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Romantic Love

Review Article

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Abstract

This research review based on literature derived from a Pubmed search on the terms romantic love revealed only 149 studies from 1953 to 2016. These include self-report and behavior observation studies as well as research on neurotransmitter/neurohormonal systems and electrophysiological monitoring and neuroimaging. The protocol used in most of these studies involved fMRI responses by the romantic love person viewing photos of the loved one versus photos of familiar and/or unfamiliar others. Although as many as nine areas have been activated by love photos, the most frequently included the orbitofrontal cortex, the ventral tegmental area, the caudate nucleus and the anterior and posterior cingulates. These areas are rich in dopamine and oxytocin, both of which have been notably high in romantic love partners. Overlapping areas in the brain have been reported for different types of love including romantic, maternal and filial love. The widespread activation by the different types of love suggests a "general arousal" effect. Behavioral observation research may be more functional for its therapeutic implications. However, to date, the observational research has focused on young adult couples who are newly in love. The paucity and limitations of this literature on romantic love highlight the need for future research that is focused on interaction behaviors in love relationships that have endured. These data might then be used for interaction coaching of those having difficulties in their love relationships.

Introduction

Love can be called a deep feeling of affection and care that involves intimacy, commitment and passion, that nourishes like air, food, water, words and touch and has a behavioral, physiological and biochemical signature (Field, Deutsch, Sternberg, personal communications). Although there are similarities between romantic love, filial love and maternal love, the lion's share of the research is focused on romantic love. Romantic love has been considered a "commitment device" for motivating pair-bonding in humans and, in turn, care giving of children [18]. And, as these authors noted, "love is universal, suppressing mate-searching mechanisms, has specific behavioral, hormonal and neuropsychological signatures and is linked to better health and survival".

A Pubmed literature search on the termsromantic love yielded 149 articles from 1953 to 2016. Of those, nine were surveys or empirical studies on love behaviors and 8 pertained to neurotransmitter and neuroendocrine systems, but the lion's share of the research (132 studies) has been on activation of different areas of the brain by photos of the loved one as measured by electroencephalography (EEG), magnetoencephalography (MEG), positron emission technography (PET), event related potentials (ERP) and functional magnetic resonance imaging (fMRI) technology.

Self-report and behavior observation literature

As universal as the love experience appears to be, a very small scientific literature exists on romantic love behavior. The feelings have been captured by poetry, fiction, music and art, but love behaviors have rarely been researched. This may relate to the dearth of funding available for the study of love. The 'Golden Fleece' award was started by Wisconsin Senator William Proxmire who apparently vetoed the funding of a research project on love, noting that "we already know enough about love". More recently the development of technology to assay neurotransmitter and neuroendocrine systems and the neuroimaging techniques for examining activation of various parts of the brain has made love,

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among other emotions, the focus of research. Very few self-report and behavior observation studies have been conducted. Examples of those in the recent literature include a survey on gender differences, questionnaires on depression, anxiety, hypomania and sleep problems related to romantic love, studies on the enhancement of attention and memory by love words and analgesic responses to thermal pain as a function of preoccupation with the love partner.

In the gender differences survey, men were more prone to fall in love if they "tended to overestimate women's sexual interest and highly valued physical attractiveness in the potential partner" [19]. And women were more prone to fall in love if they had a strong sex drive.

In a questionnaire study on romantic love in adolescents, 60 of them had recently fallen in love and experienced intense romantic love and 47 had a longer lasting relationship or were single [7]. The adolescents completed questionnaires related to hypomania and sleep habits and kept a sleep log for seven nights. Compared to the singles, adolescents in early stage intense romantic love had higher scores on a hypomania scale and reported more positive mood states in the mornings and evenings and fewer hours of sleep. Although, they also reported better sleep quality, less daytime sleepiness and better concentration during the day. Comparisons between early stage lovers and those who had longer relationships would have been interesting.

In a similar study on romantic love 100 young adults with a mean age of 26 years completed questionnaires related to romantic love. In this study romantic love relationships varied on a continuum of intensity. Using a correlation analysis model, the authors reported that a more intense state of romantic love was associated with depression and anxiety, but also with the bright side of hypomania and better sleep quality, although love was not related to sleep duration.

Attention and memory for beloved – related information has also been assessed. In one study, event-related potentials (ERPs) were recorded during the presentation of beloved–related versus friend–related words/phrases [23]. The late positive potential (which is the ERP component reflecting motivated attention) was enhanced during the beloved-related condition. Memory was better for beloved–related than for friend–related words/phrases. The authors interpreted these attention and memory biases for beloved–related information as being an arousal phenomenon.

A similar study addressed the question of whether there was increased attention towards one's partner in a love relationship or a deflection of attention away from other potential partners. The researchers addressed this question by assessing women's ability to identify body odors of their boyfriend versus a same-sex friend and an opposite-sex friend and the relationship between that ability and the degree of romantic love. The results suggested a correlation between the degree of romantic love and the ability to identify the body odor of the opposite sex friend but not the body odor of their boyfriend or same-sex friend. This finding suggested that romantic love deflects attention away from potential partners as opposed to increasing attention toward the current partner. This result is surprising in as much as even new borns can identify and prefer the odor of their parents versus the odor of strangers [8]. And it's not clear in this study how the women became so familiar with the odor of their opposite sex friends.

In another correlation analysis model, the researchers assessed the relationship between pain thresholds and preoccupation with the love partner [27]. The participants were shown pictures of the romantic partner or an equally attractive familiar acquaintance while being subjected to thermal pain at low, moderate or high levels. They were also asked to report the amount of time they spent thinking about their romantic partner during an average day which was used as the preoccupation measure. The degree of pain relief was positively correlated with partner preoccupation. As the authors noted, viewing pictures of romantic partners produced ananalgesic effect. Although it is not clear how the infliction of pain was permitted by a university institutional review board for research purposes, the viewing of loved one's photos could be a clinically useful analgesic for painful procedures.

Neurotransmitter/neurohormonal systems literature

Several neurotransmitters and neural hormones have been implicated in romantic love. Some have referred to the roles of serotonin, cortisol, nerve growth factor and testosterone in romantic love [9]. For example, a positive association has been found between the intensity of early romantic feelings and serum levels of nerve growth factor [11]. The lion's share of the neurohormonal research has focused on oxytocin. In one study, three-minute interactions between romantic partners were observed [20]. Verbal and physical displays of romantic love for the partner were related to the release of oxytocin. In another study 120 new lovers (60 couples) and 40 singles were observed for their conflict behavior [29]. In addition, plasma levels of affiliation and stress-related hormones were assessed including oxytocin and cortisol. The conflict interactions were coded for empathy and hostility. Higher cortisol levels predicted greater hostility. In contrast, individuals whose partners had higher oxytocin levels showed greater empathy. Mediation analysis indicated that high cortisol in both partners was associated with relationship breakup as mediated by decreased empathy. Their observations of interactions for empathy and conflict behaviors may be a better model than the use of partner photos as stimuli in terms of learning about romantic love behaviors. Their plasma sampling simply for love research, however, would likely be subject to a cost/benefits assessment by most human subjects committees.

The same research group observed 120 new lovers in support-giving interactions and those interactions were coded for empathic behaviors [28]. The empathic behaviors that were coded included affective congruence, maintaining focus on partner, acknowledging the partner's distress, reciprocal exchange and nonverbal empathy. In addition, this research team looked at various alleles of the oxytocin receptor gene to assess the relationship between oxytocin and empathy. Alleles on the oxytocin receptor gene predicted empathy problems beyond the level of the couple, relationship duration and anxiety and depression symptoms. The authors suggested that the oxytocin receptor gene is a potential biomarker for social dysfunction. However, this type of assessment may be considered invasive and impractical for clinical diagnostic purposes.

In still another study by this group of researchers, 163 young adults including 120 new lovers and 43 unattached singles were observed three months after the initiation of their relationship

and again six months later [30]. Their dyadic interactions were observed and the individuals were interviewed regarding their relationship–related thoughts and behaviors. Oxytocin was higher in new lovers compared to singles, and the high levels of oxytocin among the new lovers did not decrease over the six-month period. Oxytocin was correlated with the couples interactive reciprocity including their social focus, positive affect, affectionate touch and synchronized dyadic states as well as with anxieties and worries regarding the partner and their relationship. The authors noted that these relationships are similar to data reported for relationships between oxytocin and parent–infant bonding, suggesting that they have similar underlying biobehavioral mechanisms.

Parallels have been drawn between maternal love, romantic love and long-term attachment. Although they each have distinctive patterns in the neuronal circuitry, they also have activated overlappingbrain areas [32]. These authors referred to dopamine, serotonin, opioids, oxytocin and vasopressin as being neurotransmitter/neurohormonal systems involved in these three types of love. Still others have noted the similarities between romantic and maternal love n [37]. This researcher suggested that both romantic and maternal love activate regions that are specific to each of them but also that they have overlapping regions in the brain's reward system that involve areas that are rich in oxytocin and vasopressin receptors. Both types of attachment appear to activate reward circuitry that bonds individuals and both deactivate regions associated with negative emotions.

Electrophysiological and imaging data

Several electrophysiological and imaging technologies have been used over the last couple decades to assess brain activity underlying romantic love. They include EEG, ERP (event-related potentials), magnetoencephalography (MEG), positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). The lion's share of the studies have involved fMRIs. In many of these studies the reactions to photos of the loved one versus photos of familiar and unfamiliar people were monitored. This paradigm was simultaneously developed here in the the U.S. by Fisher and her colleagues [26]. and in England by Zeki and his colleagues [4], all pioneers in this field. These electrophysiological and imaging studies are reviewed in the order of their increasingly sophisticated recording technology.

In one of those exemplary EEG studies, photos of a loved one were presented to females as well as pictures of a known and appreciated person or an unknown person. The response to the photo of the loved one showed higher amplitude Delta waves than to the unknown person or the appreciated person. In a similar study, but using event-related potentials, the face of the loved one was expected to elicit an enhanced late positive potential (LPP) which usually reflects greater attention [24]. The participants viewed photos of their loved one, a friend and an unknown beautiful person. The friend photo was to control for familiarity and the photo of the unknown beautiful person was to control for perceived beauty. As expected, the late positive potential (attention) was larger in response to the face of the loved one. Still another study attempted to control for not only familiarity but also arousal [22]. In this study, female university students were presented with faces of their fathers who were considered higher on familiarity but lower on emotionality and with faces of their romantic partners who were thought to be higher on emotionality but lower on familiarity. Baby faces and unfamiliar faces were used as control faces. One index of familiarity (the P3 amplitude) was higher for the faces of the fathers. However, intense positive emotional reactions were elicited by both loved faces (partners and fathers) suggesting commonality of romantic and filial love.

In an MEG (magnetoencephalography) study, loved faces were combined with recalling past emotional experiences [35]. Photos of the romantic partner were compared with those of two long-term friends along with imagining a positive emotional experience with that person. Greater responses occurred in the women, suggesting that they had greater autobiographical and emotional memory. The authors noted that the late-latency evoked magnetic field was the magnetic counterpart of late positive potentials in event-related potentials, showing consistency of results across those two technologies.

In a positron emission tomography (PET) study, a dopamine receptor antagonist was given while adults viewed photos of their romantic partners and friends of the same sex [34]. The results suggested that the dopaminergic system was activated in two regions, the medial orbitofrontal cortex and the medial prefrontal cortex. The authors noted that both the activation of the prefrontal cortex and excitement levels were correlated with dopaminergic activation, but only for the romantic partner photos. Although these findings are informative, arguably institutional review boards in our country would not have permitted the administration of a dopamine receptor antagonist simply for research purposes.

Other data, but from an fMRI study, also suggested that dopamine-rich areas were activated by photos of romantic partners who had been "intenselyin love" from 1 to 17 months [2]. Those dopamine rich areas included the right ventral tegmental area, the right posterior dorsal body and the medial caudate nucleus.The authors suggested that dopaminergic reward pathways contribute to the "general arousal" component of romantic love and that romantic love would change over time [2]. Despite their prediction that romantic love would change over time, the same research group found similar data on romantic partners who had been married an average of 21 years, suggesting that early-love and later-love were activating similar areas [1]. In this study, facial photos of the romantic partner were compared to highly familiar acquaintances, close long-term friends and a less familiar person. The fMRI data showing the activation of the dopamine–rich reward system including the ventral tegmental area and dorsal striatum were consistent with the results from their earlier study on early–stage romantic love partners. In addition, regions that had been activated in maternal attachment were also activated in this study on romantic partners including the anterior and posterior cingulate. The ventral tegmental area and caudate responses were correlated with romantic love scores and the globus pallidus activation was correlated with friendship scores.

Another fMRI study measured activation in mothers while they viewed pictures of their own and other children they knew and of their best friend and acquainted adults as additional controls [4]. These fMRI data were then compared to the romantic love data described in their previous study [37]. As already mentioned, the two types of love activated different regions but they also activated overlapping regions including those rich in oxytocin and vasopressin receptors. Both types of love also deactivated similar

regions that are associated with negative emotions. The authors described this activation and deactivation as a "push–pull mechanism. Although several researchers have suggested the similarities between the brain regions activated by different types of love, the comparisons between maternal and romantic love in this study were based on data from different samples. The data are suggestive of the need for a study that monitors brain activation in women from the same sample while viewing the photos of their children and those of their romantic partners.

The early–stage activation patterns of romantic love can be predictive of long – term relationship stability, as is suggested by another fMRI study [36]. Participants from a previous fMRI study of early-stage love were invited back 40 months later and those who were still together were compared to those who had terminated their relationship. Those who were still together had shown activation of the medial orbitofrontal cortex, right sub colossal cingulate and right accumbens which are regions that have been implicated in long-term love.

In still another fMRI study, individuals who were "intensely in love" and others who had recently separated from their romantic partners were scanned viewing partner pictures versus erotic photos [33]. Decreased brain activity occurred in the separated group as compared to the happy lovers group in frontal areas, the anterior cingulate cortex and the posterior cingulate cortex. The unhappy lovers also had clinical depression symptoms on the Beck Depression Inventory.

Even at rest without the stimulation of photos, similar differences occurred between those in love and those no longer in love [31]. In this study, the left dorsal anterior cingulate cortex was more activated in the group in love as compared to the no longer in love group. In addition, the activation of the left dorsal anterior cortex was positively correlated with length of time in love and negatively correlated with the time since breakup in the no longer in love group. Activation was also noted in the insula, caudate, amygdala and nucleus accumbens.

Both unique and similar activation patterns occur in separate and overlapping regions in romantic love, maternal love and even unconditional love [6]. In this study on "unconditional love" participants were scanned while looking at a series of pictures of individuals with intellectual disabilities. The experimental condition participants were asked to feel "unconditional love" toward the disabled individuals in the photos while in the control condition they were simply asked to look at the photos of the same disabled individuals. Some distinct networks were activated for the unconditional love condition including the right periaqueductal gray, the right globus pallidus, and the middle insula. The regions that overlapped those noted for romantic love and maternal love included the caudate, the ventral tegmental area and the dorsal anterior cingulate cortex.

Limitations of the love literature and future directions

The comparisons between maternal, filial and romantic love suggestunique areas of activation as well as overlapping areas of the brain being affected by photos of loved ones. Even photos used to elicit unconditional love and photos viewed by those no longer in love activated overlapping areas. At least nine different areas of the brain have been activated by the loved-ones photos. The most often cited are the medial orbitofrontal cortex, the right ventral tegmental area, the medial caudate nucleus and the anterior and posterior cingulates. All of these areas are reward pathways rich in dopamine and oxytocin. As has been suggested by others [17], the activation of so many areas of the brain and the overlapping areas for different love objects including romantic love, maternal love and filial love are highly suggestive of "general arousal". Photos of loved ones alone stimulate powerful feelings. This science is interesting and informative, but perhaps not clinically useful, as these areas of the brain cannot be manipulated to alleviate pain in the "no longer loved" or to facilitate greater love or perpetual love in those already in love.

Studying the interactions and the oxytocin levels of couples in love might be clinically more useful. As in Schneiderman et al., (2012, 2014) interactions might be observed for empathic behaviors including those they coded in one study (affective congruence, maintaining focus on partner, acknowledging partner's distress, reciprocal exchange, nonverbal empathy). And in their 2012 study, the interactive reciprocity behaviors were informative (i. e. social focus, positive affect, affectionate touch, synchronized dyadic states, anxieties and worries regarding the partner and relationship) [30]. It is not clear why these authors changed the behaviors they coded from one study to the other unless they were simply re-coding the video tapes from the same sample. And, the generalizability of these behaviors to enduring love relationships cannot be assumed given that their samples were limited to new love relationships and to young adults. In any case, other love behaviors such as nurturing behavior might be added to this coding list, or different behaviors may emerge in the study of love relationships that have endured.

Once behaviors have been studied and identified in love relationships that have endured, these behaviors could be modeled or coached as in, for example, the interaction coaching that has been done with mothers and infants [12, 14]. Or couples therapy could feature modeling and coaching on these behaviors [21]. And romantic couples identified as having low oxytocin levels or non-matching oxytocin levels across partners could be administered oxytocin intranasally, as has been done in other research [10]. These approaches to the science of love would seem to be more functional and ultimately more therapeutic than continuing to find consensus for brain areas activated by the photos of loved ones using imaging technology. The fact that only 149 studies could be found on romantic love from the last 63 years and that many of those studies are imaging studies, highlights the need for more behavior observation research focused on couples whose love has endured.

Romantic Breakups

The literature on romantic breakups may further inform the love literature. Research suggests that romantic breakups may lead to the broken heart syndrome and immune dysfunction (see [15] for a review). Although the broken heart syndrome has mimicked real heart attacks, angiograms revealed no clogged arteries or permanent heart damage. Compromised immune function may result from increased cortisol and inflammatory cytokines and decreased natural killer cell activity. The model we have proposed is

that romantic breakups result in the loss of a person as a regulator of stimulation and arousal modulation that can then lead to these physiological and biochemical effects.

Psychobiological attunement

The model we have called "psychobiological attunement" or "being on the same wavelength", suggests that loved ones need optimal stimulation and arousal modulation from each other [13]. Each partner provides meaningful stimulation for the other and has a modulating influence on the other's arousal level. Both over-stimulation and under-stimulation are aversive, and stimulation that helps keep an individual within an optimal arousal zone is considered reinforcing. Thus, the absence or loss of a loved one means the loss of both activating and calming stimulation. The individual experiencing the loss might then fluctuate between one end of the continuum of under-stimulation and the other end of over-stimulation and not be able to modulate these levels to experience optimal arousal.

Other terms used to describe this phenomenon are synchrony or the matching of physical activity rhythms by individuals in a close relationship. Examples of these rhythms are mothers and infants behavioral and heart rate synchrony and partners coordinating their physical movements and expressions while talking, as well as their cortisol cycles being synchronized on weekends when they are together [13]. This attunement or "being on the same wavelength" happens for both behavioral and physiological rhythms in those who have a love relationship. Seemingly, the only way this can happen is if each partner of the dyad is sensitive and responsive to each other's stimulation and arousal-modulation needs. As in a feedback loop, the partners accordingly adjust their behaviors to facilitate the behavioral and physiological synchrony of the couple.

If and when the partner is not there to meet the need for different types and degrees of stimulation, dysregulation may occur including physiological disorganization such as decreased vagal activity, increased cortisol levels and changes in immune function such as increased inflammatory cytokines and decreased natural killer cell activity. In our model, the loss of a loved one may result in this dysregulation because the source of stimulation and arousal modulation is no longer present.

Physical intimacy can enhance attunement. Via touching, for example, individuals can learn each other's stimulation and arousal modulation needs. Although it is possible to self-regulate in the absence of an intimate partner, it may not be as easy or effective. When a partner is no longer there and touch stimulation, for example, is missing, it may become necessary to find that type of stimulation from other activities until the loved one returns. Massage, yoga, and other forms of exercise, for example, may help avoid the physiological dysregulation and immune problems that can result from touch deprivation (See [16], for a review).

Summary

The protocol used in most of these studies involved fMRI responses by the romantic love person viewing photos of the loved one versus photos of familiar and/or unfamiliar others. Although as many as nine areas have been activated by love photos, the most frequently included the orbitofrontal cortex, the ventral tegmental area, the caudate nucleus and the anterior and posterior cingulates. These areas are rich in dopamine and oxytocin, both of which have been notably high in romantic love partners. Overlapping areas in the brain have been reported for different types of love including romantic, maternal and filial love. The widespread activation by the different types of love suggests a "general arousal" effect. Behavioral observation research may be more functional for its therapeutic implications. However, to date, the observational research has focused on young adult couples who are newly in love. The paucity and limitations of this literature on romantic love highlight the need for future research that is focused on interaction behaviors in love relationships that have endured. These data might then be used for interaction coaching of those having difficulties in their love relationships.

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