor loadings of the CFA estimated on the calibration and validation groups. Results were comparable in the two samples, supporting the reliability of the model tested. Moreover, both samples exhibited good fit indexes and suggest that the factorial solution ideated by Hatfield and Sprecher (1986) can be adapted to the Italian sample.

Table 4.1 Mean, standard deviation and factor loadings of the PFA and CFA estimated in the calibration and validation samples.

Items PLS-R-IT	M (SD)	PAF Factor Loading Calibration	CFA Factor loading Calibration	CFA Factor loading Validation
ITEM 1	5.27(2.84)	0.51	0.64	0.71
ITEM 2	3.96(2.62)	0.56	0.66	0.56
ITEM 3	7.76(1.81)	0.41	0.58	0.66
ITEM 4	6.71(2.54)	0.58	0.68	0.73
ITEM 5	7.41(2.29)	0.47	0.69	0.73
ITEM 6	6.68(2.50)	0.46	0.66	0.70
ITEM 7	7.38(2.16)	0.72	0.74	0.76
ITEM 8	5.99(2.47)	0.54	0.71	0.75
ITEM 9	5.78(2.50)	0.26	0.41	0.56
ITEM 10	7.51(1.99)	0.55	0.53	0.61
ITEM 11	5.67(2.42)	0.62	0.79	0.77
ITEM 12	7.01(2.35)	0.38	0.58	0.57
ITEM 13	5.27(2.69)	0.43	0.59	0.54
ITEM 14	7.39(2.07)	0.71	0.70	0.75
ITEM 15	5.16(2.51)	0.50	0.64	0.61

4.4 Discussion

The present study was focused on verifying the psychometric properties of the PLS in the Italian population. The results of this study reproduced what was found in the original study conducted in the United States (Hatfield & Sprecher, 1986). The exploratory and confirmatory factorial analysis clearly indicated that this Italian version of the PLS has one main factor with very good internal

consistency. This version of the scale is perfectly valid to be used among the Italian population. These statistical results indicate that passionate love felt in Italy shares one common basis with other cultures regarding some emotional, cognitive and behavioral elements. This corroborates with the growing idea that this strong feeling is a universal experience and emotion.

Our results also matches with what was found in other countries outside the United States that have tested the psychometric properties of the PLS in their cultures. Other countries have used this measure but without providing psychometric information beside the Cronbach alpha. We are surely aware of five different countries: Brazil (Hernandez, 2015; Feybesse, 2015), France (Feybesse, 2015) Japan (Kawano, Hanari & Ito, 2015), Turkey (Yildirim et al., 2014) and Portugal (Feybesse et al., 2011). All these studies reported findings that the 15 items of the short version loaded above .45 in one main factor. The Cronbach alpha found in all these studies reached a value above .90 like it was almost always found in studies using the PLS (Graham & Christiansen, 2009). The main difference that is noticeable between all these studies is that although all the samples were composed by undergraduate students, the ratio of people declaring to be in love when they were answering to the scale was different. The cultures that can be considered to be more communitarian had fewer people in love (Japan = 31,74% and Turkey = 33,3%). The samples of students from the West had always more than 50% saying that they were in love. In Turkey (Yildirim et al., 2014), 33,3% of the sample said they have never felt in love whereas the ratio of this group was always lower than 10% in the West. These differences between the East and the West may be due to the dynamics that romantic relationships has between these countries. Young adults are probably socially freer to date in the West.

The same thing can be said regarding the overall scores we obtained with this sample. As predicted, participants in love scored higher than those who were not in love. They also tended to rate their passionate love feeling around 7 ($x = 6.92$) when they were answering the scale items, which is exactly what was found in the United States (Hatfield & Sprecher, 2010) and other

cultures, such as France or Brazil (Feybesse, 2015). Cross-cultural studies tend to find no effect of culture in love types that involve high levels of feeling, such as passionate love (Neto et al., 2000).

The only difference that we noticed in this study compared with what is usually found in the results was gender differences among participants who were in love when they were answering the questionnaire. In this study, women scored higher than their male counterparts. If we consider what we have found, the effect of gender was rather small but nonetheless significant. This result is hard to explain because it is rare to find gender or even cultural differences when someone is measuring the intensity of passion in romantic lovers. When they occur, females tend to love with more passion (Hatfield, 1998), as was seen here. We recommend that future research using the Italian version of the PLS look for gender differences among participants who stated to be either in love or in romantic relationships, especially if they want to compare gender in any way.

CHAPTER 5

THE MULTIDIMENSIONAL EVALUATION OF LOVE (MEVOL): DEVELOPMENT AND PRELIMINARY VALIDATION[1]

5.1 Introduction

Regarding the issue of measurement, scientists have focused on the assessment of love, which has generally involved the use of self-report questionnaires; thus, several scales have been proposed (for an overview, see Hatfield, Bensman, & Rapson, 2012). Many authors, even if they evaluate love as unidimensional, include within the description of their questionnaires several dimensions that may feature in romantic love (e.g. Hatfield & Sprecher, 1986; Tennov, 1979) suggesting that many variables are involved in this complex sentiment. The main dimensions that have been investigated so far are: *erotic feeling* (Hatfield & Sprecher, 1986), *idealization* (e.g. Fehr, 1994; Fengler, 1974; Hatfield & Sprecher, 1986; Tennov, 1979), *negative emotion* (Hatfield & Sprecher, 1986), *positive emotion* (Hatfield & Sprecher, 1986) and *obsessive behavior* (Hatfield & Sprecher, 1986; Tennov, 1979). Surprisingly, despite the fact that previous authors have mentioned these dimensions, none have analyzed them separately. For example, these dimensions are in part already included in the Passionate Love Scale (Hatfield & Sprecher, 1986) which, as we described in the previous chapter, is a measure designed in the field of psychology and built to assess cognitive, physiological and behavioral indicators of passionate love. However, the outcome of this scale is represented by a unique value which describes the level of passionate love felt for the partners and is not possible to obtain a reliable measure of a specific dimension. Therefore, our first goal in this study was to support the multi-dimensional measurement of love by investigating several dimensions simultaneously. It is important to specify that multidimensionality means the possibility of obtaining a single value for each of the dimensions mentioned above. In fact, in the literature, there

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is an enormous number of multidimensional scales that investigate other aspects of love. For example, the Triangular Love Scale (Sternberg,1997) which assess different kind of love; the Love Attitude Scale (Hendrick, Hendrick, & Dicke,

1998) which assess six types of love or the Love Schema Scale (Hatfield & Rapson, 1993, 2005) designed to measure six love styles. Furthermore, several other important dimensions are involved in romantic relationships. For example, the ability to predict what one's partner is thinking and the awareness to be loved or not. This dimension, also known as perspective taking (PT), implies a complex cognitive process that is essential for social interactions (Dixon & Moore,1990; Ruby & Decety,2004). It involves the ability to infer knowledge and thoughts of other people from previous and/or online information (Dixon & Moore, 1990). Relative to this point, Wlodarski and Dunbar (2014) showed that, when individuals in love were primed with images of their partners, their performance improved when attributing emotional states to others. Other research has similar implications: lovers can more quickly recognize the intentions of their partner than those of a friend or stranger (Ortigue, Patel, Bianchi-Demicheli, & Grafton, 2010). However, it is not clear whether people who feel rejected—in other words, those who have taken the perspective that their partner does not love them—show the same *erotic feeling*, *idealization*, *negative emotion*, *positive emotion* and *obsessive behavior* as those who feel reciprocated. Determining the role that this PT ability plays in love was our second goal in the present research.

Our third goal in this research was to measure love as a subjective feeling (Sternberg, 1995; Watts & Stenner, 2005). Indeed, love can be extremely subjective, and the concept of love can have dissimilar meanings depending on individuals' personalities (Brown, Acevedo, & Fisher, 2013) and past experiences (Bolmont, Cacioppo & Cacioppo, 2014). Surprisingly, however, no measures for assessing individual experiences of love exist in the literature. To reach these goals in the present study, we propose a novel measure of love: the Multidimensional Evaluation of Love (MEVOL). Moreover, its psychometric properties will be presented, such as reliability and validity.

5.2 The structure of MEVOL

As mentioned previously, researchers have used perspectives from various fields to attempt to disentangle the underlying mechanism of love. MEVOL is a questionnaire that combines knowledge coming from social and personal psychology and neuroscience. In this sense, MEVOL is based on a definition of romantic love as a mix of fast-moving feelings that can have different meanings based on individuals' experiences and personalities. We designed MEVOL with the goal of measuring not just the components of love that are prototypical of romantic love but also certain novel aspects of love that researchers have not yet investigated. MEVOL is a multidimensional questionnaire that is quick and easy to administer.

5.2.1 Dimensions of MEVOL

As previously mentioned, love is not a one-dimensional emotion; rather, it is made up of several components, thus making this sentiment quite complicated. To make these dimensions measurable, we took several steps. Based on the literature on love we selected five dimensions of love that have been identified in the previous research (Fehr, 1994; Fengler, 1974; Hatfield & Sprecher, 1986; Sternberg, 1997; Tennov, 1979). In addition, we included two other important dimensions in this new scale. The following are the five aspects deriving from the literature:

Positive idealization: Idealization is the tendency to exaggerate the qualities of another person, as if that person were perfect; it represents an essential part of falling in love (Hattis, 1965). This process is often present, but mainly at the beginning of love relationships (Tennov, 1979). In one study, scholars showed that people tend to see their partners more positively than those partners perceive themselves. This mechanism has been shown predict satisfaction in a relationship (Murray, Holmes, & Griffin, 1996).

Sexual attraction: This dimension refers to sexual desire and sexual excitement toward a partner. It is a predominant dimension in love-based or romantic relationships, and many authors have found that sexual desire is strongly present in love (Aron & Aron, 1991; Hendrik & Hendrik, 1992). Other

theorists have stated that love and sexual desire present different expressive behaviors, relationships outcomes and experiential correlates (Gonzaga, Turner, Keltner, Campos, & Altemus, 2006).

Positive and negative emotion: These dimensions refer to the levels of positive and negative feeling that partners experience during love-based or amorous relationships. Sprecher and Regan (1998) suggested that both positive and negative emotions fuel love, noting that lovers alternate between states of excitement or joy when events go right and grief or desolation when they do not.

Obsessive thinking: This dimension refers to intrusive thoughts or actions that are obsessively focused on the partner. Researchers have demonstrated that romantic lovers spend more time thinking about their beloved than thinking about other people (Fisher, 1998; Hatfield & Sprecher, 1986; O'Leary, Acevedo, Aron, Huddy, & Mashek, 2012), which may lead to obsessive behaviors that are comparable to those found in addiction (Aron et al., 2005).

Furthermore, in order to investigate new aspects that often surface in a clinical setting other two novel and exploratory dimensions have been introduced in the questionnaire:

Taking love for granted: This refers to the feeling of being excessively certain of the partner's love. People with a high score on this dimension perceive their partners as being always present and completely in love.

Negative idealization: We distinguished two kinds of idealization: *positive*, which, as said before, represents simple admiration of the partner's qualities, and *negative*, which implies a devaluation of the self that leads to an indirect enhancement of the partner.

5.2.2 Perspective Taking

What is it PT, and why is important in the definition of love? As stated in the introduction, PT represents the ability to read one's partner's mind. This process could reveal various kinds of love sentiments that have not previously been explored. During scientific experiments with love paradigms, researchers commonly evaluate the extent to which participants are in love but rarely

consider the degree to which those participants feel loved. It is important to underline that PT does not represent one of the love dimensions described above; rather, it is a meta-thought that deserves attention when seeking to obtain a clear picture of a relationship. For example, during an assessment, it is possible to find two people who declare that they are madly in love and to have both of them actually obtain high scores on a general love scale. If the evaluation stops at this point, researchers would conclude that both people are deeply in love, and this would not be a mistake. However, if PT is also assessed, the researchers might discover that one of the people does not feel loved by his or her partner. The differences between the two enamored people could relate to various processes that require attention, both in clinical assessment and in scientific research. Therefore, this factor represents an important aspect of love relationships.

For these reasons, to investigate PT, we selected particular items to reflect the awareness of being loved. Therefore, we added another measure to our investigation called *PT-positive* that reflects the feeling of reciprocation from a partner. Obviously, lower scores on this dimension will reflect the opposite feeling. In this sense this dimension of PT represents a new way of conceptualizing love, as it provides information about meta-thoughts that can influence lovers' feelings.

5.3 Study 1

Study 1 was a preliminary construction of the MEVOL. First, a team composed of the authors and two psychotherapists constructed a pool of items that could be used to assess love's components. One purpose of this study was to identify the items that could represent the multiple components that are representative of love; in this sense, we tried to combine the dimensions found in the previous literature with a new dimension that we identified. Furthermore, within these categories, we designed some items to carefully reflect PT. Another goal of the present study was to create a reliable scale that would be easily administrable during experiments or in a clinical setting.

5.3.1 Methods

5.3.1.1 Participants

The sample comprised 143 students (114 women) who were native Italian speakers; we recruited the students from psychology classes at the University of Padua. The participants' average age was 21.35 years (*SD* = 6.50). To be eligible for this study, we asked that the students be either married or currently in a close relationship, regardless of their gender identity and sexual orientation. Of the participants, 11% were dating regularly, 86% were engaged (of whom 7% were living together), and the remaining 3% were married. The average length of time that the participants had been in their relationships was 4 months for those who were dating regularly, 21 months for those who were engaged and 241 months for those who were married. Most (78%) of the participants declared that they were actually in love, but 4% of the declared that they were not in love, and the remaining 18% were unsure as to whether they were in love.

5.3.1.2 Materials

We collected the data through a survey divided into three blocks, resulting in complete profiles of the participants. The first block comprised demographic questions about topics such as age, gender and sexual orientation. The second part comprised specific questions about the participants' relationships: length of relationship, type of relationship (e.g., married, engaged, single or dating regularly), the partner's name or nickname, and whether they are living together. The third block contained both the first version of MEVOL, in which participants were asked to respond on a scale from 1 (*absolutely false*) to 6 (*absolutely true*) to 33 items, and the Italian validation of the Passionate Love Scale (PLS-R-IT; Cannas Aghedu, Veneziani, Manari, Feybesse & Bisiacchi, 2018), which was composed of 15 statements that the participants rated from 1 (*not at all true*) to 9 (*definitely true*). In this phase the PLS-R-IT was submitted in order to have the possibility to use some items of the scale to build some of the dimensions. Moreover, we measured the reliability of

the PLS-R-IT using Cronbach's alpha, and the results suggest that its internal consistency was very good, just as in the original version (α = .914).

5.3.1.3 Procedure

We implemented the entire experiment using LimeSurvey, an open-source survey tool that uses online forms. The participants provided consent after being informed that they could stop the experiment whenever they wanted; they also certified that they were over 18 years old. The two questionnaires, MEVOL and PLS-R-IT, were presented randomly to ensure there were no order effects.

5.3.1.4 Data analysis strategy

We analyzed the data using the statistical software Mplus (Version 7; Muthén & Muthén, 2012) and Statistical Package for Social Sciences (Version 21; SPSS Inc.).

As stated above in the description of MEVOL's structure, we designed an initial pool of 33 items, with the aim of capturing seven dimensions of love: *positive idealization* (4 items, of which 1 we took from the PLS), *negative idealization* (4 items), *taking love for granted* (3 items), *sexual attraction* (3 items), *positive emotion* (7 items), *negative emotion* (9 items), and *obsessive thinking* (3 items).

Through a confirmatory factor analysis (CFA), we tested this seven-factor solution on an initial set of items. The purpose was twofold; the first goal was to sustain the hypothesized seven-factor structure for MEVOL. In a CFA, a model is accepted or rejected on the basis of goodness-of-fit indices. In the present study we designed the questionnaire with the idea to have 7 separated dimensions that are supposed to be independent. Therefore, as suggested in the Encyclopedia of Statistics in Behavioral Science (Stangl, 2008), we have run only the CFA which represent a good way to show the goodness of the model. As Hu and Bentler (1999) suggested, we took several fit indices into account to prove the goodness of the model's fit to the data: the Satorra-Bentler scaled chi-square (SB χ^2; Satorra & Bentler, 1994), the χ^2/df ratio, the root mean square error of

approximation (RMSEA), the comparative fit index (CFI), the Tucker-Lewis index (TLI; sometimes called the non-normed fit index), and the standardized root mean square residual (SRMR). Although a nonsignificant chi-square indicates a good fit to the data, this value is usually significant in large samples. Therefore, chi-square is usually combined with the χ^2/df ratio, which suggests an adequate fit for values less than 3. RMSEA values less than .08 and SRMR values less than .10 also usually suggest an acceptable fit (Hu & Bentler, 1999). Finally, a CFI or TLI higher than .90 is recommended for an adequate fit. However, these indices, as computed in Mplus, may be lower than they would be when calculated in other packages, as covariances among exogenous observed variables are not constrained to zero in Mplus (Widaman & Thompson, 2003).

The second aim of the CFA was to identify which statements did not adequately capture their intended love components, thus allowing us to reduce the number of items. The aim of this item-deletion procedure was to refine the instrument, thus resulting in the inclusion of only the items that adequately measured the hypothesized dimensions of love while maintaining the originally theorized structure as much as possible. As decision criteria for this item selection process, we took the following factors into account: the factor loadings, the modification indices and the meaning of the items. A factor loading represents the correlation between an item and its hypothesized factor, thus indicating the strength of the association between that indicator (i.e., item) and its latent dimension (i.e., factor; Bollen, 1989; Jöreskog & Sörbom, 1999). A factor loading is usually considered meaningful if it has a value of .32 or higher (Tabachnick & Fidell, 2007). Modification indices suggest misfit causes, as they identify items whose loadings involves factors other than those specified in the model and correlated measurement errors between items. Correlated error measurements are not recommended, as they indicate that "*some of the covariance in the indicators not explained by the latent variable is due to another exogenous common cause*" (Brown, 2006, p. 157); these errors thus cause a loss of validity and theoretical meaningfulness for the instrument (Bagozzi, 1983; Fornell, 1983). A modification index is conceived as significant for a value higher

than 3.48; this value is usually approximated to 4 (Brown, 2006). We developed all of the instrument's items with the aim of detecting exactly one love component. Each item should therefore show a meaningful factor loading for its own component, and no modification indices should suggest that an item saturates more than one factor. Additionally, the measurement errors should not be correlated between items. We thus took factor loadings and modification indices values into account in the item-selection procedure, which was also driven by items' meanings. Regarding this point, we categorized the items by relative importance and by their representativeness regarding PT and the essential dimensions.

Before analyzing the data, we tested for normal distribution and multivariate normality. The absolute values of skewness and kurtosis suggested a violation of multivariate normality, which we confirmed using Mardia's test (multivariate skewness: $b_{1p} = 268.75$, $p < .001$; multivariate kurtosis: $b_{2p} = 1139.16$, $p < .001$). Therefore, due to the partial non-normality of our data, we employed in the confirmatory factor analysis a robust maximum likelihood estimation procedure, starting from the asymptotic covariance matrix of polychoric correlations.

5.3.2 Results

5.3.2.1 Confirmatory factor analysis

We tested the hypothesized seven-factor solution using a CFA. Overall, the indices of fit were not satisfactory. The Satorra-Bentler chi-square was significant: SB χ^2 (474) = 930.93, p □ .00. In addition, the χ^2/df and RMSEA values suggested an adequate fit (χ^2/df = 1.96; RMSEA = .08 [.074 – .090]). Nevertheless, the other indices were not satisfactory (CFI = .72; TLI = .69; SRMR = .11). As a first step, we therefore proceeded to take into account the factor loadings. The factor loadings for *taking love for granted*, *sexual attraction*, *positive emotion* and *obsessive thinking* all were significant and ranged from .47 (item 1 of *obsessive thinking*) to .88 (item 1 of *sexual attraction*). We found two low but significant factor loadings with regard to the other

subscales: item 2 of *positive idealization* (.24, p = 005) and item 1 of *negative emotion* (.23, p = 017). In addition, item 9 of the *negative emotion* subscale was not significant (.04, p = .433). As a first attempt at instrument refinement, we discarded the three items with low or no significance and then retested the seven-factor structure on the remaining 30 items. Although this led to fit improvement, taken together, the fit indices in the CFA were still not satisfactory: SB χ^2 (384) = 723.70, p □ .00; χ^2/df = 1.88; RMSEA = .08 [.067 – .085]; CFI = .78; TLI = .69; SRMR = .11. Nevertheless, all the factor loadings were significant and clearly above the threshold value of .32; they ranged from .39 (item 7 of *negative emotion*) to .88 (item 1 of *sexual attraction*). We thus took the modification indices into account, starting with the items that the results implied could saturate more than one factor. Thus, following the modification indices' suggestions, we progressively dropped item 4 of *negative idealization*, items 3 and 6 of *positive emotion*, and item 8 of *negative emotion*. Notably, these items were discarded one by one, and we did not always eliminate the item with the highest modification index; our decisions were driven by the meaning of the item. As already noted, we intentionally maintained either some items either because of their meaning or to provide an indicator of PT. Our goal was to develop a scale with at least three items for each subscale. Therefore, although the modification indices suggested that the first item of the *positive idealization* subscale also detected aspects of *taking love for granted*, we decided not to discard this item. Moreover, we retained item 3 of the *obsessive thinking* subscale even though it seemed to saturate aspects of *positive idealization* so as to ensure the presence of at least three *obsessive thinking* items. Finally, we retained item 7 of *positive emotion* and the item 4 of *negative emotion* to provide pure measures of anxiety and trust, respectively, as both these are considered important aspects of love.

After discarding four items (item 4 of *negative idealization*; items 3 and 6 of *positive emotion*; and item 8 of *negative emotion*), we retested the hypothesized seven-factor structure with the remaining 26 items. The resulting fit indices showed improvement and seemed to be acceptable: SB χ^2

(278) = 469.48, p □ .00, χ^2/df = 1.69; RMSEA = .07 [.058 – .080]; CFI = .83; TLI = .80; SRMR = .09. Nevertheless, the modification indices suggested correlated measurement errors between various items. Therefore, driven by the meaning of the items and the modification indices, we proceeded to discard item 3 of *negative emotion*, which seemed to covary with the error measurement of various items. We then tested the seven-factor structure on the remaining 25 items: SB χ^2 (254) = 432.54, p □ .00, χ^2/df = 1.70; RMSEA = .07 [.059 – .081]; CFI = .83; TLI = .80; SRMR = .09. In this 25-item version, most of the subscales involved three items, with the sole exceptions being the *positive emotion* and *negative emotion* subscales. In an attempt to equalize the number of items in all subscales, we therefore decided to discard two items from the *positive emotion* subscale and two items from the *negative emotion* subscale. This process was exclusively driven by item meaning. Thus, items 4 and 5 of the *positive emotion* subscale were dropped, as they measured more than one dimension and therefore could not be considered pure measures. Similarly, we dropped items 2 and 6 of the *negative emotion* subscale, as their meanings reflected measures that were already included in the subscale.

We then tested the seven-factor structure using this 21-item version, and the fit indices indicated a satisfactory fit to the data: SB χ^2 (168) = 277.77, p □ .00, χ^2/df = 1.65; RMSEA = .07 [.053 – .081]; CFI = .86; TLI = .83; SRMR = .09. Regarding the factor loadings, as reported in Table 5.1, they were all significant, ranging from .40 (item 3 of *negative idealization*) to .87 (item 1 of *sexual attraction*).

Concerning the relationships between the love components, our hypotheses were largely confirmed, as reported in Table 5.2. Indeed, *positive idealization* was unrelated to *negative idealization*, *taking love for granted* and *negative emotion*; moderately associated with *obsessive thinking*; and highly linked to *sexual attraction* and *positive emotion*. As expected, *negative idealization* was related to lower levels of *taking love for granted* and *positive emotion*, as well as to higher levels of *negative emotion* and *obsessive thinking*; no significant link was found between this love component and *sexual attraction*. Moreover, in line with our predictions, *taking love for granted* was unrelated to

either *sexual attraction* or *obsessive thinking*, but it was related to higher levels of *positive emotion* and lower levels of *negative emotion*. *Sexual attraction* was linked to *positive emotion* and *obsessive thinking*, but no significant association was found with *negative emotion*. *Positive emotion* was related to lower levels of *negative emotion*; however, it was unrelated to *obsessive thinking*, which was highly associated with *negative emotion*.

The fits of the indices were satisfactory, and the love components showed the predicted pattern of relationships. Therefore, we discarded no further items; the final version of the MEVOL comprised 21 items, three for each of the seven love dimensions.

Table 5.1 Standardized factor loadings of the EVOL subscales in its final version.

Subscale	Item	Factor Loadings CFA	
		Study 1	Study 2
Positive idealization	1.	.77	.76
	2.	.77	.79
	3.	.58	.62
Negative idealization	1.	.64	.62
	2.	.70	.71
	3.	.40	.63
Taking love for granted	1.	.66	.68
	2.	.67	.52
	3.	.70	.78
Sexual Attraction	1.	.87	.81
	2. (R)	.65	.55
	3. (R)	.75	.71
Positive emotions	1.	.64	.64
	2.	.67	.61
	3.	.66	.75
Negative emotions	1.	.57	.57
	2.	.68	.62
	3.	.61	.69
Obsessive thinking	1.	.55	.60
	2.	.76	.69
	3.	.47	.57

Note: R indicates items that have to be recoded. All the factor loadings were standardized and significant at $p < .001$.

Table 5.2 Latent correlations between the EVOL subscales in the Confirmatory Factor Analysis (Study 1)

Subscale	*1*	*2*	*3*	*4*	*5*	*6*
1. Positive idealization	__					
2. Negative idealization	.03	__				
3. Taking love for granted	.05	-.39***	__			
4. Sexual Attraction	.75***	.03	-.04	__		
5. Positive emotions	.77***	-.34*	.33*	.72***	__	
6. Negative emotions	.06	.48**	-.15	.07	-.29	__
7. Obsessive thinking	.39**	.64***	.06	.33**	.14	72***

Note. * $p < .05$; ** $p < .01$; *** $p < .001$

5.3.2.2 Instrument reliability

For each love component, we proceeded to sum the scores of the three items to provide subscale scores and then determined each subscale's standard deviation and Cronbach's alpha (see Table 5.3). Although Cronbach's alpha values of at last .5 are acceptable, values of at least .7 are preferred (George & Mallery, 2003). As reported in Table 5.3, the Cronbach's alpha values for *positive idealization*, *taking love for granted* and *sexual attraction* were all above .70; these subscales were therefore reliable. We found acceptable but low levels of reliability for *negative idealization*, *positive emotion* and *negative emotion*. In addition, *obsessive thinking* showed a poor but still acceptable Cronbach's alpha value. Most of the MEVOL subscales thus showed low levels of reliability.

Table 5.3 Means, standard deviations and Cronbach's alpha values of the EVOL subscales

Measure	*M*		*SD*		*Cronbach's alpha*	
	Study 1	*Study 2*	*Study 1*	*Study 2*	*Study 1*	*Study 2*
Positive idealization	16.69	16.82	3.65	3.69	.71	.76
Negative idealization	8.80	8.23	3.57	3.99	.60	.68
Taking love for granted	8.80	8.85	3.59	3.75	.71	.71
Sexual attraction	15.40	7.71	3.21	1.74	.79	.72
Positive emotions	15.85	15.77	2.20	2.67	.68	.70
Negative emotions	8.17	16.63	3.61	9.62	.65	.66
Obsessive thinking	10.19	9.26	3.67	3.80	.59	.65

Note. Response scales ranged from 1 to 6.

5.3.3 Discussion

In Study 1, we supported the hypothesis that love can be measured as a multidimensional construct. We identified six representative dimensions of MEVOL from the literature: *sexual attraction*, *idealization*, *negative emotion*, *positive emotion* and *obsessive thinking*; in addition, we aimed to introduce a final dimension: *being taken for granted*. We aimed to represent most of the components that can intervene during romantic relationships. We identified a pool of items that could represent the 7 dimensions, starting from a pool of 33 items; after several statistical analyses, we obtained a 21-item scale. Moreover, for each dimension, we performed a reliability test using Cronbach's alpha. The results showed that MEVOL can be a reliable scale for measuring the seven main components that characterize love. Nevertheless, it has to be noted that alpha values are influenced by the number of items involved; therefore, it is not surprising to find low alpha coefficients in three-item subscales (John & Benet-Martinez, 2000). However, to confirm the reliability and validity of MEVOL, we performed another study.

5.4 Study 2

This study was a further replication of the key findings from Study 1's factor analysis and scale construction results. The present study examines the following hypothesis: MEVOL should measure the components of love that other scales have already taken into account, we expect that a) MEVOL is correlated with other love questionnaires. Researchers have demonstrated that people in love activate peculiars brain areas (Bartels & Zeki, 2000) therefore we expect b) people who are madly in love differ from those who are not and those who are not sure if they are in love. Moreover, scholars have shown that people who are rejected often feel despair and a profound sense of loss (Fisher, Brown, Aron, Strong, & Mashek, 2010), so we expect that c) people who do not feel loved and those who do feel loved display different measures.

5.4.1 Methods

5.4.1.1 Participants

The sample comprised 477 people (58% women) who we recruited either from the Psychology Department at the University of Padua or through online advertisements. The participants' average age was 30.75 years ($SD = 8.97$), and all participants were native Italian speakers. The eligible criteria were the same as in Study 1.

In terms of religious background, 64% of participants were Catholic, 21% were atheist, and 13% were agnostic; those who remained classified themselves as belonging to other religions. Regarding education, 93% of the subjects had at least a high-school education, and the remaining 7% had a middle-school diploma. Of the participants, 12% were dating regularly, 67% were engaged (of whom 41% were living together), and 14% were married. The average length of time that the participants had been in their relationships was 10 months for those who were dating regularly, 39 months for those who were engaged and 143 months for those who were married. When asked if

they were in love, 76% of the sample declared that they were, 6% declared that they were not, and 18% were unsure.

5.4.1.2 Materials

The structure of the survey was quite similar to that of Study 1. We added some demographic questions regarding level of education and religious background in the first block of questions. In the third block, we added two other tests to the MEVOL and the PLS-R-IT: the 7-item adapted Companionate Love Scale (CLS; Sprecher & Regan, 1998; Sternberg, 1986) and 3-item Personal Assessment of Intimacy in Relationships Scale (PAIR ;Schaefer & Olson, 1981). CLS is designed to assess companionate love or "the affection and tenderness we feel for those with whom our lives are deeply entwined" (Hatfield & Rapson, 1993, p. 9). PAIR is a 3-item sexual intimacy scale taken from Schaefer and Olson (1981); it describes how partners see their relationships in terms of sex behaviors. We translated these two questionnaires into Italian using the same procedure that we used for the PLS-R-IT, including back-translation. Despite the fact that the only validated scale in the Italian language is the PLS-R-IT (Cannas Aghedu et al., 2018), we calculated the reliability of the instruments that we used before performing the validity test. The CLS items showed acceptable levels of internal consistency ($\alpha = .65$). PAIR's reliability was quite low ($\alpha = .41$), as is usual for three-item measures (John & Benet-Martinez, 2000). We asked the participants to rate items on a scale from 1 (*absolutely false*) to 6 (*absolutely true*). We also added a fourth block to the survey with two explicit questions (EQ) so as to control for the subjectivity of the love construct. One of these questions investigated the participants' feelings relating to the love they experience toward their partners (e.g., "Do you love__? If so, how much from 1 to 10 would you rate your love for___?"), and the other explored PT regarding the loved ones' feelings (e.g., "Does___ love you? If so, how much from 1 to 10 would you rate his/her love for you?"). Finally, we presented

questions to investigate certain important events that could influence the participants' responses (e.g., arguments, disagreements and misunderstandings).

5.4.1.3 Procedure

As in Study 1, we conducted the entire experiment using LimeSurvey which is an open-source tool to create online forms. The participants provided consent after being informed that they could stop the experiment whenever they wanted; they also certified that they were over 18 years old. We presented the scales randomly across participants.

5.4.2 Results

5.4.2.1 Preliminary analysis

As a first step, we performed a CFA with the aim of confirming the seven-factor structure of the MEVOL in its final, 21-item version. As in the first study, Mardia's test confirmed a violation of normality (multivariate skewness: $b_{1p} = 48.35$, $p < .001$; multivariate kurtosis: $b_{2p} = 478.69$, $p < .001$). Due to the non-normality of our data, we therefore performed the CFA while employing a robust maximum-likelihood estimation procedure, as in Study 1.

Goodness-of-fit indices confirmed the seven-factor structure, as hypothesized. Indeed, although the Satorra-Bentler chi-square was significant, SB χ^2 (168) = 489.15, p □ .00, all the other indices suggested a good fit to the data (χ^2/df = 2.91; RMSEA = .06 [.057 – .070]; CFI = .88; TLI[2] = .85; SRMR = .07). As reported in Table 5.1, the standardized factor loadings were all significant at $p < .001$, ranging from .52 (item 2 of *taking love for granted*) to .81 (item 1 of *sexual attraction*). Regarding the relationships between love components, as reported in Table 5.4, the findings largely confirmed the results from Study 1.

[2] As already noted, CFI and TLI index computed in Mplus may be lower than they would be as calculated in other packages, as in Mplus covariances among exogenous observed variables are not constrained to zero (e.g. Widaman & Thompson, 2003). As additional check, we repeated the same confirmatory factor analysis with LISREL 8.71, which uses a different chi-square to calculate the null model than Mplus (Jöreskog & Sörbom, 2004): the resulting CFI was .93, while the TLI (NNFI) was of .91, thus confirming the adequate fit of the model to the data.

As reported in Table 5.3, all the MEVOL subscales showed acceptable levels of reliability, with values ranging from .60 (*positive emotion*) to .72 (*sexual attraction*). The main psychometric features of the scale in its final, 21-item version were therefore largely replicated, thus sustaining the preliminary results from Study 1. Based on these encouraging findings, we proceeded to test MEVOL's convergence and validity issues.

Table 5.4 Latent correlations between the EVOL subscales in the Confirmatory Factor Analysis (Study 2)

Subscale	*1*	*2*	*3*	*4*	*5*	*6*
1. Positive idealization	__					
2. Negative idealization	.07	__				
3. Taking love for granted	.25**	-.22**	__			
4. Sexual Attraction	.66***	.12	.05	__		
5. Positive emotions	.83***	-.26**	.47***	.45***	__	
6. Negative emotions	.22**	.84***	-.23**	.23**	-.17*	__
7. Obsessive thinking	.49***	.73***	.20*	.29***	.22**	.78***

Note. (*) $p < .85$; * $p < .05$; ** $p < .01$; *** $p < .001$

5.4.2.2 Convergent and divergent validity

We selected three measures to validate MEVOL. Specifically, we expected PLS-R-IT, which measures passionate love, to have high correlations with all MEVOL's category; CLS, which measures companionate love, to be primarily associated with *positive emotion* and less correlated with the dimensions that are linked to negative feelings; and PAIR, which measures sex satisfaction, to be correlated with *sexual attraction.*

Consistently with our hypotheses, the results shown in Table 5.5 highlight the correlations between MEVOL and the PLS-R-IT. Similarly, in line with our predictions, CLS was highly correlated with all the dimensions of MEVOL except those that are linked to negative feelings. Moreover, as

expected, we observed a positive correlation between *sexual attraction* and PAIR. The last hypothesis that we tested, based on previous findings of Sprecher and Regan (1998), involved the correlations between the length of a relationship and several measures: *obsessive thinking*, *sexual attraction* and CLS. Our results showed that *sexual attraction* was negatively related with the passage of time (r = -.20, p < .001) but that the other measures were not correlated.

Table 5.5 *Pearson correlations between MEVOL's subscales and PLS-R-IT, CLS and 3-item PAIR.*

MEVOL' s subscales	*Love measures*		
	PLS-R-IT	*CLS*	*3-item PAIR*
Positive idealization	.68***	.52***	.31***
Negative idealization	.34***	.04	.04
Taking love for granted	.14**	.11**	.05
Sexual Attraction	.56***	.37***	.27***
Positive emotions	.42***	.43***	.30***
Negative emotions	.42***	.05	-.01
Obsessive thinking	.63**	.25***	.06

Note.* p < .05; ** p < .01; ***p < .001

5.4.2.3 Perspective taking and subjective measures

As previously mentioned, we extracted one measure called *PT-positive* to measure PT. It was composed of item 1 of the *positive emotion* subscale summed with the reverse scores of items 2 and 3 of the *negative idealization* subscale and item 1 of the *negative emotion* subscale. The reliability was acceptable (α = .67) and allowed us to compute a single score of PT-positive. To analyze the data for the EQ, we divided the participants into four groups. The first group included those who had declared that they were currently in love (EQ-*yes*); the second group comprised those who were unsure as to whether they were in love (EQ-*unsure*); the third group consisted of those who felt loved by their partners (EQ-*yes-PT*); and the fourth group was made up of those who were unsure

of their partners' love (EQ-*unsure-PT*). People who were not in love or those who did not feel loved at all by their partners were not taken into consideration for this analysis, as there were few such participants (and, therefore, their results would not be representative). Therefore, the four groups were compared with respect to the MEVOL's categories, included PT-positive, and PLS-R-IT.

The majority of these variables had non-normal distributions; therefore, we analyzed the differences between the four groups using a Mann-Whitney *U* test of variance for nonparametric variables with non-normal distributions. Regarding effect size, Grissom and Kim (2012) suggested, for a two-group independent-samples design, dividing the Mann-Whitney *U* statistic by the product of the two sample sizes. In line with our hypothesis, as shown in Table 5.6, there are important differences in both the MEVOL and PLS-R-IT scores between people who are in love and those who are unsure. Specifically, the EQ-*yes* group had significantly higher scores than did the EQ-*unsure* group with regard to the *positive idealization*, *sexual attraction*, *positive emotion*, *obsessive thinking*, *PT-positive* subscales and to the PLS-R-IT scores. As expected, the EQ-*yes-PT* and EQ-*unsure-PT* groups had significant differences on several dimensions (see Table 5.7). In particular, those in the EQ-*yes-PT* group were more positively oriented than those in the EQ-*unsure-PT* group, as can be noted from the former group's significantly higher scores in the *positive idealization*, *taking love for granted*, *positive emotion*, *PT-positive* dimensions and its lower scores in the *negative idealization*, *negative emotion* dimensions.

Another aspect that we analyzed in the explicit questions' answers was the intensity of love, which participants in the EQ-*yes* and EQ-*yes-PT* groups rated from 1 to 10. For the EQ-*yes* group, the intensity was positively correlated with the *positive idealization*, *sexual attraction*, *positive emotion* and *obsessive thinking* subscales, as well as with the CLS, PLS-R-IT and PAIR scores (all $r > .20$; all $p < .001$). For the EQ-*yes-PT* group, intensity was positively correlated with the *positive idealization*, *taking love for granted*, *sexual attraction* and *positive emotion* subscales, as well as with the CLS and PLS-R-IT scores (all $r > .13$; all $p < .05$); intensity in this group was also

negatively correlated with the *negative idealization* and *negative emotion* subscales (all $r < -.15$; all $p < .05$).

Moreover, to support the fact that the assessment of PT should be integrated within the evaluation of love in order to have a complete profile of participants, a box plot has been used to demonstrate the importance of this dimension (see Figure 5.1). As you can see a significant number of participants that were passionately in love (PLS-R-IT > 86) declared that they were not sure that they were loved in return (EQ-unsure-PT).

Figure 5.1 Box Plot of level of passionate love among people who feel loved by their partner (EQ-yes-PT) and who declared that they were not sure that they were loved in return (EQ-unsure-PT).

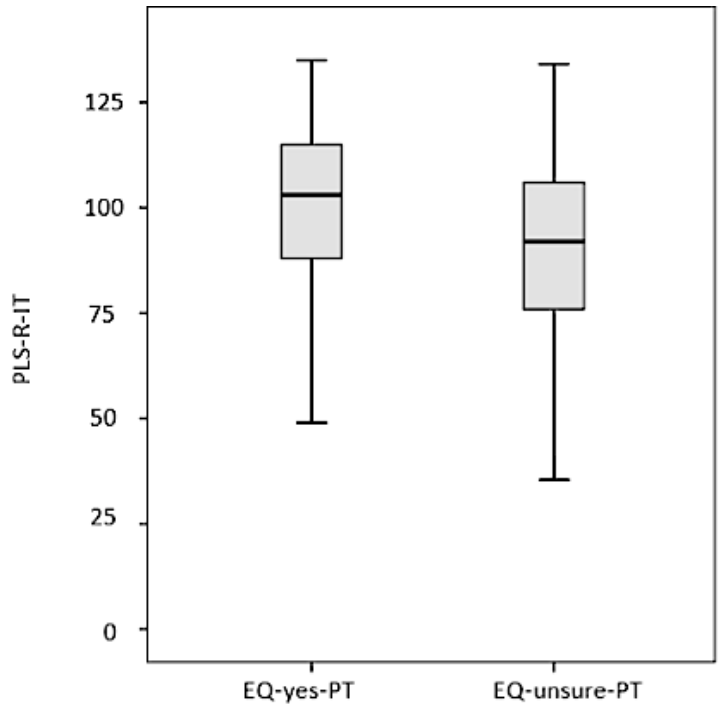


Table 5.6 Differences between people in love (EQ-yes) and people who were unsure (EQ-unsure) in MEVOL's categories and PLS-R-IT.

	EQ-yes (N=360) Mean (SD)	*EQ-unsure* (N=86) Mean (SD)	*U*	Effect size η^2
Positive idealization	14.90 (2.56)	11.70 (3.60)	7428***	0.23
Negative idealization	8.19 (3.92)	8.80 (4.26)	14344	0.46
Taking love for granted	8.71 (3.74)	8.05 (3.69)	13902	0.45
Sexual Attraction	15.06 (3.17)	13.30 (4.05)	11555***	0.37
Positive emotions	15.84 (2.09)	12.87 (3.26)	6893***	0.22
Negative emotions	7.93 (3.69)	8.24 (4.03)	15030	0.48
Obsessive thinking	9.12 (3.89)	7.48 (3.12)	11764***	0.37
PT-positive	18.81 (4.12)	16.91 (5.01)	12230**	0.39
PLS-R-IT	101.55 (18.36)	83.26 (22.85)	8202***	0.26

Note. N= Number; PT-positive= Positive perspective taking; SD= Standard Deviation. *p<.05, **p<.01, ***p<.001.

Table 5.7 Differences between people that felt loved by their partner (EQ-yes-PT) and people who were unsure (EQ-unsure-PT) in MEVOL's categories and PLS-R-IT.

	EQ-yes-PT (N=333) Mean (SD)	*EQ-unsure*-PT (N=121) Mean (SD)	*U*	Effect size η^2
Positive idealization	14.55 (2.98)	12.68 (3.74)	14174***	0.35
Negative idealization	7.69 (3.64)	9.48 (4.54)	15678***	0.38
Taking love for granted	9.12 (3.80)	7.64 (3.31)	15487***	0.38
Sexual Attraction	14.47 (3.56)	14.55 (3.82)	19425	0.48
Positive emotions	15.92 (2.05)	13.37 (3.23)	10399***	0.25
Negative emotions	7.46 (3.44)	8.67 (4.37)	17288**	0.42
Obsessive thinking	8.92 (3.83)	7.91 (3.80)	16936	0.42
PT-positive	19.43 (3.69)	16.46 (4.98)	13106***	0.32
PLS-R-IT	98.75 (21.20)	89.05 (25.20)	15365***	0.38

Note. N= Number; PT-positive= Positive perspective taking); SD= Standard Deviation.
*p<.05, **p<.01, ***p<.001.

5.4.3 Discussion

The present study widely supported MEVOL's psychometric features in its final, 21-item version. Indeed, the scale's factorial structure and reliability were confirmed, as were the relationships between MEVOL dimensions reported in Study 1. We also checked MEVOL's preliminary validity, and the results are in line with our expectations; indeed, MEVOL showed high correlations with other love measures. Furthermore, as Sprecher and Regan (1998) previously hypothesized, PLS-R-

IT (but not CLS) correlates with *negative emotion*; in contrast, CLS is primarily associated with *positive emotion*. Our data suggest that *obsessive thinking* is common not only in the early stages of relationships, as Acevedo and Aron (2009) hypothesized; rather, this dimension is more strongly correlated with the intensity of love.

Our results suggest that various profiles can emerge depending of the status of a relationship (e.g., in love vs. unsure). Our data also suggest that people who are not sure if they are in love tend to display low *positive idealization* and *positive emotion* and that those who are not sure if they are loved present higher negative feelings. We also analyzed PT, which led to surprising results. As we expected, people who felt loved tended to show more positive sentiments than did people who were unsure if they felt loved. This is the first study to show the importance of considering PT when assessing love, as it provides an index of meta-thought for people who are in love. These results showed that it is extremely important to evaluate love as a multi-dimensional construct because several dimension may intervene and therefore create different profiles of love relationships.

5.5 General discussion

This research introduced MEVOL, which is a scale for assessing love's components based on the latest research coming from different perspectives (e.g. social psychology and neuroscience) that suggest that love is composed of many dimensions (e.g. Acevedo, Aron, Fisher, & Brown, 2012; Bartels & Zeki, 2000; Hatfiled & Sprecher, 1986.). The results indicate that MEVOL is short, clear and homogenous and that it has strong psychometric properties, including a clear factorial structure and acceptable internal consistency and construct validity.

Study 1 aimed to identify and create MEVOL's structure, resulting in a 21-item scale with 7 factors: *positive idealization*, *negative idealization*, *taking love for granted*, *sexual attraction*, *positive emotion*, *negative emotion* and *obsessive thinking*. Study 2 confirmed the findings of Study 1, included a preliminary validity test and added two other measures to assess PT through indirect estimation using particular items from the 7 dimensions.

Study 2's results indicate that MEVOL can be considered a reliable and validated scale that can diversify and measure love's components. Specifically, several aspects that had not previously been investigated are essential to the assessment of love. The high correlation between MEVOL and other love measures provides support for the scale's construct validity. As Hatfield and Sprecher (1986) theorized, PLS represents a measure of passionate love that includes cognitive, behavioral and emotional components. Therefore, the high correlations between MEVOL's dimensions and PLS indicate that our scale involves various components of love. Furthermore, the weak correlation between PLS and *taking love for granted* indicates that this dimension is new to the assessment of love. Moreover, CLS has a high correlation with all MEVOL components (but particularly with those that are linked to positive feelings). It is noteworthy to underline the fact that PAIR, which is a measure of sexual satisfaction, did not correlate with any of the negative dimensions of MEVOL but did correlate with *sexual attraction*, *positive emotion* and *positive idealization.* This indicates that MEVOL's dimensions are independent and that each one measures a different aspect (sometimes in contrast). Moreover, another aspect that MEVOL highlights is that love can be considered a subjective experience (Watts & Stenner, 2005). We directly asked people if they would define themselves as *in love*, *not in love* or *unsure*. In line with our expectations, people who stated that they were in love and those who were unsure had different configurations of love components.

The present study shows also the importance of PT (Dixon & Moore, 1990). As expected, the results demonstrate that people who think that their partners are not very involved in their relationships showed more negative feelings. These findings are in line with previous studies, which demonstrated that lovers who are rejected display deep senses of loss and negative affect; sometimes, these feelings can lead to clinical depression and even to suicide and/or homicide (Fisher et al., 2010). Moreover, the results showed that evaluating participants only with unidimensional measure could neglect some aspects that can be crucial for the assessment; for

example two participants could obtain the same PLS' score but they perceive the love from their partner differently. Furthermore, the novelty of PT implies that several other mechanisms may deserve attention from scientists or clinicians. It is important to specify that the PT-positive's index should not be considered an integral dimension of MEVOL but as an extra indicator that provides additional value to the evaluation.

The current study has evident limitations. The results are representative only of our sample, so we cannot infer causality between the dimensions and love states. For example, our results show that people who are in love seem to have lower levels of negative emotion and negative idealization than other people, but we could expect to also find people who are in love but who have high negative feelings. Moreover, two dimensions, *negative idealization* and *taking love for granted*, have been introduced as exploratory and therefore there is not literature that supports them. Furthermore, study 1 present important limits especially with regard to sample size, which should be larger to fully meet the criteria for a CFA, and gender imbalance among participants. However, these limits have been overcome with study 2. Another limitation of the present study is represented by the fact that for the validity indexes two scales not validated in Italian have been used. Moreover, some variables that have been considered (e.g. education and religion), have not been analyzed for this research. Therefore, we do not know whether the level of education or religion can influence the response to the questionnaire.

There are several implications of this study. First, MEVOL reflects the multidimensionality of the love construct using a clear and well-defined structure. Therefore, MEVOL—even combined with other measures (e.g., PLS)—represents a good scale that can be employed during scientific research. For instances, in future researches that investigate romantic love it will be possible, through MEVOL, to select participants, not only on the basis of the single love score (e.g. measured with the PLS) but also on the basis of the seven dimensions which will give a more clear profile for each participant. One of the main issues present in romantic love studies is the selection of participants based on a single score. In this way, we risk equating two participants who are actually

very different from each other. For example, if we evaluate two people who are madly in love with their partner they probably would get the same score in the unidimensional scale. However, the administration of MEVOL reveals that one of the two subjects has low PT-positive scores, so we know that this subject does not feel reciprocated by his/her partner. These two subjects, therefore, despite having the same score on the unidimensional scale, could have different emotional reactions during love paradigms. In this way, MEVOL helps to overcome this issue and avoid misinterpretation of results. Another implication of MEVOL is in the clinical setting. Although, the seven dimensions of MEVOL are characteristics of romantic love, high levels of negative emotions and negative idealization could suggest an unhealthy relationship. However, these interpretations are speculative, as data are not yet available to confirm these hypotheses. Therefore we recommend for future studies to investigate possible correlations between psychopathology and the different profiles that emerge with the administration of MEVOL. Moreover, MEVOL represents an Italian study, so we suggest further validation in other countries. For further study, we suggest investigating MEVOL's potential in neuroscientific paradigms; Aron and colleagues (2005) found a strong positive correlation between PLS and the brain areas associated with love, so we could expect interesting findings in a similar study of MEVOL's categories. We also expect that in further studies more dimensions will be taken into account as part of this complex concept.

PART III

CENTRAL AND AUTONOMIC MEASURE OF LIT AND ITS EFFECTS ON EMOTION ELABORATION

CHAPTER 6

THE LOVE INDUCTION TASK INTERFERES WITH EMOTIONAL PROCESSING: AN EEG/ERP STUDY

6.1 Introduction

As previously described, there are two main paradigms for studying love (see Chapter 2). However, the most widely used, the *love-related picture paradigm,* consists of showing photo of the partner and comparing the response with that of neutral photos (e.g., friends, relatives, or unknown persons). Functional Magnetic Resonance Imaging (fMRI) studies showed that when people looked at photos of their beloved, there was increased activity in the dopaminergic-related brain areas, namely the ventral tegmental area (VTA), associated with euphoria and reward in both early-stage (Bartels & Zeki, 2000; Aron et al., 2005; Xu et al., 2011; for a review, see Ortigue et al., 2010) and long-term relationships (Acevedo et al., 2012). Other robust activations were shown in the middle insula and the anterior cingulate cortex. Moreover, some deactivations were observed, in particular in the amygdala and right-lateralized in the prefrontal, parietal, and middle temporal cortices (Aron et al., 2005; Bartels & Zeki, 2000, 2004). Other authors have investigated the brain electrical activity and demonstrated that people in love display higher amplitude of the delta waveband (Başar, Schmiedt-Fehr, Öniz, & Başar-Eroğlu, 2008) when viewing their partner's photos compared to those of an unknown person. Looking at a picture of the beloved also elicited a late positive potential (LPP; Langeslag, Jansma, Franken, & Van Strien, 2007). These results seem to suggest that attention towards love-stimuli is enhanced (Bradley, 2009; Langeslag et al., 2014; Liu et al., 2012); this is consistent with fMRI studies of romantic love showing enhanced activation of the thalamocingulate circuit (Acevedo, 2015), which is involved in attention and arousal (Seifert et al., 2011).

Another paradigm that has not received much attention is the *Love Induction Task* (LIT). In 2000, Mashek et al. demonstrated through a behavioural study that this paradigm is able to evoke intense and positive feelings through the use of sounds, memories of an event, pictures, and even smells. However, it is interesting to note that no studies have investigated its neural or peripheral correlates. Therefore, to explore the neural effects of this paradigm in terms of brain electrical activity, we measured EEG activity, recorded while LG participants listened to a song that they chose as partner-related (for the CG, the experimenter assigned a song previously chosen by the LG). Several studies using EEG demonstrated that while people that feel positive emotions and display higher activity (correlated with lower alpha power) in the left-frontal regions of the brain (Davidson et al., 1990; Schmidt & Trainor, 2001; Trochidis & Bigand, 2012). Therefore, we hypothesized that the LG would show lower alpha activity in the left-frontal sites during the LIT. However, another aim of this research was to examine whether increasing of alpha band, mainly in posterior sites, is strictly correlated with internal focused attention and imagination (Cooper et al., 2003; Jensen et al., 2002; Klimesch et al., 2007). Therefore, because the participants remembered the events of their relationships, we predicted that internal attention and imagination processes could be triggered during the LIT.

The second aim of the present research is based in previous results from fMRI studies showing that romantic love involves a series of subcortical areas that are closely related to the processing of emotions (e.g., amygdala, insula, and anterior cingulate cortex). Therefore, whether being in love affects brain electrical activity during emotional processing tasks was investigated. To answer this question, the picture viewing task (Lang, Bradley, & Cuthbert, 1997) was employed. It includes facial expressions and emotionally evocative scenes, ranging from pleasant to unpleasant, and from calm to excited states. Viewing these pictures seems to be correlated with changes in the viewer's heart rate and skin conductance, providing physiological validity to subjectively reported emotions (Lang, Greenwald, Bradley, & Hamm, 1993). Moreover, an fMRI study demonstrated that there is brain circuitry involved in the processing of both positive and negative emotions

(Aldhafeeri, Mackenzie, Kay, Alghamdi, & Sluming, 2012). Specifically, the authors suggested that the amygdala is mainly involved in the processing of negative emotions. Because the amygdala is deactivated during romantic love paradigm, we expect that LG will allocate fewer resources to negative stimuli.

Finally, this study aimed to demonstrate that the LIT is able to evoke intense and positive feelings of romantic love. Therefore, we expect that the LG would show more positive emotions than the CG during the LIT.

6.2 Methods

6.2.1 Participants

The sample was composed of 42 healthy participants (22 in love and 20 not in love). The love group (LG; 19 F, M_{age} = 23.09, SD_{age} = 2.59) included individuals who reported that they were currently in love. The LG was currently in a relationship (M = 30 months, SD = 18 months). The control group (CG; 15 F, M_{age} = 23.2, SD_{age} = 3.58) was matched to the LG by education level. All participants were recruited during classes at the University of Padova. All participants had no history of neurological or psychiatric conditions and normal or corrected-to-normal vision. The study was approved by the Ethics Committee of the Psychology Departments at the University of Padova.

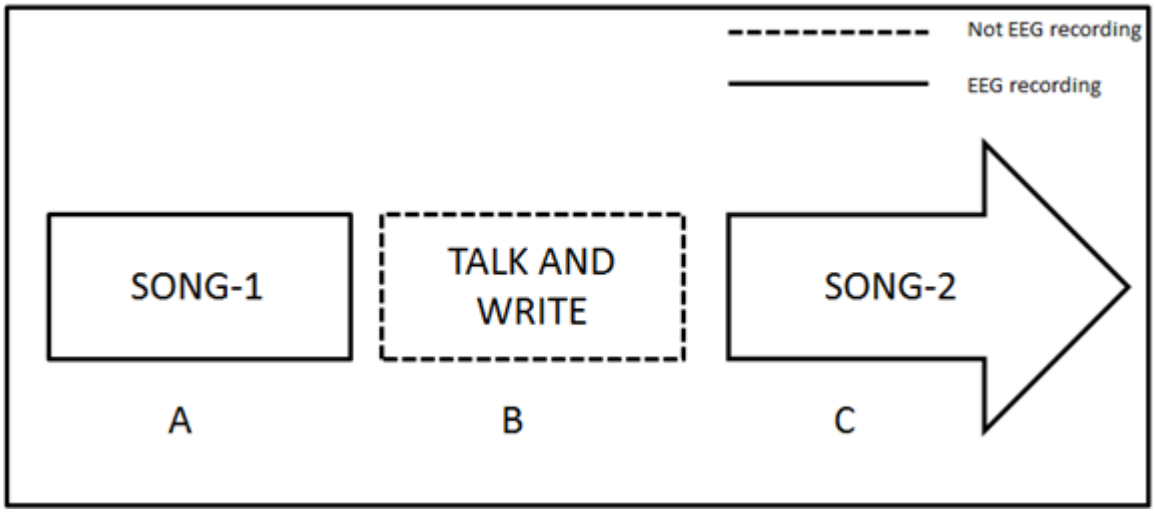
6.2.2 LIT

The LIT consisted of a modified version of Mashek et al.'s (2000) procedure (see Van Steenbergen et al., 2014). The induction period lasted 10 minutes and was composed of three sessions that differed for the two groups (see Figure 1). First, the LG listened, via headphones and with their eyes closed, to a song that they chose that reminded them of their romantic partner. They were asked to

focus their thoughts on that person and their relationship (love-song-1 session). Second, they were asked to talk and write something about specific events spent with their relationships (talk and write-love session). The third session was a replication of the first one (love-song-2 session). This procedure has been shown to evoke intense feelings of romantic love (Mashek et al., 2000).

For the CG, the same induction structure was maintained, but participants were instructed to think about an acquaintance's romantic relationship (e.g., the romantic relationship of a neighbour). During the first session the CG had to listen to one of the songs that was randomly extracted from the list of songs already used by the LG (control-song-1 session). In the second session, control participants were instructed to think and talk about an acquaintance's romantic relationship (think-control session). As with the LG, the third session was a replication of the first (control-song-2 session).

Figure 6.1 The structure of LIT



Note: A, corresponds to the listening of the chosen song; B, participants were instructed to talk and write some events related to the relationship; C, Refers to the repetition of the song presented during A.

6.2.3 Picture viewing task

Ninety coloured pictures were selected from the International Affective Picture System (Lang et al., 1997) and divided into five categories according to their content, including two pleasant (erotic couples and sport/adventure), two unpleasant (attacking humans and mutilated bodies), and one neutral (household objects/neutral people) picture category. To obtain an effective emotion induction, only highly arousing content was selected for the pleasant and unpleasant picture categories.

Each picture was displayed for 1000 ms, with intertrial intervals varying between 1000 and 3000 ms, and the order of the stimuli was fully randomized. Participants were instructed to view each picture for its entire duration. Six practice neutral pictures were presented to the participants to allow adjustment to the experimental setting. Each picture (1024 × 768 pixel resolution) was presented full-screen, on a 19-inch computer screen with a frame refresh rate of 60 Hz. The screen was placed 0.6 m in front of the viewer.

6.2.4 Self-report measures

Multidimensional Evaluation of Love (MEVOL). This self-report scale, which was recently developed by Cannas Aghedu et al. (in press), is composed of 21 statements that participants rate from 1 (*not at all true*) to 6 (*definitely true*). It was designed to assess several dimensions of love. Specifically, MEVOL investigates positive and negative idealization, sexual attraction, taking love for granted, positive and negative emotions, and obsessive thinking. Moreover, the authors introduced another important variable, called positive perspective-taking, which aimed to assess how much people feel loved by their partners

Passionate Love Scale (PLS-R-IT). This scale, developed by Hatfield and Sprecher (1986), is composed of 15 items that participants rate from 1 (*not at all true*) to 9 (*definitely true*). It assesses

cognitive, physiological, and behavioural indicators of passionate love. In this study, the Italian version by Cannas Aghedu, Veneziani, Manari, Feybesse, and Bisiacchi (2018) was administered.

Inclusion of Other in the Self Scale (IOS). This self-report scale, developed by Aron, Aron, and Smollan (1992), is designed to measure relationship closeness. Participants are asked to select one from a series of seven overlapping circles labelled 'self' and 'partner' that best describes their relationship. Scores range from 1 (where the circles touch but did not overlap) to 7 (where the circles are nearly entirely overlapping).

Self-Assessment Manikin (SAM). This is an affective rating system devised by Lang (1980), in which a graphic figure depicting values along the dimensions of valence (pleasantness/unpleasantness) and arousal (activation/calm) is used to measure emotional reactions. Participants can select any of the 5 figures comprising each scale, or between any two figures, resulting in a 9-point scale for each dimension, with 1 indicating *very unpleasant* for valence and *very calm* for arousal, and 9 indicating *very pleasant* for valence and *very excited* for arousal.

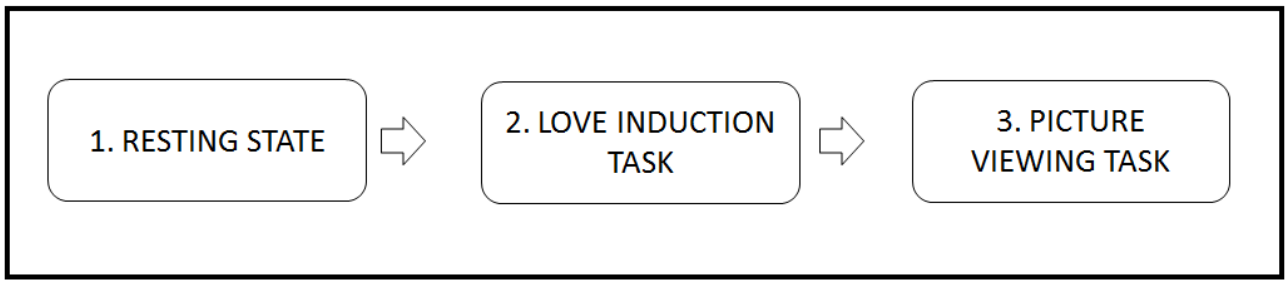
6.2.5 Procedure

Participants provided their email addresses during classes and were asked to complete an Italian online version of the Mutilation Questionnaire (MQ; Klorman et al., 1974) to exclude phobic participants due to the unpleasant content of some visual stimuli. Participants also had to specify, on a 10-point Likert scale, whether they were in love or not. Upon arrival, participants had to sign an informed consent form.

The EEG acquisition was divided into three phases (see Figure 2). In the first phase (resting state), participants were instructed to relax and think about neutral things with the eyes closed for 3 minutes. In the second phase, the LIT was applied. In the final phase, participants were given the picture viewing task. At the beginning of the study and just after each phase, the SAM was administered to evaluate the participant's current affective state. At the end of the experimental session, each participant had to complete the self-report measures (PLS-R-IT and IOS).

Additionally, the LG completed the MEVOL. Participants in the LG were asked to answer the surveys while thinking about their partner, whereas the CG were asked to answer the survey questions based on their sentiments toward their previous partner. To assess the reliability of the target of love responses, each participant returned to the laboratory one week after the experimental session to complete an interview with a psychologist, who gave them feedback on the love questionnaires and ensured that all the questions were understood correctly.

Figure 6.2 Experimental design.



6.2.6 EEG recording and analysis

The experimental sessions were conducted in a dimly illuminated and electrically shielded room in a laboratory located at the Department of General Psychology, University of Padova. Participants were seated comfortably in a chair at a viewing distance of approximately 60 cm from the monitor. Participants were instructed to avoid eye blinks, eye movements, and body movements during the recording.

The electroencephalogram (EEG) was recorded from an array of 32 Ag/AgCl active electrodes on an elastic recording cap (Brain Products, Munich) placed in accordance with the 10-20 International System (Jasper, 1958), with FCz serving as reference. Electrode impedances were kept below 10 kΩ and balanced. Data were recorded continuously, with a sampling rate set at 512 Hz using a BrainVision LiveAmp amplifier and processed offline with a digital band-pass filtering from 0.1 Hz to 30 Hz.

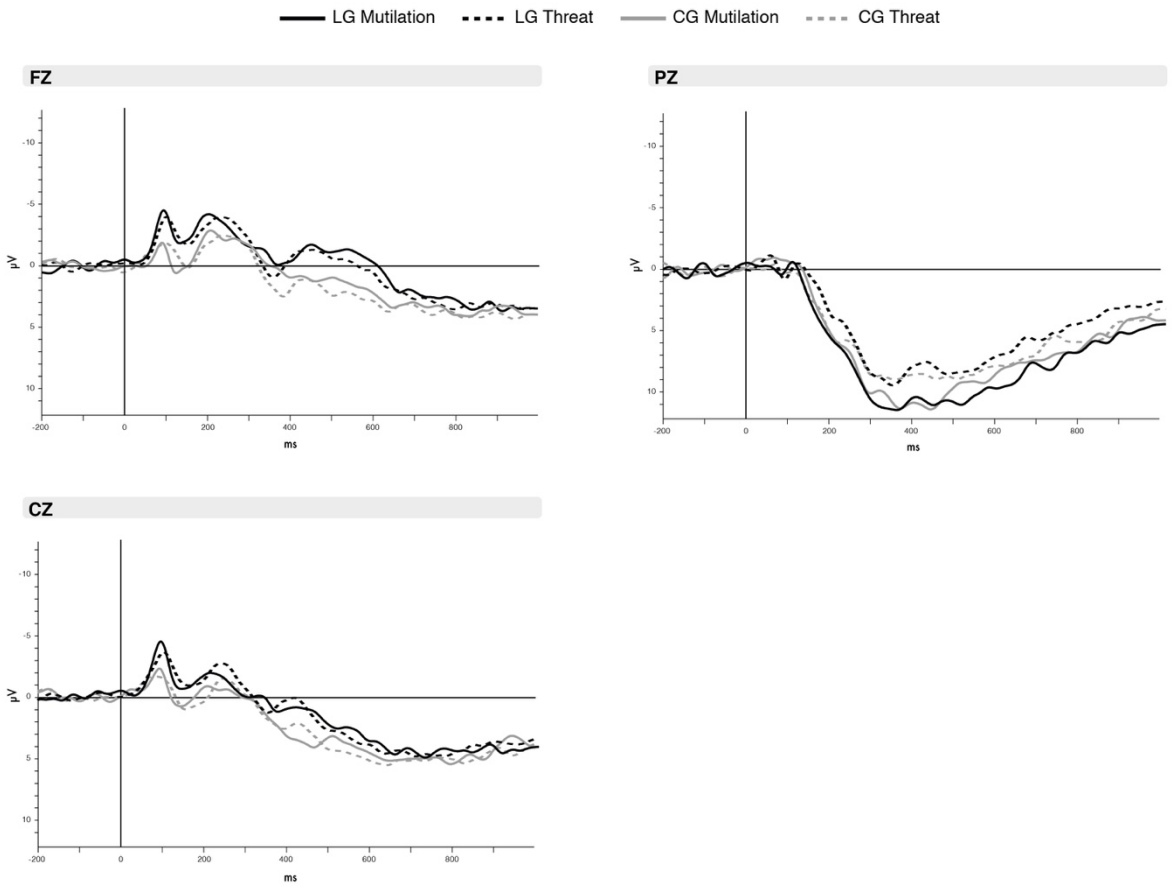
EEG data were corrected for eye blinks and vertical and horizontal eye movements using the independent components analysis (ICA) technique (Makeig, Bell, Jung, & Sejnowski, 1996).

The first analysis aimed to explore the effects of the LIT in terms of intermispherical differences of alpha rhythm. EEG data were referenced to the common average. Power spectral densities (PSDs) were separately estimated for each EEG channel in baseline, song-1 and song-2 conditions. A standard Welch procedure was used with 4-second hamming windowing, resulting in a frequency resolution of 0.25 Hz and no overlap. Alpha activity was calculated by averaging the PSD values in the 8-13 Hz frequency band. Band power values were log-transformed. Because some studies demonstrated a decrease of left-frontal alpha activity during positive feelings (Harmon-Jones & Allen, 1997, 1998; Poole & Gable, 2014; Quirin et al., 2016; Sutton & Davidson, 1997) and an increase of posterior alpha activity during focused internal attention (Cooper et al., 2003; Jensen et al., 2002; Klimesch et al., 2007). For each condition, asymmetries were evaluated as differences between right and left electrode covering the frontal (F4 vs F3), parietal (P4 vs P3), and occipital (O2 vs O1) areas. In line with previous studies (Poole & Gable, 2014), only right-handed subjects were considered, and 6 left-hand participants were excluded. To assess differences of alpha interhemispheric asymmetries of LIT (song 1 and 2) vs resting state between the two groups (LG and CG), repeated measure Analyses of Variance (ANOVAs) were performed. A 3 X 3 design was applied, with *Electrodes* (F3–F4, P3–P4, O1–O2) and *Conditions* (song-1, song-2, resting state) as within-subject factors. *Group* (LG, CG) was the between-subject factor. Greenhouse-Geisser correction was applied if the sphericity assumption was not valid. When a significant triple interaction *Electrodes* x *Conditions* x *Group* was found, reduced models were separately applied for each electrode, with Conditions as within-subject factor and Groups as between subject factor. Post-hoc t-tests were carried out to assess significant differences of Conditions between the 2 groups. For this analysis, EEGLAB software implemented in MATLAB (Delorme & Makeig, 2004). EEGLAB is an open-source toolbox for analysis of single-trial EEG dynamics, including independent component analysis (ICA).

To compute the ERPs during the picture viewing task, continuous EEG was segmented offline into 1200 ms epochs from 200 ms before to 1000 ms after the onset of each picture using BrainVision Analyzer (Brain Products, Munich). The EEG epochs were then baseline-corrected against the mean voltage during the 200 msec pre-stimulus period. All epochs were visually scored for residual artefacts, and each portion of data containing artefacts greater than ±70 μV in any channel was rejected for all the recorded channels before further analysis. Artefact-free trials were averaged separately for each participant in each experimental condition. The number of trials did not differ among stimulus conditions or the two groups (LG and CG). On the basis of visual inspection of grand-averaged ERP waveforms (see Figure 3) and in line with the existing literature, the P1 was measured at 01 and 02 and specified as the most positive peak between 60 and 130 ms, and N1 was measured as mean amplitude within a 50–150 ms post-stimulus time window. Furthermore, slow wave activity was measured as mean amplitude within two successive post-stimulus time windows: 400–500 ms (early slow wave, ESW), and 500–600 ms (late slow wave, LSW).

Separate repeated-measure ANOVAs were performed on mean N1, ESW, and LSW amplitudes with *Emotion* (threat, mutilations, erotica, sport, neutral), *Area* (frontal, central, parietal), and *Laterality* (left, midline, right) as within-subject factors and *Group* (LG, CG) as a between-subject factor. On mean P1 amplitudes measured at the occipital sites (i.e., O1 and O2), a repeated-measure ANOVA was performed with *Emotion* and *Laterality* (left, right) as within-subject factors and *Group* as a between-subject factor.

Figure 6.3 Grand average waveforms for the negative conditions (threat and mutilation) at frontal, central and parietal midline recording sites.



6.3 Results

6.3.1 Descriptive Statistics

The results of PLS-R-IT showed that the LG reported stronger passionate feelings compared to the CG, t (40) = 11.53, $p < .001$ (LG, M = 99.86, SD = 7.97; CG, M = 46.90, SD = 19.88). Moreover, the results of the IOS scale showed that the LG reported greater closeness to their partners (M = 5.23; SD = 1.02) compared to the CG (M = 1.79, SD = 1.24), t (40) = 9.74, $p < .001$.

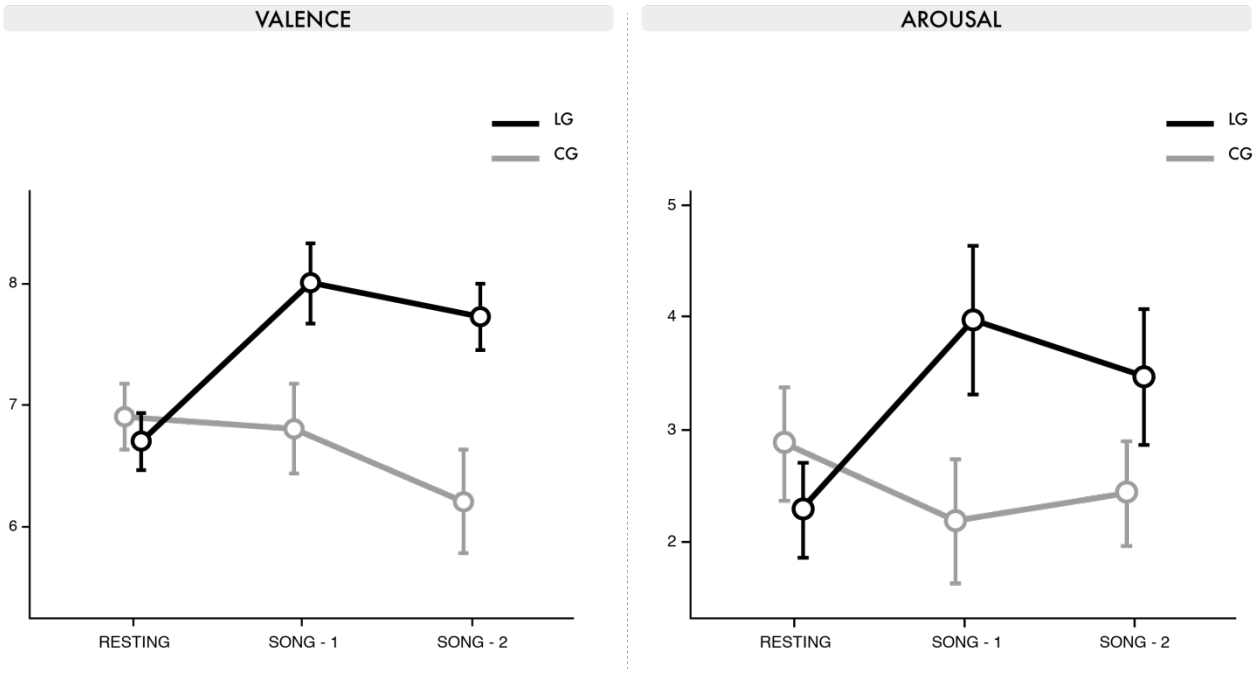
The results of the MEVOL questionnaires (6-point scale) showed that the LG reported high levels of positive emotion (M = 5.48; SD = 0.46), positive idealization (M = 5.04; SD = 0.74), positive perspective-taking (M = 5.02; SD = 0.74), sexual attraction (M = 4.98; SD = 0.93) and

lower levels of negative idealization (M = 2.69; SD = 0.87), taking love for granted (M = 2.25; SD = 0.96) and negative emotions (M = 2.09; SD = 1.03). Moreover, they reported moderate levels of obsessive thinking (M = 2.97; SD = 0.80).

6.3.2 Love induction task (EEG alpha band data)

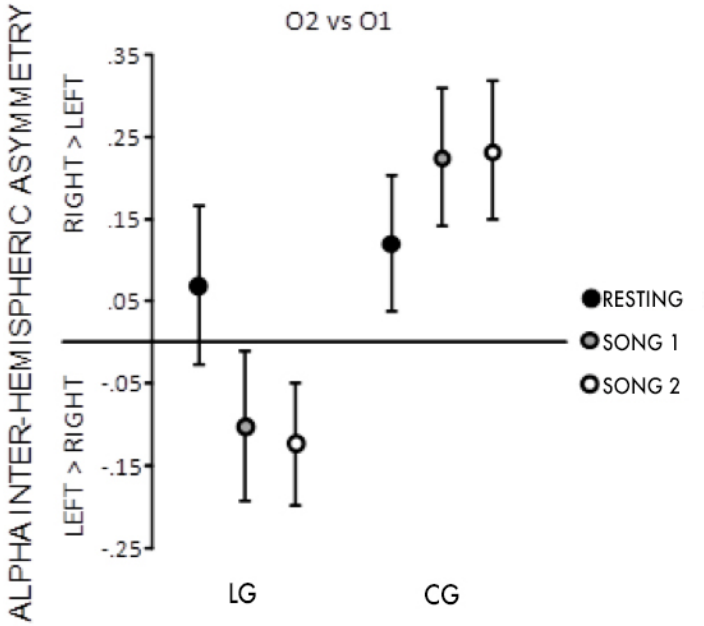
To assess the reliability of the LIT, we compared participants' ratings of valence and arousal measured with the SAM before and after the induction. Therefore, two different repeated measure ANOVAs were performed on scores of valence and arousal with *Conditions* (resting state, song-1, song-2) as within-subject factors and *Group* (LG, CG) as a between-subject factor. The ANOVA of valence scores yielded significant main effects of *Group* (F (1,40) = 4.84, p = .034) and *Conditions* F(2,80) = 4.61, p = .013). Moreover, significant interactions were found between *Conditions* x *Group* (F (2,80) = 10.07, p < .001). Post-hoc analysis (see Figure 4) of the *Conditions* x *Group* interaction showed that the LG displayed higher levels of valence (more pleasant state) compared to the CG during song-1 (M = 8.0 vs 6.8, respectively, p = .019) and song-2 (M = 7.7 vs 6.2, respectively, p = .003) but not during resting state (M = 6.7 vs 6.9, respectively, p = .549). Regarding the ANOVA for arousal, scores yielded significant main effects of *Conditions* F(2,80) = 10.41, p < .001). Moreover, significant interactions were found between *Conditions* x *Group* (F (2,80) = 3.44, p = .037). Post-hoc analysis (see Figure 4) of the *Conditions* x *Group* interaction showed that the LG displayed higher level of arousal compared to the CG during song-1 (M = 4.6 vs 3.2, respectively, p = .041) but not during song-2 (M = 4.2 vs 3.3, respectively, p = .180) and resting state (M = 2.6 vs 2.7, respectively, p = .845).

Figure 6.4 Mean (standard error) of SAM scores for valence and arousal after resting-state, song-1 and song-2.



Regarding the EEG, results of the ANOVA showed a significant triple interaction for *Electrodes* x *Conditions* x *Group* ($F(4,136) = 3.181$, $p = .016$, $\eta_p^2 = .086$). Reduced models, applied separately for each electrode with Condition as within-subject factor and Group as within-subject factor, showed a significant *Condition x Group* interaction for O2-O1 ($F(2,68) = 4.854$, $p=.011$, $\eta_p^2 =.125$) differences, but not significant main effects of Condition or Group (consistently $p >.100$). No effect was found for the other electrodes (F4 vs F3 and P4 vs P3). The Condition x Group interaction indicated a different asymmetry of alpha activity between the two groups (CG and LG) when comparing songs to resting state. As shown in Figure 5, there is an asymmetry of alpha activity in the occipital electrodes between the two groups. Specifically, the CG showed higher alpha activity in the left and lower in the right in compared with the LG. This effect was present during song-1 [un-paired t-test between LG and CG $t(34) = -2.621$, $p = .013$] and song-2 $t(34) = -2.477$, $p = .018$], but not during resting-state [$t(34) = -.682$, $p = .500$].

Figure 6.5 Mean (standard error) of inter-hemispheric alpha activity in baseline (black), song 1 (grey) and song 2 (white) for occipital (O2 vs O1) derivations in LG and CG. Positive values indicated that alpha activity was higher in the right hemisphere than in the left, and negative values indicated the opposite (alpha activity higher in the left than in the right hemisphere).



6.3.3 Picture viewing task (ERPs data)

P1

The ANOVA on the peak-P1 amplitude did not yield any significant effects (all *p*s > .594; all η_p^2 < .016).

N1

The ANOVA on the N1 amplitude yielded significant main effects of *Area* (F (2,80) = 42.75, p < .001; η_p^2 = .517) and *Laterality* (F (2,80) = 42.50, p < .001; η_p^2 = .515). Moreover, significant interactions were found between *Area* and *Group* (F (2,80) = 4.87, p = .01; η_p^2 = .109), *Area* and *Laterality* (F (4,160) = 30.56, p < .001; η_p^2 = .433), and *Emotion* and *Laterality* (F (8,320) = 2.83, p = .005; η_p^2 = .066). Significant effects were also obtained for *Area* x *Emotion* x *Group* (F (8,320) =

2.01, $p < .05$; $\eta_p^2 = .048$) and *Area* x *Emotion* x *Laterality* (F (16,640) = 1.84, $p = .02$; $\eta_p^2 = .044$) interactions.

Post-hoc analysis of *Area* showed that the N1 amplitude was larger in frontal (M = -1.39) compared to central (M = -.92) and parietal (M = 1.47) and in central compared to parietal (frontal vs central, $p = .012$; frontal vs parietal, $p < .001$; central vs parietal, $p < .001$). Post-hoc comparison of *Laterality* showed lower positivity on midline (M = -.89) with respect to the left (M = -.19) and right (M = .24) sides and in left compared to right (midline vs left, $p < .001$; midline vs right, $p < .001$; left vs right, $p < .016$).

Moreover, post-hoc analysis of the *Area* x *Emotion* x *Group* interaction showed that the LG displayed a larger N1 amplitude for mutilations in frontal area compared to the CG (Ms = -2.30 vs. -1.04 uV, respectively, $p = .001$). Similar results were found in the central area for threat (Ms = -1.60 vs. -.53 uV, respectively, $p = .04$) and mutilations (Ms = -1.42 vs. -.36 uV, respectively, $p = .037$).

ESW

The ANOVA on the ESW amplitude showed significant main effects of *Area* (F (2,80) = 104.81, $p < .001$; $\eta_p^2 = .724$), *Emotion* (F (4,160) = 75.58, $p < .001$; $\eta_p^2 = .654$), and *Laterality* (F (2,80) = 3.21, $p = .045$; $\eta_p^2 = .074$). Moreover, significant interactions were found between *Area* and *Group* (F (2,80) = 4.13, $p = .020$; $\eta_p^2 = .094$), *Area* and *Emotion* (F (8,320) = 11.26, $p < .001$; $\eta_p^2 = .220$), *Area* and *Laterality (F* (4,160) = 4.78, $p = .001$; $\eta_p^2 = .107$), and *Emotion* and *Laterality* (F (8,320) = 12.15, $p < .001$; $\eta_p^2 = .233$). The *Area* x *Emotion* x *Laterality* (F (16,640) = 4.39, $p < .001$; $\eta_p^2 = .099$) were also significant.

Post-hoc analysis of *Area* showed that the ESW displayed lower positivity in frontal (M = -1.25) compared to central (M = 1.43) and parietal (M = 8.22) areas and in central compared to parietal (frontal vs central, $p < .001$; frontal vs parietal, $p < .001$; central vs parietal, $p < .001$). Post-hoc comparison of *Emotion* showed a significant difference between the five emotions (all *p*s < .02)

except between neutral and sport (p = .051) and threat and mutilation (p = .470). More precisely, neutral emotion displayed lower positivity (M = -.146) with respect to threat (M = 3.36), mutilation (M = 4.15), erotica (M = 5.80), and sport (M = .82) stimuli. Moreover, post-hoc comparison on *Laterality* showed lower positivity on midline (M = -.98) with respect to right (M = .245) side (p = .02).

Furthermore, post-hoc comparisons of the *Area* x *Group* interaction showed that the LG showed lower positivity than the CG (Ms = -2.40 vs. -.10 uV, respectively, p = .046) only in the frontal area.

LSW

The ANOVA on the LSW amplitude yielded significant main effects of *Area* (F (2,80) = 91.26, p < .001; η_p^2 = .695) and *Emotion* (F (4,160) = 67.81, p < .001; η_p^2 = .629). Moreover, significant interactions were found between *Area* and *Group* (F (2,80) = 5.23, p = .007; η_p^2 = .116), *Area* and *Emotion* (F (8,320) = 10.68, p < .001; η_p^2 = .211), and *Emotion* and *Laterality* (F (8,320) = 6.02, p < .001; η_p^2 = .131). Post-hoc analysis of *Area* showed that the ESW displayed lower positivity in frontal (M = -.613) compared to central (M = 2.66) and parietal (M = 7.44) and central compared to parietal (frontal vs central, p < .001; frontal vs parietal, p < .001; central vs parietal, p < .001). Moreover, post-hoc comparison of *Emotion* showed a significant difference between the five emotions (all p < .02) except between threat and mutilation (p = .32) and between mutilation and erotica (p = .104). Precisely, neutral emotion displayed lower positivity (M = .32) with respect to threat (M = 3.99), mutilation (M = 4.46), erotica (M = 5.61), and sport (M = 1.43) stimuli.

Finally, post-hoc comparisons of the *Area* x *Group* interaction showed that the LG displayed lower positivity than the CG (Ms = -1.84 vs. .62, respectively, p = .023) only in the frontal area.

6.4 Discussion

The main goal of our work was to examine the brain electrical activity of groups of individuals in love (LG) versus a control group (CG) of individuals not in love while performing the Love Induction Task (LIT), a task that, through the use of specific stimuli (songs and thinking back to events), is able to evoke intense positive feelings of romantic love (Mashek et al., 2000). Moreover, self-report measures were administered to investigate the emotional responses induced by the LIT.

Results showed that during the LIT, the LG displayed a higher alpha activity in occipital-right electrodes compared to the CG. Considering that the investigation of alpha activity (8–12 Hz) led to some controversy about its functional significance, the interpretation of this result is discussed from two different perspectives. On the one hand, studies discuss the fact that alpha synchronization reflects cortical deactivation or cortical idling (Cook et al., 1998; Davidson et al., 1990); on the other hand, many studies revealed that an increase of alpha activity in the posterior sites (mainly Oz and O2) might reflect internal directed attention and imagery (Cooper et al., 2003; Jensen et al., 2002; Klimesch et al., 2007). Our findings appear to be in line with the latter theory, suggesting that the LIT might trigger internal focused attention in people who think about their own relationships. Regarding the first theory, some studies showed that left frontal activation, that results from lower alpha activity, seems to be related to positive emotion (Harmon-Jones & Allen, 1997, 1998; Poole & Gable, 2014; Quirin et al., 2016; Sutton & Davidson, 1997). Therefore, we also hypothesized that the LG would have shown a greater activity in the front-left sites (lower frontal-left alpha activity) during the LIT. However, in the present study, we did not observe significant findings in frontal sites. One possible explanation is that romantic love led to several emotions that are more than just positive feelings.

The second main finding highlighted the differences between the LG and CG ERPs response during the picture viewing task. In detail, considering P1 as an index of physical difference of stimuli (Linkenkaer-Hansen et al., 1998), results showed that the two groups perceive the physical characteristics of stimuli in the same way. Considering N1 as an index of selective attention

(Hillyard, Hink, Schwent, & Picton, 1973), the results suggest that the LG paid more attention to unpleasant pictures compared to the CG. This finding could reflect, as suggested by the literature (Atkinson, Drysdale, & Fulham, 2003), that the higher amplitude of N1 is a response to the incongruence of the stimuli. In this case, the incongruence may be due to the fact that the LG—once induced in the positive motivational state through the LIT—tends to perceive negative stimuli in conflict with its own emotional state. Moreover, considering positive slow wave (ESW and LSW) as an indicator of attentional resources to the picture (Cuthbert et al., 1998; Lang et al., 1998; Woodcock, Yu, Liu, & Han, 2013), the results suggest that the LG seems to allocate a reduced amount of motivated attention to the entire task (higher negativity in frontal sites), not only to negative pictures as expected. This finding is consistent with the previously advanced theory, suggesting that the LIT would trigger an internally focused attention that interferes with the processing of external tasks. However, another interpretation of these results arises from a neuroscientific study that assumed that slow negative activity in the frontal areas is associated with dopaminergic pathway activity (Tieges et al., 2006). This interpretation is consistent with previous studies that found that romantic love is associated with activation of dopamine-rich areas involved in reward and motivation, including the VTA, the dorsal caudate body, and the caudate tail (Acevedo et al., 2012; Aron et al., 2005; Fisher et al.,2005; Takahashi et al., 2015).

The third main finding showed that the LG (compared to the CG) obtained higher values in the SAM scale both in valence and arousal during the LIT. These results emphasized the effectiveness of the LIT in inducing intense and positive feelings, as previously assumed by Mashek et al. (2000). However, the feelings of love are often associated with positive emotions, such as euphoria (Fisher, Aron, Mashek, Li, & Brown, 2002), self-esteem (Acevedo & Aron, 2009), and happiness and life satisfaction (Kim & McKenry, 2002), but can be also associated with negative states, such as stress (Marazziti & Canale, 2004), hypomania (Brand et al., 2007), obsession (Acevedo & Aron, 2009), and jealousy (De Silva, 1997). Accordingly, a multidimensional

questionnaire was administered to measure several different dimensions of love. The results of MEVOL showed that our sample was characterized by high levels of positive emotions and low levels of negative emotions.

The present study provides the reader the first neural correlates of LIT and discusses its effects during an emotional elaboration paradigm. However, the exact nature of the LIT responses reported here remains unclear and will be the object of further investigation.

Some limitations of this study must be mentioned. The participants in our sample were mainly women; therefore, these results cannot be generalized in terms of gender. Also, the LG displayed a high level of positive emotions. Therefore, we suggest further studies to control this dimension and see if there are any differences between groups with high and low levels of positive emotions. Furthermore, although we are one of the first group to study the electrical activity during LIT, we have explored only the listening phase but not the talking and writing one. Would be interesting if further studies will test the effects of talking and writing to see if these factors can elicit the same response as the song.

Further studies are needed to test the effects of love induction, in the way we proposed, using other instruments of investigation (e.g., fMRI, PET, GSR, HRV etc.). Furthermore, it is important to highlight that this study confirms the efficacy of the paradigm ideated by Mashek et al. (2000), which uses auditory stimuli to elicit love, as an alternative to the *love-related picture paradigm* often implemented in studies of romantic love. Furthermore, to avoid possible confounding between positive emotional states (induced with the love-related song) and romantic love would be indicated to compare the latter one with positive emotions instead of neutral ones.

Moreover, some implications of this study can be addressed. Specifically, this study shows how romantic love can be associated with areas of the brain that control reward and motivation. In fact, our results show that listening to the love-related song activates all the circuits that have been found in previous studies of romantic love (Acevedo, Aron, Fisher, & Brown, 2012; Aron et al., 2005; Bartels & Zeki, 2004; Ortigue et al., 2010). This suggests that in daily life, lovers, if exposed to

highly evocative stimuli (see Mashek et al., 2000), activate all the previously mentioned areas. This could lead to behavioural and emotional changes in many situations. For example, as shown in this study, after the LIT, lovers are able to pay greater attention, especially to negative stimuli. This could have applications that are yet to be explored.

CHAPTER 7

THE COLORS OF LOVE: FACIAL THERMAL REACTIONS OF PEOPLE THINKING ABOUT THEIR LOVERS

7.1 Introduction

The previous chapter gives us a first overview of central indices (EEG) about the paradigm of the Love Induction Task. Whilst studies in neurosciences have focused essentially on the activity of the central nervous system in relation with romantic love, psychophysiologists have explored the activity of the autonomic nervous system (Guerra et al., 2011, 2012; Vico, Guerra, Robles, Vila, & Anllo-Vento, 2010). Together, they unveil some of the processes, activating in humans when in love. The brain and bodily organs interact through the principal channel of the sympathetic and parasympathetic divisions of the autonomic nervous system; those play distinct but complementary roles towards homeostasis and the regulation of physiological responses to emotional stimuli (Critchley, 2009). Therefore, it appears plausible that romantic love, which has generally been construed in terms of brain activation, can also generate a direct sharing of changes in body physiology between lovers (Critchley, 2009; Preston and de Waal, 2002; Damasio, 1999).

In 2010, Vico et al. used various psychophysiological approaches to show that the faces of romantic partners elicited higher physiological and subjective responses than those of parents, siblings, or friends. Skin conductance and zygomatic activity increased, and emotional responses were heightened. These findings suggested that the very action of looking at the image of a loved one affects our bodies in a manner that goes far beyond a mere feeling of familiarity or recognition: it provokes strong positive affective responses and emotional/cognitive arousal. The study demonstrated that those three peripheral measures provide consistent and accurate tools to understand humans' bodily responses when looking at the faces of loved people. Other methods

have also been used to study affective states. For instance, when responses to varied emotional states such as aggression (Kuraoka & Nakamura, 2011), deception (Panasiti et al., 2016), social exclusion (Ponsi et al., 2019), empathy (Ebisch et al., 2012; Manini et al. 2013) and sexual arousal (Hahn et al. 2012; Merla & Romani, 2007) were measured using a thermal camera, the authors found that facial thermal responses were indicative of particular emotional states. Merla and Romani (2007) tested facial thermal responses to stress, pain and sexual arousal in a male cohort. Discomfort due to stress was seen to cause emotional sweating; pain (or the anticipation of it) resulted in a decrease of the facial temperature, induced by both peripheral vasoconstriction and sudomotor activity; finally, sexual arousal manifested itself through an increased rate of skin blood perfusion in specific areas of the face regions, particularly on the forehead (cutaneous projection of the corrugators muscle, i.e. increased attention), and over the lips (increased perfusion of mucosa tissue for augmented sensitivity) and nose (Cardone & Merla, 2017).

In line with the above, the present study aims to assess thermal responses in love paradigms. So far, most of the studies that have aimed to assess autonomic responses to romantic love have focused on event-related paradigms, using pictures stimuli. However, another paradigm has been developed, called the induction of love (Mashek et al., 2000), which has been showed to be reliable when studying the intense feelings involved in romantic love. In this procedure, participants are asked to think about their relationships for a specific length of time, first without music, and then whilst listening to the song they chose as related to their partners (for the full procedure, see Methods and procedure).

The aim of the present study is to investigate if feelings of romantic love are correlated with an increase of the temperature (as sexual arousal) in the nose and in perioral regions. This hypothesis is based on the fact that if on the one hand a decrease of the temperature, as previously said, has been associated to stress and fear, on the other hand it is also associated to an activation of the sympathetic system. Therefore, as already suggested recently by some authors (Schneiderman,

Zilberstein-Kra, Leckman & Feldman, 2011) we expect that the response to romantic feelings is much more similar to a parasympathetic response. Moreover, we also surmise that the love song intensifies emotions (Rickard, 2004) and enhances psychophysiological responses (Bartlett, 1996; Krumhansl, 1997; Vaitl, Vehrs, & Sternagel, 1993). In this experiment, a positive-content song was introduced in the neutral condition in order to control the effect of a simply positive state, and to ensure that the changes of the temperature were not merely linked to positive feelings, rather than to romantic love. Therefore, we posit that although the positive-content song can indeed provoke positive emotions, the effects of the love song are much more intense.

7.2 Methods

7.2.1 Participants

Forty-four healthy volunteers (thirty-nine females) with a mean age of 18.9 years (Standard deviation (SD) = 1.03), were enrolled in this study. All subjects received a detailed explanation of the study design and gave their written informed consent according to the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 1997). They had normal cognitive development and no known physical or psychological disease. They were recruited from the Department of Psychology at the University of Aix-Marseille. The sample consisted of individuals with different sexual orientations (86.8% heterosexuals, 13.2% bisexuals). All participants were in a sentimental relationships at the time of the experiment, and 8% of them were living together. The average length of time the participants had been in their relationships with their partners was 19.9 months. The protocol was approved by the Ethics Committee of the Aix-Marseille University.

7.2.2 Materials

7.2.2.1 Love induction task

The love paradigms consisted in a modified version of the procedure used by Van Steenbergen, Langeslag, Band, & Hommel, (2014). Participants were instructed, through a recorded voice, to think about their partners and to remember specific events of their relationships (recall-love phase). After this first phase, participants had to keep thinking about their relationships and at the same time listen, through speakers and with their eyes-closed, to a song that they chose and that reminded them of the person they were in love with (song-love phase). This procedure is known to induce intense feelings of romantic love (Mashek et al., 2000). In the control condition, the same structure of induction was maintained, but instead of thinking about their love relationships, participants were asked to think about one of their acquaintance's relationship for the first phase (recall-neutral phase). Then, they were instructed to keep thinking about that person's relationship, whilst at the same time listening to a positive-content song that they had never heard before (song-neutral phase).

7.2.2.2 Self-report measures

- **Multidimensional Evaluation of Love (MEVOL).** This scale was recently developed by Cannas Aghedu, Veneziani, and Bisiacchi (2018) as a questionnaire composed of 21 statements which participants have to rate on a scale of 1 (*not at all true*) to 6 (*definitely true*). The questionnaire was designed to assess several dimensions of love under different perspectives (social and personal psychology and neuroscience). Specifically, MEVOL investigates positive and negative idealization, sexual attraction, taking love for granted, positive and negative emotions, and obsessive thinking. Moreover, the authors introduced another important variable

called positive perspective taking, which aimed to assess the extent to which participants felt loved by their partners. For this experiment, the scale was translated into French, following translation recommendations.

- **Passionate Love Scale, French version (PLS-FR).** This scale was developed by Hatfield and Sprecher (1986). It is composed of 15 items, which the participants have to rate on a scale of 1 (*not at all true*) to 9 (*definitely true*). It is a questionnaire designed in the field of psychology and built to assess the cognitive, physiological and behavioral indicators of passionate love. This scale was subject to the French validation (Feybesse, 2015).
- **Inclusion of Other in the Self Scale (IOS).** This scale was designed by Aaron, Aaron and Smollan, (1992). Participants were asked to describe their relationships by selecting one out of a series of seven drawings of two partly overlapping circles that represented the 'self' and the 'partner'. Scores ranged from 1 (where the circles touched but did not overlap) to 7 (where the circles were nearly entirely overlapping). This scale was designed to measure closeness in relationships.
- **Self-Assessment Manikin (SAM)**. This is an affective rating system devised by Lang (1980), in which a graphic figure depicting values along the dimensions of valence (pleasantness/unpleasantness) and arousal (activation/calm) is used to measure emotional reactions. Participants can select any of the 5 figures comprising each scale, or between any two figures, resulting in a 9-point scale for each dimension, with 1 indicating very unpleasant for valence and very calm for arousal, and 9 indicating very pleasant for valence and very excited for arousal.

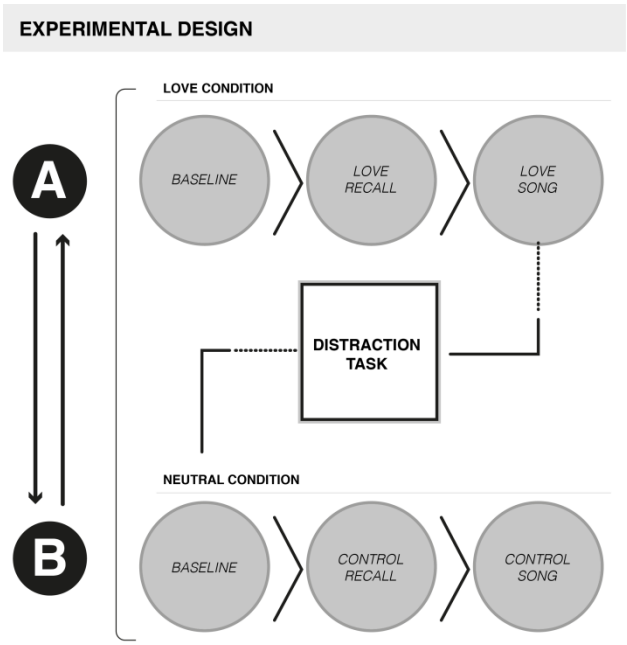
7.2.3 Procedure and data acquisition

Experimenters contacted the participants who had provided their email addresses during classes, and asked them to complete an online survey designed to exclude participants with skin problems

and users of psychotropic substances, as suggested by Ioannou, Gallese and Merla (2014). Moreover, to garantee homogeneity, we ensured that all the female participants were measured in the same menstrual week (first week after menstruation) (Dreher, Schmidt, Kohn, Furman, Rubinow, & Berman, 2007). Participants also had to specify, on a 10-point Likert scale, whether they were in love or not. Based on that, only those who were in loving relationships at the time of the experiment were selected. Data were collected in the Studio of the H2C2 platform at Aix-Marseille University (Aix Marseille Univ, CRISIS, Aix-en-Provence, France). Upon arrival, participants had to sign an informed consent form. In order to avoid potential bias from anyone of the experimenters, the experimental sessions were carried out by two different researchers. The experiment took place in a room which was maintained at a stable temperature of 22 °C, 50–60% humidity, with no direct ventilation. Before starting the acquisition, participants were left to acclimatize to the room temperature for fifteen minutes (Cardone & Merla, 2017). Every participant took part in both conditions of the love induction task: love and neutral. The two conditions were administered randomly, with the love condition coming either before or after the control condition. As illustrated in Figure 7.1, both conditions were preceded by the baseline, in which participants were asked to think about neutral things; they were also separated by a distraction task (Pasat Auditory Number Reading Task (PANRAT), Tanosoto, Bendixen, Arima, Hansen, Terkelsen & Svensson, 2015), in which participants listened to a list of numbers, before repeating them. Each block of the paradigms (baseline, recall, song) lasted for two minutes and was recorded by means of a FLIR A655sc thermal infrared camera (Focal Plane Array of 640 × 480 detectors, 0.02-second time resolution, FPA, sensitivity/Noise Equivalent Temperature Difference : < 30 mK @ 30°C). Thermal videos were acquired at a frequency rate of 10 Hz. Given that the camera had a 24° lens, the distance between the thermal camera and the participant was set to one meter (Cardone & Merla, 2017). Participants answered the SAM questionnaire at the end of each song, in order to evaluate their affective valence and arousal at the time of the experiment (Lang, 1980); they also

had to define the songs, using adjectives such as "happy", "melancholic" or "neutral". Moreover, each participant had to complete the love questionnaire described in the material list. The entire session lasted for an average of 40 minutes.

Figure 7.1 Experimental design.

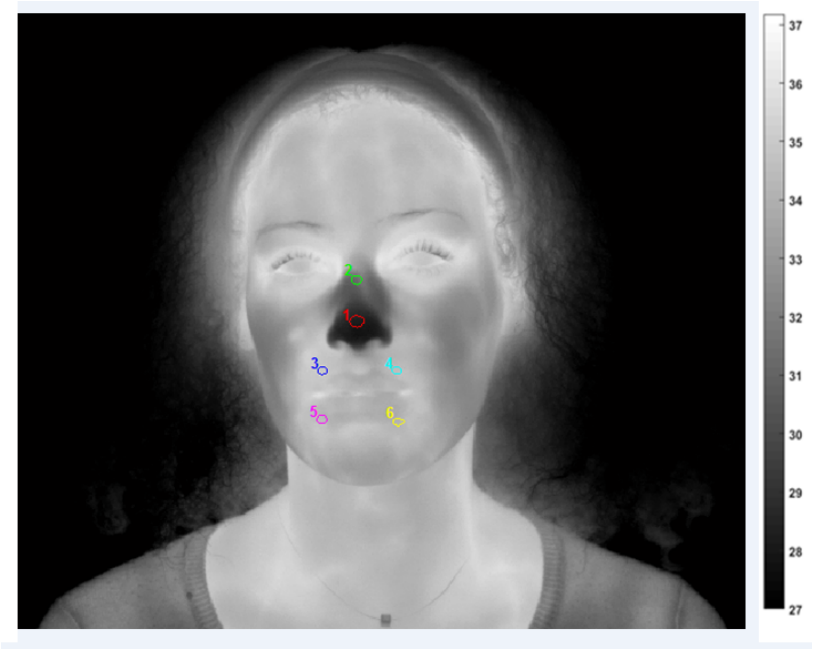


7.2.4 Thermal data analysis strategy

Thermal video preprocessing and thermal data extraction was performed using the software IRI IMAGEPRO© (Developed by Cardone D., Pinti P., Di Donato L., and Merla A., University of Chieti-Pescara, Italy). The final data sets were analyzed using the statistical software Jamovi (Version 0.9) [Computer Software]. Basing on previous studies on psychophysiology (Cardone & Merla, 2017) revealing areas of significant valence by means of thermal cameras, we extracted data from six circular Regions of Interest (ROIs) corresponding to participants' tip of the nose (ROI 1), upper nose (ROI 2) and perioral region (ROI 3, 4, 5 & 6; see Figure 7.2). Then, we computed relative rates of change in temperature for each ROI between each condition and the baseline

(differential scores were computed by subtracting ROI average temperature in the baseline condition from ROI average temperature of each experimental condition). This allowed us to obtain a meaningful, readily interpretable dependent variable. To analyze the effects of the love induction task on changes in the participants' facial temperatures, we decided to use hierarchical mixed models (Schielzeth & Nakagawa, 2013). This analytic strategy was implemented to estimate and partial out noise stemming from the within-subject clustering of our measures.

Figure 7.2 ROIs distribution on a subject's face (ROI1 - tip of the nose, ROI2 - upper nose, ROI3, 4, 5, 6 - perioral region).



7.3 Results

7.3.1 Self-report measures

In order to explore the romantic relationships of the groups, participants were given PLS, MEVOL and IOS questionnaires. The results of the PLS questionnaires showed that participants were passionately in love with their partners (M = 111, SD = 10.9). Moreover, the analysis of the MEVOL dimensions results showed that the participants' relationships were homogenously characterizes by high levels of positive emotions (M = 5.5; SD = 0.4), positive idealization (M = 4.8; SD = 0.7), positive perspective taking (M = 4.5; SD = 0.9) and sexual attraction (M = 5.1, SD = 0.6) as well as by lower levels of negative idealization (M = 2.9; SD = 1.1), taking love for granted (M = 3.2; SD = 0.6) and negative emotions (M = 2.8; SD = 1.1). Moreover, it revealed average levels of obsessive thinking (M = 3.5; SD = 1). Regarding the level of closeness, results on the IOS scale showed that participants were feeling very close to their partners (M = 5.5, SD = 0.8).

Manipulation check. To assess the reliability of the priming manipulation through the listening of a love song, we compared participants' responses on both SAM scales for valence and arousal. Paired student *t*-tests indicated that love songs induced more positive [$t(175) = 12.8$, $d = .96$, $p < .001$ (Love, M = 4.6; Neutral, M = 3.8)] and intense [$t(175) = 11.5$, $d = .86$, $p < .001$(Love, M = 3.5; Neutral, M = 2.3)] feelings among our sample. Moreover, all participants defined the unknown song as a 'happy song' despite never having heard it before.

7.3.2 Thermal measurements

Omnibus tests. Mixed models for each ROI were computed using the following generic formula: *ROI ~ 1 + (1 | ID) + CONDITION*, where ID was the participants' identification number (random

term) and CONDITION the within-subject fixed effect term. Model parameters for each ROI can be seen in Table 1. As predicted, we were able to observe a main effect of the conditions upon ROI1 and a smaller but still substantial one upon ROI 2. However, ROI 3, 4, 5 and 6 did not display meaningful differences.

Table 7.1

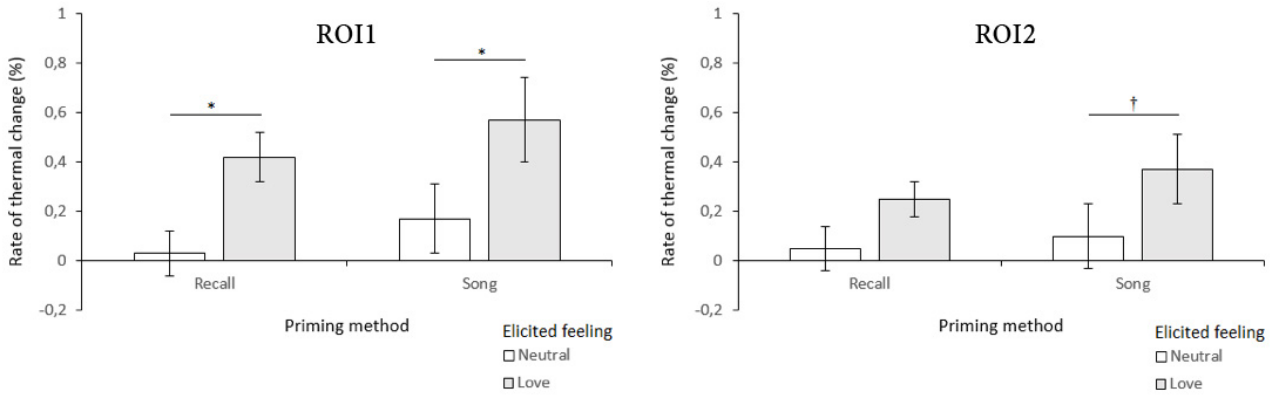
Mixed model parameters for each ROI (N = 44).

Model	*AIC*	*R²-marginal*	*R²-conditional*	$P_{Fixed\text{-}Effect}$
ROI 1	437.87	.06**	.29	.004
ROI 2	387.70	.03†	.28	.075
ROI 3	74.56			.133
ROI 4	132.06			.472
ROI 5	70.72			.243
ROI 6	84.07			.480

Note. AIC = Akaike Information Criterion, †$p < .10$, **$p < .01$

Contrast analyses. In order to break down our main effects on ROI 1 and 2, we carried out contrast analyses. The recall-love prime lead to greater temperature changes in ROI 1, compared to the recall-neutral prime, ($t(129) = 2.45$, $d = .49$, $p = .016$) and a similar effect was observed for the song-love prime, compared to the song-neutral prime ($t(129) = 2.53$, $d = .55$, $p = .013$). Furthermore, the thermal effects between both love prime conditions did not substantially differ from each other ($t(129) = .97$, $d = .10$, $p = .34$). A similar result is obtained for the neutral conditions ($t(129) = .89$, $d = .09$, $p = .37$). The same pattern was observed for ROI2, although the recall-love prime failed to induce detectable thermal responses ($t(129) = 1.48$, $d = .28$, $p = .14$), while the song-love prime's effect compared to the neutral one was a bit smaller than for ROI 1 ($t(129) = 1.98$, $d = .44$, $p = .05$). Results are shown in Figure 7.3.

Figure 7.3. Relative rates of thermal change by condition for ROI 1 (left) and ROI 2 (right).



$^{\dagger}p < .10$, $*p < .05$

7.4 Discussions

The present study aimed to explore peripheral activation during the auditory love paradigm by means of a thermal camera. The facial temperatures of the resting state were compared with those recorded while thinking about their own partners (love-recall) or about someone else's relationship (control-recall) and while listening to a love song (love-song) or an unknown positive-content song (control-song). We investigated thermal dynamics over time on six different region of interest located in the nose and in perioral region. One main finding is that participants during love-related conditions showed an increase in temperature over the nose tip region compared with the control conditions. In particular, the temperature increased during the recall-phase and was amplified with the song-phase. A tendency of an increase in temperature was also visible on the upper nose, but no other significant results were found on the perioral regions.

It is noteworthy that nose skin temperature has been widely investigated in studies involving human emotions. In particular, it has been demonstrated its responsiveness to a variety of emotions such as guilt (Ioannou et al., 2013), sexual arousal (Merla & Romani, 2007), joy (Nakanishi & Imai-Matsumura, 2008) and stress (Calvin & Duffy, 2007). Considering that the increment of nasal skin temperature has been demonstrated to be highly correlated with sexual arousal (Hahn et al., 2012), whereas the decreasing was more related to stress (Calvin & Duffy, 2007; Pavlidis et al.,

2012) and fear (Kuraoka & Nakamura, 2011; Merla & Romani, 2007), our results suggest that the peripheral activation induced by romantic feelings is configured with a pattern that is much more similar to that of sexual arousal and more distant from those of negative emotions. However, previous studies have shown that sexual arousal (induced by the presentation of erotic stimuli) produced a response not only in the nose but also in the perioral area (Merla & Romani, 2007). This difference between love and sexual response could be due to the fact that in the study of Merla and Romani (2007) the paradigm was focused on videos stimuli that in themselves very activating.

To better explain the interpretation of our results, we refer to theories on love that come from the field of neuroscience and psychophysiology. For example, through an fMRI study, it has been reported that some brain areas involved in romantic love overlapped with those associated with sexual arousal (Zeki, 2007). According to this study, we can argue that sexual arousal and romantic love also share a temperature increase in the area of the nose. This can be also justified by the fact that our sample is composed by young adults in passionate relationship that is recognized to be characterized by high levels of sexual attraction (Aron, Aron, Tudor, & Nelson, 1991; Hendrick, & Hendrick, 1992). These data are also validated by the administration of MEVOL which confirms the high levels of sexual attraction of lovers towards their partner. Furthermore, it has been demonstrated that the amygdala, known to be engaged during fearful and stressful situations, is deactivated during the love paradigm (Acevedo et al., 2012; Aron et al., 2005; Bartels & Zeki, 2000; Xu et al., 2011; Zeki & Romaya, 2010). As a matter of fact, the deactivation of the amygdala could justify why the temperature pattern of the lovers goes in the opposite direction from the stress and fear ones.

Another important contribution to our findings comes from a recent study that showed that people in love avoid autonomic stress to facilitate the regulation of emotions (Schneiderman, Zilberstein-Kra, Leckman & Feldman, 2011). According to these authors, this ability to regulate emotions comes from the activation of the parasympathetic system that is actively involved in the creation of

intimate bonds. Therefore, on the basis of this theory we can assume that the increase in temperature, which we found in lovers, could correlate with an activation of the parasympathetic system.

Moreover, the results show that the increase in temperature, in addition to being significantly evident during the love-recall phase, reaches its maximum intensity while listening to the love-song. This fact emphasizes recent studies (Rickard, 2004), asserting that music amplifies the emotional response. However, this effect is present in the love condition but also, to a lesser extent, in the control group. This response in the control condition may derive from the fact that the participants were exposed to an unknown song, that they defined as a 'happy song', and therefore we infer that music also amplified their emotions in this case.

This study has deepened our understanding of the peripheral mechanisms that intervene during the love induction task and provided a specific insight into the complex mechanisms underlying love. Our results indicate that the love induction paradigm elicits an intense and positive emotional reaction that cannot be compared to a simple activation of more general positive emotions. Those are new and promising preliminary results, which remain to be proofed further. First, the temperature should be simultaneously reordered with other psychophysiological metrics (e.g. Heart Rate Variability (see Bailey & Davis, 2017 for link between HRV and romantic love), Galvanic Skin Response, Respiratory Sinus Arrhythmia) in order to better define the patterns involved in romantic love. Second, the experiment should ideally be tested on a sample involving equal numbers of men and women therefore data cannot be generalized in terms of gender. Moreover, we suggest further studies to investigate whether the effect we found is also present in long-term relationship where the passion is probably less than the early-stages. Notwithstanding these limitations, this study foregrounds the very first findings relating to peripheral activation during the auditory love paradigm. Furthermore, it offers scientific evidence that the love induction paradigm is an alternative to the usual visual paradigms (such as the processing of the familiar faces of loved ones).

CHAPTER 8

GENERAL DISCUSSION

The aims of this experimental work were manifold. Firstly, two questionnaires to assess romantic love in the Italian context have been designed and validated. Secondly, neural and autonomic correlates of romantic love through the use of an auditory paradigm were explored. Finally, the hypothetical interference of romantic love in the emotional processing task has been investigated.

The studies reported in the second part of this work aimed to introduce, for the first time in the Italian context, questionnaires capable of assessing love in both unidimensional (chapter 4) and multidimensional (chapter 5) way. Specifically, in chapter 4 we presented a study that aimed to validate the PLS which is a questionnaire designed to assess cognitive, physiological and behavioral indicators of passionate love. This questionnaire was created by Hatfield and Sprecher (1986) with the aim of measuring the various levels of intensity of passionate love. It represents one of the most widely used scientific instruments as a measure of love. Neuroscientists, psychologists and anthropologists have used this scale to select the participants of various scientific studies. The questionnaire is presented in two versions, one with 30 items and the other with 15 items (reduced version). Both versions have an undimensional factorial structure that allows obtaining a single value of passionate love that ranges from less intense to very intense feelings. Results showed that the Italian version fully complies with the validity criteria. This represented the first Italian questionnaire that is able to evaluate passionate love. This scale can only provide a unidimensional view which, while simplifying the assessment, also precludes the possibility of obtaining a more specific profile. Some authors involved in the field of love, have assumed that there are various dimensions that intervene during sentimental relationships (Fehr, 1994; Fengler, 1974; Hatfield & Sprecher, 1986; Sternberg, 1997; Tennov, 1979). Even PLS includes some items that reflect specific dimensions (e.g. idealization, obsessive thinking and positive and negative emotions). However, no one has so far analyzed these dimensions separately. Therefore, in chapter 5 is

reported a study that aimed to evaluate romantic love under a multidimensional perspective. For this reason, the Multidimensional Evaluation of Love (MEVOL) has been created. Based on literature studies, eight dimensions that intervene during romantic relationships have been selected. Specifically, are taken into account seven main dimensions: *positive* and *negative idealization*, *sexual attraction*, *obsessive thoughts*, *negative* and *positive emotions* and *taking love for granted*. However, the strength of this study is also represented by the fact that this questionnaire gives us information not only about the feelings people have towards another person but also those people perceive from their beloved. The latter dimension is called *perspective taking* and it represents the ability to read one's partner's mind. This study also demonstrated the potential for multidimensional evaluation during scientific experiments. For example, it was observed that people with identical scores in PLS obtained completely different profiles in MEVOL. In fact, it was possible to find participants passionately in love but with a very low perspective taking. This indicated that the person felt very in love but unsure of the love received. Taken together, the two questionnaires (PLS and MEVOL) are complementary. The PLS offers the possibility of obtaining a value that indicates the level of passionate love while the MEVOL indicates the level for each of the dimensions that intervene during the relationship. In the Italian context, they represent the first questionnaires that evaluate romantic love.

The third part of the present work is focused on the neuroscientific investigation. Specifically, the neural (chapter 6) and autonomic (chapter 7) correlates have been explored using an auditory-imaginative paradigm called the love induction task (LIT). It consists of a modified version of the procedure used by Van Steenbergen and collaborators (2014). Participants were instructed to think about their partners and to remember specific events of their relationships and at the same time listen to a song that reminded them of the person they were in love with. Visual paradigms have always been used in the neuroscientific and psychological literature. In fact, almost all findings in the field of neuroscience have been made using photographs depicting the image of the partner. However, no one had previously investigated the neural and autonomic correlates of

LIT. The study reported in chapter 6 aimed (a) to investigate the brain electrical activity during LIT, (b) to explore its effects during emotional processing task (picture viewing task) and (c) to investigate the emotional reaction induced by the LIT through the use of the self-report measure. The findings of this study are really interesting and could reveal a fruitful avenue of investigation. Specifically, we found an alpha activation on the right occipital that might suggest that during LIT internally focused attention processes are triggered in people in love (Cooper et al., 2003; Jensen et al., 2002; Klimesch et al., 2007). This hypothesis is also supported by the ERPs results during the picture viewing tasks. Indeed, the results show that people in love seem to allocate less attentive resource to the whole task. Whether this result is related to the fact that they are internally focused (Cooper et al., 2003; Jensen et al., 2002; Klimesch et al., 2007) or because they activated the reward system (Tieges et al., 2006) is still to be clarified. Finally, the results of the self-reports measures also show that as Mashek and collaborators (2000) have previously demonstrated, LIT is able to evoke positive and intense emotions. This study represents the first scientific evidence that LIT is able to produce neural changes that somehow interfere with the emotional processing process.

The study reported in chapter 7 aimed to investigate the autonomic correlates of LIT using functional infrared thermal imaging (fITI) which is considered a forthcoming, encouraging methodology in the emotional studies. Specifically, we measured the temperature in six regions of interest in the face (focused on the nose and perioral regions) and compared the changes in two different conditions (control and love). The result of this study showed that when people think about their partner they have an increase in temperature focused on the tip of the nose. These data may suggest a deactivation of the sympathetic system and an enhancement of the parasympathetic system which is related to the promotion of intimacy bonding (Schneiderman et al., 2011).

Overall, all the studies presented offer (a) a current view of the state of the art in neuroscience of love; (b) new evaluation tools in the Italian context that until now were absent; (c) the first neural and autonomic data on LIT that proved to be an upcoming, promising methodology in the research of love.

In conclusion, we can say that at the moment in Italy, thanks to this work, two questionnaires are available to evaluate love. These are the PLS-R-IT and the MEVOL which, although they are two questionnaires with different objectives, can be defined as complementary. The first one in fact gives the possibility to indicate the degree of falling in love of an individual, the second one instead offers the possibility to detail the various dimensions that intervene in the relationship. These two scales played a fundamental role also in the present study because they gave us the possibility to select our participants on the basis of criteria that had not been used before. For example, we recruited all participants who were happily in love and had high levels of positive perspective taking. In short, they were all participants who perceived their partners in love as much as they did. The EEG experiment present in the second part of this work suggests that the emotional paradigm used (LIT) is able to induce a positive and intense emotional state. Moreover, further ERPs analysis suggested that lovers are so absorbed by partner-focused thoughts that they seem to lose focus on the tasks required (e.g. passive picture viewing task). This aspect should be explored because it may still have unknown implications in everyday life. Furthermore, in addition to the central aspects of the LIT, autonomic aspects were also investigated. The results seem to suggest that the increasing in temperature of the face (mainly the tip of the nose) may discriminate between people in love and those not in love (see chapter 7).This aspect may correlate with a parasympathetic activation that leads to the creation of intimate relationships.

REFERENCES

Acevedo, B. (2015). Neural correlates of human attachment: Evidence from fMRI studies of adult pair- bonding. In Zayas, V. & Hazan, C. (Eds.). Bases of adult attachment: From brain to mind to behavior. NY, NY: Springer.

Acevedo, B. P., & Aron, A. (2009). Does a long-term relationship kill romantic love?. Review of General Psychology, 13(1), 59.

Acevedo, B. P., Aron, A., Fisher, H. E., & Brown, L. L. (2012). Neural correlates of long-term intense romantic love. *Social Cognitive and AffectiveNeuroscience*, *7*(2), 145-159.

Acevedo, B. P., Aron, A., Fisher, H. E., & Brown, L. L. (2012). Neural correlates of long-term intense romantic love. *Social cognitive and affective neuroscience*, *7*(2), 145-159.https://doi.org/10.1093/scan/nsq092

Aldhafeeri, F. M., Mackenzie, I., Kay, T., Alghamdi, J., & Sluming, V. (2012). Regional brain responses to pleasant and unpleasant IAPS pictures: different networks. Neuroscience letters, 512(2), 94-98.

Algoe, S. B., Kurtz, L. E., & Grewen, K. (2017). Oxytocin and social bonds: the role of oxytocin in perceptions of romantic partners' bonding behavior. Psychological science, 28(12), 1763-1772.

Aloe, L., Bracci-Laudiero, L., Alleva, E., Lambiase, A., Micera, A., & Tirassa, P. (1994). Emotional stress induced by parachute jumping enhances blood nerve growth factor levels and the distribution of nerve growth factor receptors in lymphocytes. Proceedings of the National Academy of Sciences, 91(22), 10440-10444.

Aragona, B. J., Liu, Y., Curtis, J. T., Stephan, F. K., & Wang, Z. (2003). A critical role for nucleus accumbens dopamine in partner-preference formation in male prairie voles. Journal of Neuroscience, 23(8), 3483-3490.

Ardone, R. (2002). Qualità delle relazioni sentimentali in adolescenti di famiglie unite e separate. *Psicologia clinica dello sviluppo*, *6*(3), 465-490.

Arnow, B. A., Desmond, J. E., Banner, L. L., Glover, G. H., Solomon, A., Polan, M. L., ... & Atlas, S. W. (2002). Brain activation and sexual arousal in healthy, heterosexual males. Brain, 125(5), 1014-1023.

Aron, A., & Aron, E. N. (1991). Love and sexuality. In K. McKinney & S. Sprecher (Eds.), *Sexuality and close relationships* (pp. 25-48). Hillsdale, NJ: Erlbaum.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of personality and social psychology*, *63*(4), 596.

Aron, A., Aron, E. N., Tudor, M., & Nelson, G. (1991). Close relationships as including other in the self. Journal of personality and social psychology, 60(2), 241.

Aron, A., Aron, E. N., Tudor, M., & Nelson, G. (1991). Close relationships as including other in the self. *Journal of personality and social psychology*, *60*(2), 241.

Aron, A., Fisher, H. E., & Strong, G. (2006). Romantic love. In A. L. Vangelisti& D. Perlman (Eds.), *The Cambridge Handbook of Personal Relationships* (pp. 595-614). New York: Cambridge University Press.

Aron, A., Fisher, H., Mashek, D. J., Strong, G., Li, H., & Brown, L. L. (2005). Reward, motivation, and emotion systems associated with early-stage intense romantic love. *Journal of Neurophysiology*, *94*(1), 327–37. https://doi.org/10.1152/jn.00838.2004

Atkinson, C. M., Drysdale, K. A., & Fulham, W. R. (2003). Event-related potentials to Stroop and reverse Stroop stimuli. International Journal of Psychophysiology, 47(1), 1-21.

Bagozzi, R. P. (1983). " Issues in the application of covariance structure analysis": A further comment.Journal of Consumer Research, Vol 9(4), Mar 1983, 449-450.

Bailey, L. K., & Davis, R. (2017). Heart rate variability reactivity and new romance: Cause or consequence?. Biological psychology, 128, 50-54.

Bartels, A., & Zeki, S. (2000). The neural basis of romantic love. *NeuroReport*, *11*(17), 3829–3834.

Bartels, A., & Zeki, S. (2004). The neural correlates of maternal and romantic love. *Neuroimage*, *21*(3), 1155-1166.

Bartlett, D. L. (1996). Physiological responses to music and sound stimuli. Handbook of music psychology, 343-385.

Başar, E., Başar-Eroglu, C., Karakaş, S., & Schürmann, M. (2001). Gamma, alpha, delta, and theta oscillations govern cognitive processes. International journal of psychophysiology, 39(2-3), 241-248.

Başar, E., Schmiedt-Fehr, C., Öniz, A., & Başar-Eroğlu, C. (2008). Brain oscillations evoked by the face of a loved person. Brain research, 1214, 105-115.

Berscheid, E. (2010). Love in the fourth dimension. Annual review of psychology, 61, 1-25.

Birbaumer, N., Lutzenberger, W., Elbert, T., Flor, H., & Rockstroh, B. (1993). Imagery and brain processes. The structure of emotion, 132-134.

Bollen, K. A. (1989). A new incremental fit index for general structural equation models. *Sociological Methods & Research*, *17*(3), 303-316.

Bolmont, M., Cacioppo, J. T., &Cacioppo, S. (2014). Love is in the gaze an eye-tracking study of love and sexual desire. *Psychological science*, *25*(9), 1748-1756.https://doi.org/10.1177/0956797614539706

Bradley, M. M. (2009). Natural selective attention: Orienting and motion. *Psychophysiology*, *46*(1), 1-11.

Branchi, I., Francia, N., & Alleva, E. (2004). Epigenetic control of neurobehavioural plasticity: the role of neurotrophins. Behavioural pharmacology, 15(5), 353-362.

Brand, S., Luethi, M., von Planta, A., Hatzinger, M., & Holsboer-Trachsler, E. (2007). Romantic love, hypomania, and sleep pattern in adolescents. Journal of Adolescent Health, 41(1), 69-76.

Brown, L. L., Acevedo, B., & Fisher, H. E. (2013). Neural correlates of four broad temperament dimensions: testing predictions for a novel construct of personality. *PloS one*, *8*(11), e78734.

Brown, T. (2006). CFA with equality constraints, multiple groups, and mean structures. *Confirmatory factor analysis for applied research*, 236-319.

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., Poehlmann, K. M., & Ito, T. A. (2000). The psychophysiology of emotion. Handbook of emotions, 2, 173-191.

Cacioppo, S., Bianchi-Demicheli, F., Frum, C., Pfaus, J. G., & Lewis, J. W. (2012). The common neural bases between sexual desire and love: a multilevel kernel density fMRI analysis. *The Journal of Sexual Medicine*, *9*(4), 1048-1054.

Calvin, K. L., & Duffy, V. G. (2007). Development of a facial skin temperature-based methodology for non-intrusive mental workload measurement. Occupational Ergonomics, 7, 83–94.

Cannas Aghedu, F., Veneziani, C. A., & Bisiacchi, P. S. (2018). The Multidimensional Evaluation of Love (MEVOL): Development and preliminary validation. Testing, Psychometrics, Methodology in Applied Psychology. Manuscript accepted.

Cannas Aghedu, F., Veneziani, C. A., Manari, T., Feybesse, C., & Bisiacchi, P. S. (2018). Assessing passionate love: Italian validation of the PLS (reduced version). Sexual and Relationship Therapy, 1-11.

Cannas Aghedu, F., Veneziani, C.A., Manari, T., Feybesse, C., & Bisiacchi, P.S. (2018). Assessing passionate love: Italian validation of the PLS (reduced version). Sexual and Relationship Therapy. DOI: 10.1080/14681994.2018.1442570

Cardone, D., & Merla, A. (2017). New frontiers for applications of thermal infrared imaging devices: computational psychopshysiology in the neurosciences. Sensors, 17(5), 1042.

Carter, C. S. (1998). Neuroendocrine perspectives on social attachment and love. Psychoneuroendocrinology, 23(8), 779-818.

Cook IA, O'Hara R, Uijtdehaage SHJ, Mandelkern M, Leuchter AF (1998) Assessing the accuracy of topographic EEG mapping for determining local brain function. Electroencephalogr Clin Neurophysiol 107:408–414

Cooper, N. R., Croft, R. J., Dominey, S. J., Burgess, A. P., & Gruzelier, J. H. (2003). Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the

implications for idling and inhibition hypotheses. International Journal of Psychophysiology, 47(1), 65-74.

Critchley, H. D. (2009). Psychophysiology of neural, cognitive and affective integration: fMRI and autonomic indicants. International Journal of Psychophysiology, 73(2), 88-94.

Cudeck, R., & Browne, M. W. (1983). Cross-validation of covariance structures. *Multivariate Behavioral Research*, *18*(2), 147–167. http://dx.doi.org/10.1207/s15327906mbr1802_2

Cuthbert, B. N., Schupp, H. T., Bradley, M., McManis, M., & Lang, P. J. (1998). Probing affective pictures: Attended startle and tone probes. Psychophysiology, 35(3), 344-347.

Damasio, A. R. (1999). How the brain creates the mind. Scientific American, 281(6), 112-117.

Davidson RJ, Chapman JP, Chapman LJ, Henriques JB (1990) Asymmetrical brain electrical activity discriminates between psychometrically-matched verbal and spatial cognitive tasks. Psychophysiology 27:528–543

Davidson RJ, Ekman P, Saron CD, Senulis JA, Friesen WV (1990) Approach-withdrawal and cerebral asymmetry: emotional expression and brain physiology I. J Personal Soc Psychol 58:330–341

De Boer, A., Van Buel, E. M., & Ter Horst, G. J. (2012). Love is more than just a kiss: a neurobiological perspective on love and affection. Neuroscience, 201, 114-124.

De Silva, P. (1997). Jealousy in couple relationships: Nature, assessment and therapy. Behaviour research and therapy, 35(11), 973-985.

Delgado, M. R., Nystrom, L. E., Fissell, C., Noll, D. C., & Fiez, J. A. (2000). Tracking the hemodynamic responses to reward and punishment in the striatum. Journal of neurophysiology, 84(6), 3072-3077.

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. Journal of neuroscience methods, 134(1), 9-21.

DeVries, A. C., DeVries, M. B., Taymans, S. E., & Carter, C. S. (1996). The effects of stress on social preferences are sexually dimorphic in prairie voles. Proceedings of the National Academy of Sciences, 93(21), 11980-11984.

DeVries, A. C., DeVries, M. B., Taymans, S. E., & Carter, S. C. (1995). The modulation of pair bonding by corticosteroids in female praire voles. Proc Natl Acad Sci USA, 92, 7744-7748.

Diamond, L. M. (2003). What does sexual orientation orient? A biobehavioral model distinguishing romantic love and sexual desire. Psychological review, 110(1), 173.

Dixon, J. A., & Moore, C. F. (1990). The development of perspective taking: Understanding differences in information and weighting. *Child Development*, *61*(5), 1502-1513.http://doi.org/10.1111/j.1467-8624.1990.tb02878.x

Dreher, J. C., Schmidt, P. J., Kohn, P., Furman, D., Rubinow, D., & Berman, K. F. (2007). Menstrual cycle phase modulates reward-related neural function in women. Proceedings of the National Academy of Sciences, 104(7), 2465-2470.

Dziuban, C. D., & Shirkey, E. C. (1974). When is a correlation matrix appropriate for factor analysis? Some decision rules. *Psychological Bulletin*, *81*(6), 358.

Ebisch, S. J., Aureli, T., Bafunno, D., Cardone, D., Romani, G. L., & Merla, A. (2012). Mother and child in synchrony: thermal facial imprints of autonomic contagion. Biological Psychology, 89(1), 123-129.

Eisenegger, C., Haushofer, J., & Fehr, E. (2011). The role of testosterone in social interaction. Trends in cognitive sciences, 15(6), 263-271.

Elliott, R., Newman, J. L., Longe, O. A., & Deakin, J. W. (2003). Differential response patterns in the striatum and orbitofrontal cortex to financial reward in humans: a parametric functional magnetic resonance imaging study. Journal of Neuroscience, 23(1), 303-307.

Emanuele, E., Brondino, N., Pesenti, S., Re, S., & Geroldi, D. (2007). Genetic loading on human loving styles. Neuroendocrinology Letters, 28(6), 815-821.

Emanuele, E., Politi, P., Bianchi, M., Minoretti, P., Bertona, M., & Geroldi, D. (2006). Raised

plasma nerve growth factor levels associated with early-stage romantic love. *Psychoneuroendocrinology*, *31*(3), 288-294.

Fehr, B. (1994). Prototype-based assessment of laypeople's views of love. *Personal Relationships*, *1*(4), 309-331.

Fengler, A. P. (1974). Romantic love in courtship: Divergent paths of male and female students. *Journal of Comparative Family Studies*, *5*(1), 134-139.

Feybesse, C. (2015). The adventures of love in the social sciences: social, psychometric evaluations and cognitive influences of passionate love. Dissertation completed in partial fulfillment of the doctor of philosophy Université Paris Descartes. Paris, France.

Feybesse, C., Neto, F., & Hatfield, E. (2011). Adaptação da escala de amor apaixonado na população portuguesa. *Psicologia, Educação & Cultura, 15*(1), 161-180.

Fisher, H. (1998). Lust, attraction, and attachment in mammalian reproduction. *Human Nature*, *9*(1), 23–52. https://doi.org/10.1007/s12110-998-1010-5

Fisher, H. (2004). Why we love: The nature and chemistry of romantic love. Macmillan.

Fisher, H. E., Aron, A., Mashek, D., Li, H., & Brown, L. L. (2002). Defining the brain systems of lust, romantic attraction, and attachment. Archives of sexual behavior, 31(5), 413-419.

Fisher, H. E., Brown, L. L., Aron, A., Strong, G., & Mashek, D. (2010). Reward, addiction, and emotion regulation systems associated with rejection in love. Journal of neurophysiology, 104(1), 51-60.

Fisher, H., Aron, A., & Brown, L. L. (2005). Romantic love: An fMRI study of a neural mechanism for mate choice. *Journal of Comparative Neurology*, *493*(1), 58–62. https://doi.org/10.1002/cne.20772

Flora, D. B., & Curran, P. J. (2004). An empirical evaluation of alternative methods of estimation for confirmatory factor analysis with ordinal data. *Psychological Methods*, *9*(4), 466.

Fornell, C. (1983). Issues in the application of covariance structure analysis: A comment. *Journal of Consumer Research*, *9*(4), 443-448.

Gadpaille, W. J. (1975). The cycles of sex. Scribner.

García, C. Y. (1998). Temporal course of the basic components of love throughout relationships. Psychol. Spain, 2, 76-86.

George, D., &Mallery, M. (2003). Using SPSS for Windows step by step: a simple guide and reference.

Gonzaga, G. C., Turner, R. A., Keltner, D., Campos, B., &Altemus, M. (2006). Romantic love and sexual desire in close relationships. *Emotion*, *6*(2), 163.http://dx.doi.org/10.1037/1528-3542.6.2.163

Gottman, J. M., & Levenson, R. W. (1985). A valid procedure for obtaining self-report of affect in marital interaction. Journal of consulting and clinical psychology, 53(2), 151.

Graham, J. M., & Christiansen, K. (2009). The reliability of romantic love: A reliability generalization meta-analysis. *Personal Relationships*, *16*(1), 49-66.

Graham, J. M., & Christiansen, K. (2009). The reliability of romantic love: A reliability generalization meta-analysis. Personal Relationships, 16(1), 49-66.

Grissom, R. J., & Kim, J. J. (2012). *Effect sizes for research: Univariate and multivariate applications*. Abingdon: Routledge.

Grissom, R. J., & Kim, J. J. (2012). *Effect sizes for research: Univariate and multivariate applications*. Routledge.

Guastella, A. J., Mitchell, P. B., & Dadds, M. R. (2008). Oxytocin increases gaze to the eye region of human faces. Biological psychiatry, 63(1), 3-5.

Guerra, P., Campagnoli, R. R., Vico, C., Volchan, E., Anllo-Vento, L., & Vila, J. (2011). Filial versus romantic love: contributions from peripheral and central electrophysiology. Biological psychology, 88(2-3), 196-203.

Guerra, P., Vico, C., Campagnoli, R., Sánchez, A., Anllo-Vento, L., & Vila, J. (2012). Affective processing of loved familiar faces: integrating central and peripheral electrophysiological measures. *International Journal of Psychophysiology*, *85*(1), 79-87.

Hadjiconstantinou, M., McGuire, L., Duchemin, A. M., Laskowski, B., Kiecolt-Glaser, J., & Glaser, R. (2001). Changes in plasma nerve growth factor levels in older adults associated with chronic stress. Journal of Neuroimmunology, 116(1), 102-106.

Hahn, A. C., Whitehead R. D., Albrecht, M., Lefevre, C. E., & Perret, D. I. (2012). Hot or not? Thermal reactions to social contact. Biology Letters, Physiology, 8, 1–4. doi: 10.1098/rsbl.2012.0338

Harmon-Jones, E., & Allen, J. J. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: Covariation of putative indicators related to risk for mood disorders. Journal of abnormal psychology, 106(1), 159.

Harmon-Jones, E., & Allen, J. J. (1998). Anger and frontal brain activity: EEG asymmetry consistent with approach motivation despite negative affective valence. Journal of personality and social psychology, 74(5), 1310.

Hatfield, E. (1984). The dangers of intimacy. *Communication, intimacy, and close relationships*, 207-220.

Hatfield, E. C., Pillemer, J. T., O'Brien, M. U., & Le, Y. C. L. (2008). The endurance of love: Passionate and companionate love in newlywed and long-term marriages. *Interpersona*, *2*(1), 35.

Hatfield, E., & Rapson, R. L. (1987). Passionate love/sexual desire: Can the same paradigm explain both?. Archives of sexual behavior, 16(3), 259-278.

Hatfield, E., & Rapson, R. L. (1993). *Love, sex, and intimacy: Their psychology, biology, and history*. HarperCollins College Publishers.

Hatfield, E., & Rapson, R. L. (2005). Social justice and the clash of cultures. Psychological Inquiry, 16(4), 172-175.

Hatfield, E., & Rapson, R. L. (2009). The neuropsychology of passionate love and sexual desire. In E. Cuyler & M. Ackhart (Eds.), *Psychology of social relationships*. Happauge, NY: Nova Science.

Hatfield, E., & Sprecher, S. (1986). Measuring passionate love in intimate relationships. *Journal of adolescence*, *9*(4), 383-410.

Hatfield, E., &Sprecher, S. (2010). The passionate love scale. In T. D. Fisher, C. M. Davis, W. L. Yaber, & S. L. Davis (Eds.) *Handbook of sexuality-related measures: A compendium* (3rd Ed.), (pp. 469-472). Thousand Oaks, CA: Taylor & Francis.

Hatfield, E., Bensman, L., & Rapson, R. L. (2012). A brief history of social scientists' attempts to measure passionate love. *Journal of Social and Personal Relationships*, *29*(2), 143–164. https://doi.org/10.1177/0265407511431055

Hatfield, E., Bensman, L., & Rapson, R. L. (2012). A brief history of social scientists' attempts to measure passionate love. *Journal of Social and Personal Relationships*, *29*(2), 143-164.https://doi.org/10.1177/0265407511431055

Hattis, R. P. (1965). Love feelings in courtship couples: An analysis. *Journal of Humanistic Psychology*, *5*(1), 22-53.https://doi.org/10.1177/002216786500500104

Heider, F. (2013). The psychology of interpersonal relations. Psychology Press.

Hendrick, C., & Hendrick S. S. (1989). Research on love: Does it measure up?*Journalof Personality and Social Psychology, 56*, 784-794.

Hendrick, C., & Hendrick, S. (1986). A theory and method of love. Journal of Personality and Social Psychology, 50(2), 392.

Hendrick, C., & Hendrick, S. S. (2006). Styles of romantic love. In R. J. Sternberg & K. Weis (Eds), *The new psychology of love*. New Haven, CT: Yale University Press.

Hendrick, C., Hendrick, S. S., & Dicke, A. (1998). The love attitudes scale: Short form. Journal of Social and Personal Relationships, 15(2), 147-159.

Hendrick, S., &Hendrick, C. (1992). *Liking, loving and relating*. Brooks/Cole Pub Co.

Hennessy, M. B. (1997). Hypothalamic-pituitary-adrenal responses to brief social separation. Neuroscience & Biobehavioral Reviews, 21(1), 11-29.

Hernandez, J. A. E. (2015). Validade de construto da Escala de Amor Apaixonado. *Psicologia:*

Teoria e Prática, *17*(3), 133-145.

Hillyard, S. A., Hink, R. F., Schwent, V. L., & Picton, T. W. (1973). Electrical signs of selective attention in the human brain. Science, 182(4108), 177-180.Jasper, H. H. (1958). The ten twenty electrode system of the international federation. *Electroencephalography and Clinical Neurophysiology*, *10*, 371-375.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1-55.

Hu, L. T., &Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), 1-55.http://dx.doi.org/10.1080/10705519909540118

Hurlemann, R., Patin, A., Onur, O. A., Cohen, M. X., Baumgartner, T., Metzler, S., ... & Kendrick, K. M. (2010). Oxytocin enhances amygdala-dependent, socially reinforced learning and emotional empathy in humans. Journal of Neuroscience, 30(14), 4999-5007.

Insel, T. R. (2010). The challenge of translation in social neuroscience: a review of oxytocin, vasopressin, and affiliative behavior. Neuron, 65(6), 768-779.

Insel, T. R., Winslow, J. T., Wang, Z., & Young, L. J. (1998). Oxytocin, vasopressin, and the neuroendocrine basis of pair bond formation. In Vasopressin and oxytocin (pp. 215-224). Springer, Boston, MA.

Ioannou, S., Ebisch, S., Aureli, T., Bafunno, D., Ioannides, H. A., Cardone, D., ... & Merla, A. (2013). The autonomic signature of guilt in children: a thermal infrared imaging study. PloS one, 8(11), e79440.

Ioannou, S., Gallese, V., & Merla, A. (2014). Thermal infrared imaging in psychophysiology: potentialities and limits. Psychophysiology, 51(10), 951-963.

Jänig, W. (2008). Integrative action of the autonomic nervous system: Neurobiology of homeostasis. Cambridge University Press.

Jayasundara, B. M. W. U. C. B., Wickramasuriya, K. T., &Shakila, L. G. S. (2010, August). Localisation of the LimeSurvey Software. In *Conference on Localised Systems and Applications (CLSA) 2010* (p. 36).

John, O. P., & Benet-Martínez, V. (2000). Measurement: Reliability, construct validation, and scale construction. *Handbook of research methods in social and personality psychology. Cambridge: Cambridge University Press*.

Jöreskog, K. G., &Sörbom, D. (2001). LISREL (Version 8.5) [Computer software]. Chicago: Scientific Software International.

Kaplan, H. S. (1979). Disorders of sexual desire and other new concepts and techniques in sex therapy (Vol. 2). Simon & Schuster.

Kawano, K., Hanari, T. & Ito, K. (2015). Contact avoidance for romantic interests. The *Japanese Journal of Personality, 26*(2), 65-69.

Kirsch, P., Esslinger, C., Chen, Q., Mier, D., Lis, S., Siddhanti, S., ... & Meyer-Lindenberg, A. (2005). Oxytocin modulates neural circuitry for social cognition and fear in humans. Journal of neuroscience, 25(49), 11489-11493.

Kito, M. (2005). Self-disclosure in romantic relationships and friendships among American and Japanese college students. *The Journal of Social Psychology*, *145*(2), 127-140.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: the inhibition–timing hypothesis. Brain research reviews, 53(1), 63-88.

Klorman, R., Weerts, T. C., Hastings, J. E., Melamed, B. G., & Lang, P. J. (1974). Psychometric description of some specific-fear questionnaires. Behavior therapy, 5(3), 401-409.

Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. Nature, 435(7042), 673.

Krumhansl, C. L. (1997). An exploratory study of musical emotions and psychophysiology. Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 51(4), 336.

Kuraoka, K., & Nakamura, K. (2011). The use of nasal skin temperature measurements in studying emotion in macaque monkeys. Physiology & behavior, 102(3-4), 347-355.

Landis, D., & O'Shea, W. A. (2000). Cross-cultural aspects of passionate love. An individual differences analysis. *Journal of Cross-Cultural Psychology*, *31*(6), 752-777.

Lang, P. J. (1980). Self-assessment manikin. Gainesville, FL: The Center for Research in Psychophysiology, University of Florida.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). International affective picture system (IAPS): Technical manual and affective ratings. *NIMH Center for the Study of Emotion and Attention*, 39-58.

Lang, P. J., Bradley, M. M., Fitzsimmons, J. R., Cuthbert, B. N., Scott, J. D., Moulder, B., & Nangia, V. (1998). Emotional arousal and activation of the visual cortex: an fMRI analysis. *Psychophysiology*, *35*(2), 199-210.

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, A. O. (1993). Looking at pictures: Affective, facial, visceral, and behavioral reactions. Psychophysiology, 30(3), 261-273.

Langeslag, S. J., Jansma, B. M., Franken, I. H., & Van Strien, J. W. (2007). Event-related potential responses to love-related facial stimuli. *Biological psychology*, *76*(1-2), 109-115.

Langeslag, S. J., Olivier, J. R., Köhlen, M. E., Nijs, I. M., & Van Strien, J. W. (2014). Increased attention and memory for beloved-related information during infatuation: behavioral and electrophysiological data. Social cognitive and affective neuroscience, 10(1), 136-144.

Lee, J. A. (1977). A typology of styles of loving. *Personality and Social Psychology Bulletin*, *3*(2), 173-182.https://doi.org/10.1177/014616727700300204

Lee, J. A. (1988). Love-Styles. In R. J. Sternberg & M. L. Barnes (Eds.), *The psychology of love* (pp. 38-67). New Haven, CT: Yale University Press.

Levine, S., Lyons, D. M., & Schatzberg, A. F. (1997). Psychobiological Consequences of Social Relationships a. Annals of the New York Academy of Sciences, 807(1), 210-218.

Li, C. H. (2016). Confirmatory factor analysis with ordinal data: Comparing robust maximum

likelihood and diagonally weighted least squares. *Behavior Research Methods*, *48*(3), 936-949).

Liebowitz, M. R. (1983). The chemistry of love. Little, Brown.

Lim, M. M., & Young, L. J. (2006). Neuropeptidergic regulation of affiliative behavior and social bonding in animals. Hormones and behavior, 50(4), 506-517.

Limesurvey GmbH. / LimeSurvey: An Open Source survey tool /LimeSurvey GmbH, Hamburg, Germany. URL http://www.limesurvey.org

Linkenkaer-Hansen, K., Palva, J. M., Sams, M., Hietanen, J. K., Aronen, H. J., & Ilmoniemi, R. J. (1998). Face-selective processing in human extrastriate cortex around 120 ms after stimulus onset revealed by magneto-and electroencephalography. Neuroscience letters, 253(3), 147-150.

Lionetti, F., Keijsers, L., Dellagiulia, A., & Pastore, M. (2016). Evidence of factorial validity of parental knowledge, control and solicitation, and adolescent disclosure scales: When the ordered nature of likert scales matters. *Frontiers in psychology*, *7*.

Liu, Y., Huang, H., McGinnis-Deweese, M., Keil, A., & Ding, M. (2012). Neural substrate of the late positive potential in emotional processing. *Journal of Neuroscience*, *32*(42), 14563-14572.

Luck, S. J. (2014). An introduction to the event-related potential technique. MIT press.

Makeig, S., Bell, A. J., Jung, T. P., & Sejnowski, T. J. (1996). Independent component analysis of electroencephalographic data. In Advances in neural information processing systems (pp. 145-151).

Manini, B., Cardone, D., Ebisch, S., Bafunno, D., Aureli, T., & Merla, A. (2013). Mom feels what her child feels: thermal signatures of vicarious autonomic response while watching children in a stressful situation. Frontiers in human neuroscience, 7, 299.

Marazziti, D., & Canale, D. (2004). Hormonal changes when falling in love. Psychoneuroendocrinology, 29(7), 931-936.

Marazziti, D., Akiskal, H. S., Rossi, A., & Cassano, G. B. (1999). Alteration of the platelet serotonin transporter in romantic love. Psychological Medicine, 29(3), 741-745.

Marazziti, D., Baroni, S., Giannaccini, G., Piccinni, A., Mucci, F., Catena-Dell'Osso, M., ... & Dell'Osso, L. (2017). Decreased lymphocyte dopamine transporter in romantic lovers. CNS spectrums, 22(3), 290-294.

Martín-Loeches, M., Hernández-Tamames, J. A., Martín, A., & Urrutia, M. (2014). Beauty and ugliness in the bodies and faces of others: an fMRI study of person esthetic judgement. Neuroscience, 277, 486-497.

Mashek, D., Aron, A., & Fisher, H. (2000). Identifying, evoking, and measuring intense feelings of romantic love. *Representative Research in Social Psychology*, *24*, 48-55.

Mashek, D., Aron, A., & Fisher, H. (2000). Identifying, evoking, and measuring intense feelings of romantic love. *Representative Research in Social Psychology*, *24*, 48-55.

Masuda, M. (2003). Meta-analyses of love scales: Do various love scales measure the same psychological constructs? *Japanese Psychological Research*, *45*(1), 25-37.

Mendoza, S. P., & Mason, W. A. (1997). Attachment Relationships in New World Primatesa. Annals of the New York Academy of Sciences, 807(1), 203-209.

Merla, A., & Romani, G. L. (2007, August). Thermal signatures of emotional arousal: a functional infrared imaging study. In Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE (pp. 247-249). IEEE.

Meyers, S. A., & Berscheid, E. (1997). The language of love: The difference a preposition makes. Personality and Social Psychology Bulletin, 23(4), 347-362.

Mooradian, A. D., Morley, J. E., & Korenman, S. G. (1987). Biological actions of androgens. Endocrine reviews, 8(1), 1-28.

Murray, S. L., Holmes, J. G., & Griffin, D. W. (1996). The benefits of positive illusions: Idealization and the construction of satisfaction in close relationships. *Journal of personality and social psychology*, *70*(1), 79.http://dx.doi.org/10.1037/0022-3514.70.1.79

Muthén, L. K., &Muthén, B. O. (2012). Mplus statistical modeling software: Release 7.0. *Los Angeles, CA: Muthén & Muthén*.

Nakanishi, R., & Imai-Matsumura, K. (2008). Facial skin temperature decreases in infants with joyful expression. Infant Behavior and Development, 31(1), 137-144.

Neto, F., Mullet, E., Deschamps, J. C., Barros, J., Benvindo, R., Camino, L., Falconi, A., Kagibanga, V. e Machado, M. (2000). Cross-cultural variations in attitudes towards love. *Journal of Cross-Cultural Psychology*, *30*, 626-635.

Nunnally, J. C., & Bernstein, I. H. (1994). Psychometric theory (3rd ed.). New York: McGraw-Hill.

O'Leary, K. D., Acevedo, B. P., Aron, A., Huddy, L., & Mashek, D. (2012). Is long-term love more than a rare phenomenon? If so, what are its correlates?. *Social Psychological and Personality Science*, *3*(2), 241-249.https://doi.org/10.1177/1948550611417015

Ortigue, S., Bianchi-Demicheli, F., Hamilton, & Grafton, S. (2007). The neural basis of love as a subliminal prime: An event-related functional magnetic resonance imaging study. *Journal of Cognitive Neuroscience*, *19*(7), 1218–1230. https://doi.org/10.1162/jocn.2007.19.7.1218

Ortigue, S., Bianchi-Demicheli, F., Patel, N., Frum, C., & Lewis, J. W. (2010). Neuroimaging of love: fMRI meta-analysis evidence toward new perspectives in sexual medicine. *The Journal of Sexual Medicine*, *7*(11), 3541-3552.

Ortigue, S., Patel, N., Bianchi-Demicheli, F., & Grafton, S. T. (2010). Implicit priming of embodied cognition on human motor intention understanding in dyads in love. *Journal of Social and Personal Relationships*, *27*(7), 1001-1015.https://doi.org/10.1177/0265407510378861

Panasiti MS, Cardone D, Pavone EF, Mancini A, Merla A, Aglioti SM. Thermal signatures of voluntary deception in ecological conditions. Sci Rep. 2016 Oct 13;6:35174. doi: 10.1038/srep35174.

Pardridge, W. M. (2002). Neurotrophins, neuroprotection and the blood-brain barrier. Current opinion in investigational drugs, 3(12), 1753-1757.

Pavlidis, I., Tsiamyrtzis, P., Shastri, D., Wesley, A., Zhou, Y., Lindner, P., . . . Bas, B. (2012) Fast by nature—How stress patterns define human experience and performance in dexterous tasks. Scientific Reports, 2,1–9.

Pearson.

Ponsi G, Monachesi B, Panasiti V, Aglioti SM, Panasiti MS. Physiological and behavioral reactivity to social exclusion: a functional infrared thermal imaging study in patients with psoriasis. J Neurophysiol. 2019 Jan 1;121(1):38-49. doi: 10.1152/jn.00555.2018. Epub 2018 Oct 31.

Poole, B. D., & Gable, P. A. (2014). Affective motivational direction drives asymmetric frontal hemisphere activation. *Experimental brain research*, *232*(7), 2121-2130.

Preston, S. D., & De Waal, F. B. (2002). Empathy: Its ultimate and proximate bases. Behavioral and brain sciences, 25(1), 1-20.

Quirin, M., Gruber, T., Kuhl, J., & Düsing, R. (2013). Is love right? Prefrontal resting brain asymmetry is related to the affiliation motive. *Frontiers in human neuroscience*, *7*, 902.

Rickard, N. S. (2004). Intense emotional responses to music: a test of the physiological arousal hypothesis. Psychology of music, 32(4), 371-388.

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). *Ghent, Belgium: Ghent University*. https://doi.org/10.18637/jss.v048.i02

Rubin, Z. (1970). Measurement of romantic love. Journal of personality and social psychology, 16(2), 265.

Ruby, P., &Decety, J. (2004). How would you feel versus how do you think she would feel? A neuroimaging study of perspective-taking with social emotions. *Journal of cognitive neuroscience*, *16*(6), 988-999.http://doi.org/10.1162/0898929041502661

Satorra, A., &Bentler, P. M. (1994). Corrections to test statistics and standard errors in covariance structure analysis.

Schaefer, M. T., & Olson, D. H. (1981). Assessing intimacy: The PAIR inventory. *Journal of Marital and Family Therapy*, *7*(1), 47-60.http://doi.org/0.1111/j.1752-0606.1981.tb01351.x

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of*

psychological research online, *8*(2), 23-74.

Schielzeth, H., & Nakagawa, S. (2013). Nested by design: model fitting and interpretation in a mixed model era. Methods in Ecology and Evolution, 4(1), 14-24.

Schmidt, L. A., & Trainor, L. J. (2001). Frontal brain electrical activity (EEG) distinguishes valence and intensity of musical emotions. *Cognition & Emotion*, *15*(4), 487-500.

Schneiderman, I., Zilberstein-Kra, Y., Leckman, J. F., & Feldman, R. (2011). Love alters autonomic reactivity to emotions. Emotion, 11(6), 1314.

Schultz, W. (2000). Multiple reward signals in the brain. Nature reviews neuroscience, 1(3), 199.

Seifert, S., von Cramon, D. Y., Imperati, D., Tittgemeyer, M., & Ullsperger, M. (2011). Thalamocingulate interactions in performance monitoring. Journal of Neuroscience, 31(9), 3375-3383.

Song, H., Zou, Z., Kou, J., Liu, Y., Yang, L., Zilverstand, A., ... & Zhang, X. (2015). Love-related changes in the brain: a resting-state functional magnetic resonance imaging study. Frontiers in human neuroscience, 9, 71.

Song, S., Zou, Z., Song, H., Wang, Y., d'Oleire Uquillas, F., Wang, H., & Chen, H. (2016). Romantic Love Is Associated with Enhanced Inhibitory Control in an Emotional Stop-Signal Task. Frontiers in psychology, 7, 1574.

Stangl, D. K. (2008). Encyclopedia of statistics in behavioral science.

Starka L (2007) Endocrine factors of pair bonding. Prague Med Rep 108(4):297–305.

Sternberg, R. J. (1986). A triangular theory of love. *Psychological review*, *93*(2), 119.

Sternberg, R. J. (1987). Liking versus loving: A comparative evaluation of theories. Psychological Bulletin, 102(3), 331.

Sternberg, R. J. (1995). Love as a story. *Journal of social and personal relationships*, *12*(4), 541-546.https://doi.org/10.1177/0265407595124007

Sternberg, R. J. (1997). Construct validation of a triangular love scale. *European Journal of Social Psychology*, *27*(3), 313-335.http://dx.doi.org/10.1002/(SICI)1099-0992(199705)27:3<313::AID-EJSP824>3.0.CO;2-4

Stoessel, C., Stiller, J., Bleich, S., Boensch, D., Doerfler, A., Garcia, M., ... & Forster, C. (2011). Differences and similarities on neuronal activities of people being happily and unhappily in love: a functional magnetic resonance imaging study. Neuropsychobiology, 64(1), 52-60.

Sutton, S. K., & Davidson, R. J. (1997). Prefrontal brain asymmetry: A biological substrate of the behavioral approach and inhibition systems. Psychological science, 8(3), 204-210.

Tabachnick, B. G. &Fidell, L. S. (2007). *Using Multivariate Statistics* (5th ed.). Boston, MA:

Takahashi, K., Mizuno, K., Sasaki, A. T., Wada, Y., Tanaka, M., Ishii, A., ... & Watanabe, Y. (2015). Imaging the passionate stage of romantic love by dopamine dynamics. Frontiers in human neuroscience, 9, 191.

Tanosoto, T., Bendixen, K. H., Arima, T., Hansen, J., Terkelsen, A. J., & Svensson, P. (2015). Effects of the Paced Auditory Serial Addition Task (PASAT) with different rates on autonomic nervous system responses and self-reported levels of stress. Journal of oral rehabilitation, 42(5), 378-385.

Team, R. C. (2014). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org.

Tennov D. 1979. Love and limerence: the experience of being in love. New York: Stein and Day.

Tiedt, H. O., Beier, K. M., Lueschow, A., Pauls, A., & Weber, J. E. (2014). A different pattern of lateralised brain activity during processing of loved faces in men and women: a MEG study. *Biological psychology*, *103*, 255-261.

Tieges, Z., Snel, J., Kok, A., Wijnen, J. G., Lorist, M. M., & Ridderinkhof, K. R. (2006). Caffeine improves anticipatory processes in task switching. Biological Psychology, 73(2), 101-113.

Trochidis, K., & Bigand, E. (2012). EEG-based emotion perception during music listening. Proc. ICMPC, 1018-1021.

Ulmer-Yaniv, A., Avitsur, R., Kanat-Maymon, Y., Schneiderman, I., Zagoory-Sharon, O., & Feldman, R. (2016). Affiliation, reward, and immune biomarkers coalesce to support social synchrony during periods of bond formation in humans. Brain, behavior, and immunity, 56, 130-139.

Vaitl, D., Vehrs, W., & Sternagel, S. (1993). Prompts-leitmotif-emotion: Play it again, Richard Wagner. The structure of emotion: Psychophysiological, cognitive, and clinical aspects, 169-189.

Van Steenbergen, H., Langeslag, S. J., Band, G. P., & Hommel, B. (2014). Reduced cognitive control in passionate lovers. *Motivation and Emotion*, *38*(3), 444-450.

Vico, C., Guerra, P., Robles, H., Vila, J., & Anllo-Vento, L. (2010). Affective processing of loved faces: contributions from peripheral and central electrophysiology. Neuropsychologia, 48(10), 2894-2902.

Wald, C. (2015). The aesthetic brain. Nature, 526(7572), S2.

Wang, Z., Ferris, C. F., & De Vries, G. J. (1994). Role of septal vasopressin innervation in paternal behavior in prairie voles (Microtus ochrogaster). Proceedings of the National Academy of Sciences, 91(1), 400-404.

Watts, S., &Stenner, P. (2005). The subjective experience of partnership love: AQ methodological study. *British Journal of Social Psychology*, *44*(1), 85-107.http://dx.doi.org/10.1348/014466604X23473

Widaman, K. F., & Thompson, J. S. (2003). On specifying the null model for incremental fit indices in structural equation modeling. *Psychological methods*, *8*(1), 16.http://dx.doi.org/10.1037/1082-989X.8.1.16

Wlodarski, R., & Dunbar, R. I. (2014). The effects of romantic love on mentalizing abilities. *Review of General Psychology*, *18*(4), 313.http://dx.doi.org/10.1037/gpr0000020

Woodcock, K. A., Yu, D., Liu, Y., & Han, S. (2013). The presence of a culturally similar or dissimilar social partner affects neural responses to emotional stimuli. Socioaffective neuroscience & psychology, 3(1), 20500.

Xu, X., Aron, A., Brown, L., Cao, G., Feng, T., &Weng, X. (2011). Reward and motivation systems: A brain mapping study of early-stage intense romantic love in Chinese participants. *Human brain mapping*, *32*(2), 249-257.

Yildirim, F., Hablemitoglu, S., & Barnett, R. V. (2014). Reliability and validity of a Turkish version of the Passionate Love Scale. *Social Behavior and Personality: An international journal*, *42*(4), 673-684.

Young, L. J., & Wang, Z. (2004). The neurobiology of pair bonding. Nature neuroscience, 7(10), 1048.

Zeki, S. (2007). The neurobiology of love. FEBS letters, 581(14), 2575-2579.

Zeki, S., & Romaya, J. P. (2010). The brain reaction to viewing faces of opposite-and same-sex romantic partners. PloS one, 5(12), e15802.

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