SOCIAL NEUROSCIENCE, 2006, 1 (2), 90–103
Psychology Press
Taylor & Francis Group

The power of love on the human brain

Francesco Bianchi-Demicheli
Geneva University Hospital, Geneva, Switzerland

Scott T. Grafton and Stephanie Ortigue
Dartmouth College, Hanover, NH, USA

Romantic love has been the source for some of the greatest achievements of mankind throughout the ages. The recent localization of romantic love within subcortico–cortical reward, motivation and emotion systems in the human brain has suggested that love is a goal-directed drive with predictable facilitation effects on cognitive behavior, rather than a pure emotion. Here we show that the subliminal exposure of a beloved's name (romantic prime) during a lexical decision task dramatically improves performance in women in love (Experiment 1), as the subliminal presentation of a passion's descriptive noun does (Experiment 2). The parallel between love and passion allows us to interpret these facilitation effects as corresponding to cognitive top-down processes within a motivation-enhanced neural network.

INTRODUCTION

A dominant perspective in neuroscience and experimental psychology is that the subliminal presentation of elementary emotions can facilitate subsequent motor responses (affective priming; De Houwer, Hermans, & Eelen, 1998; De Houwer & Randell, 2002; Fazio, Sanbonmatsu, Powell, & Kardes, 1986; Fitzsimons & Bargh, 2003; Hermans, De Houwer, & Eelen, 1994, 2001; Klauer & Musch, 2001; Murphy & Zajonc, 1993; Musch & Klauer, 2003; Rossel & Nobre, 2004; Wentura, 2000). In this framework, brief presentation (typically less than 50 ms) of a visual stimulus (prime) induces a change in the speed or accuracy of the processing of a following target stimulus (facilitation priming effects; Henson, 2003). Because facilitation priming effects occur on motor systems, one might conclude that perceptual information can affect stimulus-response mappings without necessarily being consciously perceived (e.g., Eimer & Schakenberg, 1998; Fazio et al., 1986; Henke, Landis, & Markowitsch, 1994; Neumann & Klotz, 1994; Taylor & McCloskey, 1990; Tulving & Schacter, 1990). Interestingly, these facilitation priming effects occur not only at a motor level (e.g., Eimer & Schakenberg, 1998; Neumann & Klotz, 1994), but also at a higher-order cognitive level. For instance, for language, several studies have demonstrated the existence of facilitation effects after a subliminal presentation of a word prime during a lexical decision task. These findings have suggested that facilitation priming effects arise not only when the relation between prime and target is a perceptual one, but also when it is a purely conceptual one (e.g., Henson, 2003; Morris, Ohman, & Dolan, 1999; Musch &

Correspondence should be addressed to: Francesco Bianchi-Demicheli, Psychosomatic Gynaecology and Sexology Unit, Emergency and Liaison Services, Geneva University Psychiatric Centre and Division of Reproductive Endocrinology and Infertility, Geneva University Hospital, 15 Pitons Street, 1205 Geneva, Switzerland. E-mail: francesco.bianchi-demicheli@hcuge.ch

This research is supported by the Committee for Protection of Human Subjects, the Swiss National Foundation, and the Swiss National Foundation for research in Biology and Medicine, grant #1223/PASMA 111563/1.

The authors thank Professor Todd Heatherton and Professor George Wolford for their helpful comments on the manuscript.

www.psypress.com/socialneuroscience DOI:10.1080/17470910600976547

Klauer, 2003; Reynvoet, Gevers, & Caessens, 2005; Stapel and Koomen, 2005; Whalen, Rauch, Etcoff, McInerney, Lee, & Jenike, 1998; Wentura, 2000). In other words, facilitation priming effects extend to the level of motor programming in the absence of direct stimulus-response mappings.

Studies using hemodynamic techniques of functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have reinforced this latter assumption by demonstrating facilitation priming effects in numerous regions of the human brain, with the specific regions depending on the type of stimulus and the level of the association. In particular, some neuroimaging studies recently demonstrated that the influence of unconscious semantic primes might operate on motor areas (Dehaene et al., 1998). These findings have suggested that the influence of primes on response-selection stages occurs through ''top-down'' amodal representations (Dehaene et al., 1998; Henson, 2003).

At least two potential effects can explain facilitation priming effects: (1) automatic spreading of activation in a semantic conceptual network from the prime to affectively congruent targets (Bargh, Chaiken, Govender, & Pratto, 1992; Bargh, Chaiken, Raymond, & Hymes, 1996; Collins & Loftus, 1975; Dehaene et al., 1998; Fazio, 2001; Hermans et al., 1994, 2001; Naccache & Dehaene, 2001; Neely, 1977; Niedenthal & Halberstadt, 1995; Reynvoet et al., 2005; Spruyt, Hermans, De Houwer, & Eelen, 2004); and (2) strategic/attentional effects (Musch & Klauer, 2003; Posner & Snyder, 1975). Whereas automatic spreading of activation from [conceptual] affective-associations is one of the most fundamental precepts of several modern cognitive-representational theories of emotion and general appraisal models of emotion generation (Hermans et al., 2001; Musch & Klauer, 2003), there is no direct support that automatic spreading of activation also exists for intense romantic love.

Intense romantic love is defined as a complex state involving erotic, cognitive, chemical, and goal-directed behavioral components (Aron & Aron, 1986; Brehm, Miller, Perlman, & Miller Campbell, 2002; Buss, 2003; Fisher, 2004; Gonzaga, Keltner, Londahl, & Smith, 2001; Hatfield & Rapson, 1993; Hatfield & Walster, 1978; Johnson, 1921; Mashek, Aron, & Fisher, 2000; Rubin, 1970; Shaver, Schwartz, Kirson, & O'Connor, 1987; Shaver, Morgan, & Wu, 1996; Sternberg, 1986; Sternberg & Barnes, 1988; Tennov, 1979).

Intense romantic love does not just mean loving someone, but it also means ''being in love'' (Berscheid & Meyers, 1996; Hatfield & Rapson, 1996; Hatfield & Walster, 1978; Johnson, 1921; Sternberg, 1986; Sternberg & Barnes, 1988; Tennov, 1979; Troy, 2005).

For instance, when involved in a romantic, passionate and intimate relationship, the person actively strives for the happiness of the loved person (Clarks & Mills, 1979). Intense romantic passionate love is often coupled with the inability to feel romantic passion for more than one person at a time (e.g., Berscheid & Meyers, 1996). Individuals who report feelings of intense romantic attraction admit thinking about the beloved over 85% of their waking hours (Tennov, 1979). Over the last century, a broad literature has been published on the explicit behavioral effects and correlates of romantic love (e.g., Brehm et al., 2002; Buss, 2003; Fisher, 1998, 2004; Jonhson, 1921). For instance, different effects of love have been reported, such as euphoria, loss of appetite, hyperactivity, delay of the onset of fatigue, and a decreased need for sleep (Aron, Fisher, Mashek, Strong, Li, & Brown, 2005; Bartels & Zeki, 2000, 2004; Brehm et al., 2002; Buss, 2003; Fisher, 1998, 2004; Fisher, Aron, Mashek, Li, & Brown, 2002; Gonzaga et al., 2001; Hatfield & Rapson, 1993, 1996; Hatfield & Walster, 1978; Kaplan & Sadock, 1998; Shaver et al., 1987; Sternberg, 1986; Sternberg & Barnes, 1988; Tennov, 1979). It has also been shown that intense romantic love has stress-reducing and health-promoting potentials (Esch & Stefano, 2005).

Functional imaging is beginning to unravel the human neural correlates of intense romantic love within a subcortico–cortical reward, motivational, and emotional system (Aron et al., 2005; Bartels & Zeki, 2000; Fisher et al., 2002; Fisher, Aron, & Brown, 2005; Najib, Lorberbaum, Kose, Bohning, & George, 2004). In particular, specific brain areas, such as the medial insula (mainly on the left), the head of the caudate nucleus and the putamen (both stronger on the left), the ventral tegmental area, bilateral anterior cingulate cortex, bilateral posterior hippocampus, left inferior frontal gyrus, left middle temporal gyrus, right parietal lobe and cerebellum, showed a specific

increased activity in response to intense romantic love, as compared to friendship (Aron et al., 2005; Bartels & Zeki, 2000). Critically, a recent study investigating the correlations between BOLD responses and highly subjective feeling of love has demonstrated a positive involvement of the antero-medial caudate nucleus and the septum fornix region (Aron et al., 2005). Similarly, correlations between the degree of cerebral activation and participants' reported length of time in love have demonstrated positive activations in the right mid-insular cortex, right anterior cingulate cortex, bilateral posterior cingulate cortices, left inferior frontal gyrus, left ventral putamen/pallidum, left middle temporal gyrus, and right parietal lobe (Aron et al., 2005). Negative correlations were also found in the posterior cingulate gyrus/BA 30/retrosplenial cortex, indicating that the shorter (1–7 months) the relationship is, the greater these brain areas are activated (Aron et al., 2005).

Taken together, these results demonstrate that intense romantic love takes place within a modular network that can be differently activated according to the potential fluctuations of love (e.g., intensity). In particular, intense romantic love mainly activates brain regions with a high concentration of receptors for dopamine and a related agent, norepinephrine, i.e., the chemical messengers closely tied to states of euphoria, craving, addiction, heightened attention, or sleeplessness (Aron et al., 2005; Bartels & Zeki, 2000, 2004; Esch & Stefano, 2005; Fischer, 1998, 2004; Fisher et al., 2002, 2005).

Critically, this love-related neural network corresponds to a subcortical network that is well-known to mediate reward and motivation processes (Aron & Aron, 1991; Aron et al., 2005; Elliott, Friston, & Dolan, 2000; Esposito, Porrino, Seeger, Crane, Everist, & Pert, 1984; Hollerman, Tremblay, & Schultz, 2000). As it has been proposed for attractiveness (Kampe, Frith, Dolan, & Frith, 2001; O'Doherty, Winston, Critchley, Perrett, Burt, & Dolan, 2003), these functional imaging results reinforce the important role of both the reward and the motivational system in social interactions.

Based on these functional imaging results, it has been recently assumed that love is a goal-directed drive with predictable positive facilitation effects on cognitive behavior, rather than a pure selective emotion without any motivational or reward mechanisms (Aron et al., 2005). Given that this love-related cerebral network also occurs within both the subcortical ''unconscious'' and cortical ''conscious'' pathways that are known to interact for integrating emotions and reasoning (Fisher, 2004; LeDoux, 1996), one might also assume that intense romantic love has not only conscious but also unconscious facilitation effects on cognitive performance (Aron et al., 2005). However, to our knowledge the behavioral evidence reinforcing such an assumption has not been demonstrated yet. Thus, we specifically assessed this question within a framework of a lexical decision task embedded in a priming paradigm, which is one of the more reliable ways of observing unconscious facilitation effects if they exist.

Thus, our aim was twofold: (1) to assess whether facilitation priming effects exist for love (Experiment 1); and (2) if so, to verify whether this phenomenon depends on mechanisms that are related to a goal-directed drive leading to varied emotions, as previously predicted (Aron & Aron, 1986; Aron et al., 2005), or a specific emotion (Gonzaga et al., 2001; Shaver et al., 1987, 1996; Experiment 2).

EXPERIMENT 1

In Experiment 1, we aimed to investigate whether a subliminal presentation of a beloved's name could boost the neuronal organization of a cognitive function, such as language. We assessed this question in women passionately in love versus women ''out of'' passionate love, using a standard lexical decision task embedded in a standard subliminal priming paradigm that included different novel types of masked primes (a beloved's name; a friend's name, and a nonword; Experiment 1). Our main hypothesis was that if intense romantic passionate love activates mental representations from ''top-down'' mechanisms coming from the love-dedicated neural network, subliminal presentation of a beloved's name (''romantic love priming'') should interact with and even facilitate subsequent cognitive behavior, as previously demonstrated for other emotions (De Houwer et al., 1998, 2002; Ferguson & Bargh, 2004; Fitzsimons & Bargh, 2003; Hermans et al., 1994, 2001; Kawakami, Dovidio, & Dijksterhuis, 2003; Klauer &

Musch, 2001; Murphy & Zajonc, 1993; Shah, 2003; Wentura, 2000).

Method

Participants. In total, forty-six healthy heterosexual women, aged 18–56 years provided written informed consent to participate in the experiment. All participants were French speakers with normal or corrected-to-normal vision, no medication, and no chemical dependency, and no psychiatric or neurological illnesses. We assessed the feeling of love and their subjective feeling of being or not in an intense romantic state of love using a detailed interview based on standard questionnaires (Fisher, 2004; Hatfield & Rapson, 1993, 1996; Rubin, 1970; Sternberg, 1986; Tennov, 1979). This interview provided insights into the women's feelings about their beloved, the duration and the intensity of their love relationship, and percentage of time they think about their beloved during their waking hours.

Women in passionate love. Twenty-six healthy women, aged 18–56 years (mean 33 years) had been in love with their partner for periods ranging from 15 days to 13 years. On average, all admitted thinking about their partner over 85% of their waking hours ($M = 85.58\%$, $SD = 10.33$). All women in love were aware of being in a state of romantic passion. Phenomenologically, they declared feeling ''butterflies'' in their stomach, experiencing a pounding heart and other bodily reactions as soon as they thought of their partner. They also declared that they felt love at first sight. Subjectively, all women in love defined their romantic relationship as harmony combining with joy, trust, respect, sexual desire, as well as feelings of union and synergy with their partner. Each participant completed the standard Passionate Love Scale (PLS), a 9-point Likert scale self-report questionnaire, which measures several traits commonly associated with romantic love (Hatfield & Sprecher, 1986). PLS scores confirmed the subjective feeling of love of the participants ($M = 8.32$, $SD = 0.42$).

Women ''out-of'' passionate love (control group). Twenty healthy women, aged 23–47 years (mean 35 years) had been with their partner for periods ranging from 10 days to 30 years. In average, all admitted thinking about their partner only 36% of their waking hours ($M = 35.5\%$, $SD = 21$). All women ''out-of'' love were aware of not being in a state of romantic passion, but rather in a state of companionate love. Phenomenologically, they declared not feeling ''butterflies'' in their stomach or any other bodily manifestations when they thought of their partner. Subjectively, all women ''out-of'' love with their partner defined their relationship as amity combining with trust and respect for a partner. PLS scores confirmed the subjective feeling of the participants ($M = 6.37$, $SD = 0.98$).

A *t*-test for independent samples showed significant different PLS scores between the two groups of participants, $t(44) = 9.12$, $p < .0001$.

Procedure. Participants were instructed to indicate as rapidly and as accurately as possible whether or not a target letter-string was a French word. Responses were made by pressing one of two response buttons on a keyboard with fingers of the right hand (response ''yes'' with the index and response ''no'' with the middle). Participants were not explicitly asked to judge the emotional content of the target words. The presence of the prime was not mentioned to the participants. Participants were not aware that the lexical decision task included their beloved's name and their friend's name. To ensure that participants were not aware of the subliminal characteristics of the primes, we used an extensive debriefing procedure in which participants were asked increasingly specific questions about the study. This procedure revealed that all participants reported that they had seen flashes. However, no participant could report on the specific emotional or semantic contents of the flashes.

Apparatus. The experiment was run using E-Prime (Psychology Software Tools Inc., Pittsburgh, USA). Each trial began with a fixation cross that was presented for 500 ms and followed immediately by a masked prime stimulus and a target stimulus. The mask consisted of a row of 10 US pound signs (##########). The target stimulus appeared immediately afterward, in the same font and point size (lowercase 43 point Courier New font). The stimulus onset asynchrony (SOA; i.e., the interval between the onset of the prime and

the onset of the target) was 173 ms. A random 1200–1900 ms inter-stimulus interval separated each target presentation in order to avoid any attentional expectancy.

Stimuli and design. Three different masked primes (''beloved''; ''friend'', ''control'') were presented centrally, silver on black on a computer screen, and followed by three different target letter-strings (non-obscene positive emotional, neutral, non-words) that appeared in the same fore and background color. In total, 168 targets (three to eleven characters long) appeared for 13 ms, which was confirmed by photocell measurements (E-prime Psychology Software Tools Inc., Pittsburgh, USA) on a computer monitor located 75 cm from each participant. Targets included 112 French words (including both non-obscene positive emotional and neutral words) and 56 pronounceable non-words. The selected positive emotional (e.g., love) and neutral (e.g., fact) words had a mean usage frequency of 110 and 170 occurrences per million words, respectively (Content, Mousty, & Radeau, 1990). No significant difference in word frequency existed between the emotional and neutral words, $p = .23$; unpaired *t*-test.

Three types of primes were used—one with the name of a beloved (beloved prime); one with the name of a good friend (friend prime), and one with a pronounceable non-word (control prime). For the ''friend'' prime, each participant gave a name of a close friend of similar age, sex and duration of friendship as their partner but with the imposed condition that they did not feel any emotional, physical, or intellectual attraction for him. Each prime was associated with a visual pattern mask such that conscious detection was prevented (subliminal presentation). Each prime (four to eleven characters long) appeared for 13 ms and the mask stayed on the screen for 160 ms, which was confirmed by photocell measurements.

Statistical analysis. Mean reaction time and percent of correct response were calculated for each participant and condition. Data for each group were submitted to a $2 \times 3 \times 3$ analysis of variance (ANOVA) with Primes (beloved; friend; control) and Targets (emotional; neutral; non-words) as within-subjects, and Groups (women in love; women ''out-of'' love) as between-subjects (see Figure 1).

Results

Reaction times. Analysis of participant's reaction times revealed a significant interaction between prime and group, $F(2, 88) = 13.11$, $p < .0001$, suggesting that women are faster when stimuli are primed by a beloved's name, especially if these women are in love ($M = 600$ ms, $SE = 24.26$) vs. women ''out-of'' love ($M = 688$ ms, $SE = 27.67$). No interaction between Target and Group, $F(2, 88) = 1.54$, $p = .22$, or between Prime and Target, $F(4, 176) = 0.93$, $p = .45$, was observed. However, a significant three-way (Prime $\times$ Target $\times$ Group) interaction was obtained, $F(4, 176) = 2.54$, $p = .041$. This three-way interaction suggests that women in love are faster to detect words ($M_{\text{emotional words}} = 582.02$, $SE = 25.01$; $M_{\text{neutral words}} = 573.08$, $SE = 28.17$) than non-words ($M = 644.14$, $SE = 26.6$) in comparison with women ''out-of'' love ($M_{\text{emotional words}} = 699.24$, $SE = 28.52$; $M_{\text{neutral words}} = 693.13$, $SE = 32.12$; $M_{\text{non-words}} = 671.98$, $SE = 30.33$), especially when these stimuli are primed by a beloved's name. For ease of interpretation, Figure 1 shows this interaction.

A negative correlation was observed between PLS scores and reaction times (the more participants were in love, the faster they were) for emotional (Pearson correlation, $r = -.401$, $p = .006$) and neutral (Pearson correlation, $r = -.298$, $p = .044$) words when primed by a beloved's name. However, no correlation was found for non-words primed by a beloved's name (Pearson correlation, $r = -.087$, $p = .567$) or for emotional (Pearson correlation, $r = .021$, $p = .891$) or neutral (Pearson correlation, $r = .027$, $p = .857$) words when primed by a friend's name.

A negative correlation was also found between the percentage of daily thoughts for the partner and reaction times (the more participants thought about their beloved every day, the faster they were) for emotional (Pearson correlation, $r = -.432$, $p = .003$) or neutral (Pearson correlation, $r = -.385$, $p = .008$) words when primed by a beloved's name. However, no correlation was found for non-words primed by a beloved's name (Pearson correlation, $r = -.127$, $p = .401$) or for emotional (Pearson correlation, $r = .045$,

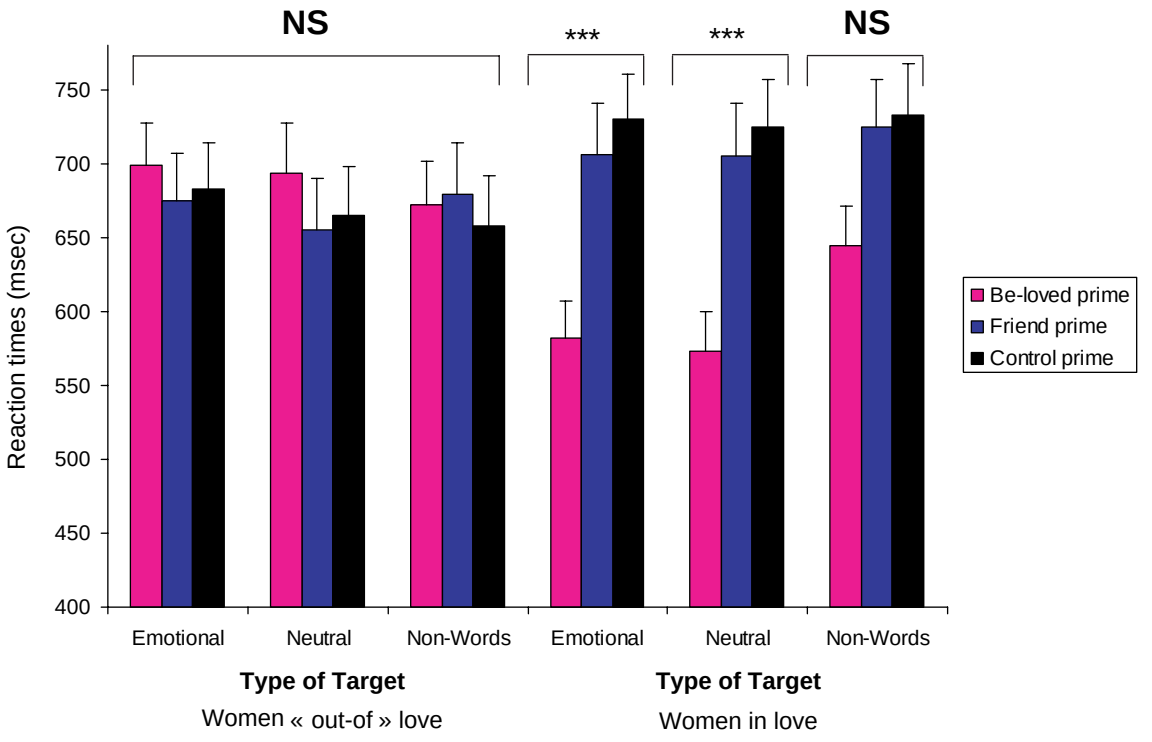

Figure 1. Mean reaction times from Experiment 1. Mean reaction times in a lexical decision task are reported for the detection of targets in link with the prior subliminal presentation of different primes for a name of the beloved (red), a name of a friend of similar age, sex and duration of friendship as the beloved (blue), or a non-word prime (black) that served as a control condition. Mean reaction time from the three experimental blocks were calculated for each condition and were submitted to an $2 \times 3 \times 3$ factorial ANOVA with Prime type (beloved, friend, or control) and Target type (emotional, neutral, or non-word) as within-subjects; and Group (in love and "out-of" love) as between-subjects. All statistical comparisons were associated with p values of less than .05 (***$p < .0001$; *$p < .05$; NS = non-significant). Error bars correspond to the standard errors of the mean of each condition individually. Results indicate that only women in love benefit from subliminal romantic love priming during decision making.

$p = .767$) or neutral (Pearson correlation, $r = .084$, $p = .577$) words when primed by a friend's name.

Accuracy. Analysis of participant's accuracy did not reveal any significant interaction between prime and group, $F(2, 88) = 0.87$, $p = .42$, or between target and group, $F(2, 88) = 0.017$, $p = .98$. However, the interaction between prime and target reached significance, $F(4, 176) = 3.62$, $p = .007$, suggesting that targets are better detected when they are primed by a beloved's name, except if they are non-words. A three-way interaction between Prime, Target and Group did not reach significance, $F(2, 88) = 1.28$, $p = .28$.

Discussion

In Experiment 1, we wanted to test whether facilitation priming effects could occur for love. The results are clear-cut. Three main results are important in this respect. First, we found that women in love were faster in detecting target stimuli when primed by a beloved's name, as compared to a friend's name. Moreover, these facilitation romantic love priming effects were only present in women in love and not in women "out-of" love. Finally, this phenomenon only occurred for word detection, suggesting that women in love are not simply faster than women "out-of" love in general but take advantage of the romantic love priming during decision making. These facilitation effects of romantic passionate love on decision making demonstrate that romantic love priming occurs at an associative level rather than a perceptual level.

The fact that these facilitation effects occur for positive emotional words is in line with previous research on affective priming suggesting that responses to target words are faster

when words are preceded by similar (vs. dissimilar) affective prime stimuli. In this sense, facilitation romantic love priming effects on positive emotional words can be explained by spreading activation accounts that assume that similarly valenced items in memory are associated with one another (e.g., Bargh et al., 1992, 1996; Collins & Loftus, 1975; Ferguson & Bargh, 2004; Fitzsimons & Bargh, 2003; Hermans et al., 1994, 2001; Innes-Ker & Niedenthal, 2002; Musch & Klauer, 2003; Niedenthal & Halberstadt, 1995; Shah, 2003; Spruyt et al., 2004). Interestingly, in the present study, these facilitation effects also occur for neutral words, which have only a conceptual relationship with primes.

Whereas this result could be interpreted as a contradictory effect of affective priming, this rather calls for automatic non-associative semantic priming, namely associative relatedness. Associative relatedness is defined as the extent to which the activation of one concept will call to mind another concept due to their repeated temporal or spatial co-occurrence (e.g., Spruyt et al., 2004). This is in agreement with recent modeling of cortical language representation that applied Hebbian principles to posit that words' representations may be segregated throughout cerebral hemispheres by their conceptual structures (see Pulvermuller, 1996, for a review). Thus, our findings reinforce our hypothesis suggesting that intense romantic love activates mental representations that are parts of that particular emotional state and thus, implicitly modulates behavior, as previously suggested for other emotions (e.g., Bargh et al., 1992, 1996; De Houwer et al., 1998, 2002; Ferguson & Bargh, 2004; Fitzsimons & Bargh, 2003; Hermans et al., 1994, 2001; Klauer & Musch, 2001; Murphy & Zajonc, 1993; Shah, 2003; Wentura, 2000). Because these significant facilitation effects of romantic love priming occurred only in women in love, one could wonder whether other stimuli that are of passionate interest to a participant might have the same beneficial effects on behavioral performance as romantic passionate love does. Moreover, based on the current theories in neuroscience, it might be of interest to determine whether romantic love priming parallels passion priming. Because passion is not only an emotion but rather a motivated desire that coexists with reason (Kant, 1798) that corresponds to a goal-directed drive (Fisher, 2004), our second hypothesis was that if passion and intense romantic love share some motivational components, subliminal presentation of passion's primes should parallel beneficial effects of romantic love's primes. Critically this similar effect should be observed only in women who are intensively in love.

In order to clarify whether facilitation effects of love are secondary not only to emotional but also to motivational influences on cognitive behavior, we introduced a novel type of priming, i.e., passion priming (Experiment 2). Although we believe that passion for a person is different to passion for sports, arts or objects, we assume that these two components might share some common mechanisms that could be observed on cognitive behavior.

EXPERIMENT 2

Method

Participants. In total, thirty-six healthy heterosexual women, aged 20.1 ± 3.1 years provided written informed consent to participate in the experiment. Participants were recruited in the same way as in Experiment 1. Moreover, all participants had a favorite passion in life (e.g., science, sport, art). In order to avoid any differences in passion's intensity between the two groups, every participant was asked to indicate a passion's descriptive noun that she thought about more than 60% of the day. Moreover, in order to verify that these selected passion's descriptive nouns did not differ in terms of number of letters, we performed an unpaired *t*-test that did not reveal any significant differences, $t(34) = 1.07$, $p = .29$, between the two groups (in love and control women).

All participants were English speakers with normal or corrected-to-normal vision, no medication, no chemical dependency, and no psychiatric or neurological illnesses.

Women in passionate love. Eighteen healthy women, mean age 20.8 ± 3.8 years (range 18 to 31 years) had been in love with their partner for periods ranging from 15 days to 36 months. In average, all admitted thinking about their partner over 82% of their waking hours ($M = 82.06$, $SD = 12.04$). All women in love were aware of

being in a state of intense romantic passion with their partner. Each participant completed the standard PLS (Hatfield & Sprecher, 1986). PLS scores confirmed the subjective feeling of love of the participants ($M = 8.49$, $SD = 0.47$).

Women "out-of" passionate love. Eighteen healthy women, mean age 19.5 ± 2.1 years (range 18 to 26 years) had been with their partner for periods ranging from 30 days to 60 months. In average, all admitted thinking about their partner only 35% of their waking hours ($M = 35.28\%$, $SD = 12.89$). All women "out-of" love were aware of not being in a state of intense romantic passion with their partner. PLS scores confirmed the subjective feeling of the participants ($M = 6.9$, $SD = 1.23$).

A *t*-test for independent samples showed significant different PLS scores between the two groups of participants, $t(34) = 5.11$, $p < .0001$.

Design and procedure. Design and procedure were identical to those of Experiment 1.

Apparatus. This experiment was carried out using Matlab 7.0.1 and Cogent 2000 developed at the Laboratory of Neurobiology and the Wellcome Department of Imaging Neuroscience, University College London. Each trial began with central presentations of a 26 ms masked-prime stimulus and a 26 ms target stimulus. As in Experiment 1, the mask consisted of a row of 10 US pound signs (##########). The target stimulus appeared immediately afterward, in the same font and point size (lowercase 43 point Courier New font). The stimulus onset asynchrony (SOA; i.e., the interval between the onset of the prime and the onset of the target) was 176 ms. A random 1500–6000 ms inter-stimulus interval separated each target presentation in order to avoid any attentional expectancy.

Stimuli. We selected as target stimuli 40 non-obscene positive emotional words from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999), and 20 pronounceable non-words.. As a control condition, 20 blank presentations were also performed. In the blank condition, participants were asked to select "non-words". Three types of primes were used—one with the name of a beloved (beloved prime); one with the name of a good friend (friend prime), and one with a name of a passion (passion prime). As in Experiment 1, for the "friend" prime, each participant gave the name of a close friend of similar age, sex and duration of friendship as their partners, but with the imposed condition that they did not feel any emotional, physical, or intellectual attraction for him. For the passion prime, each participant gave the name of a favorite hobby. The different types of stimuli, one for each condition of the 3×3 factorial design, were randomly presented in a run and ordered according to a Latin square.

Statistical analysis. Behavioral data were analyzed using a $2 \times 3 \times 3$ ANOVA with Target (word, non-word, blank) and Prime ("beloved", "friend", "passion") as within-subjects and Group (in love, "out-of" love) as between-subjects (see Figure 2).

Results

Reaction times. Analysis of participant's reaction times revealed no interaction between Target and Group, $F(2, 68) = 0.97$, $p = .38$, or between Prime and Target, $F(4, 136) = 1.91$, $p = .11$, or between Prime and Group, $F(2, 68) = 2.26$, $p = .11$.

However, a significant three-way interaction, Prime $\times$ Target $\times$ Group, $F(4, 136) = 3.25$, $p = .014$, was observed, suggesting that women are faster to detect words when they are primed by a beloved's name or a passion's descriptive noun as compared to words primed by a friend's name, especially if these women are passionately in love ($M_{\text{beloved's name}} = 526.83$ ms, $SE = 29.40$; $M_{\text{friend's name}} = 584.94$ ms, $SE = 40.55$; $M_{\text{passion's descriptive noun}} = 540.28$ ms, $SE = 31.75$). Women who were not passionately in love did not present such a pattern of response ($M_{\text{beloved's name}} = 635.50$ ms, $SE = 20.56$; $M_{\text{friend's name}} = 629.11$ ms, $SE = 23.53$; $M_{\text{passion's descriptive noun}} = 621.39$ ms, $SE = 19.43$).

Post-hoc analyses (paired *t*-test) reinforced that only women who were passionately in love took advantage of the subliminal presentation of a beloved's name during word detection as compared to a friend's name, women in passionate love, $t(17) = 3.22$, $p = .005$; women "out-of" passionate love, $t(17) = 0.72$, $p = .48$. *T*-test for independent samples reinforced this finding demonstrating that only women in love (as com-

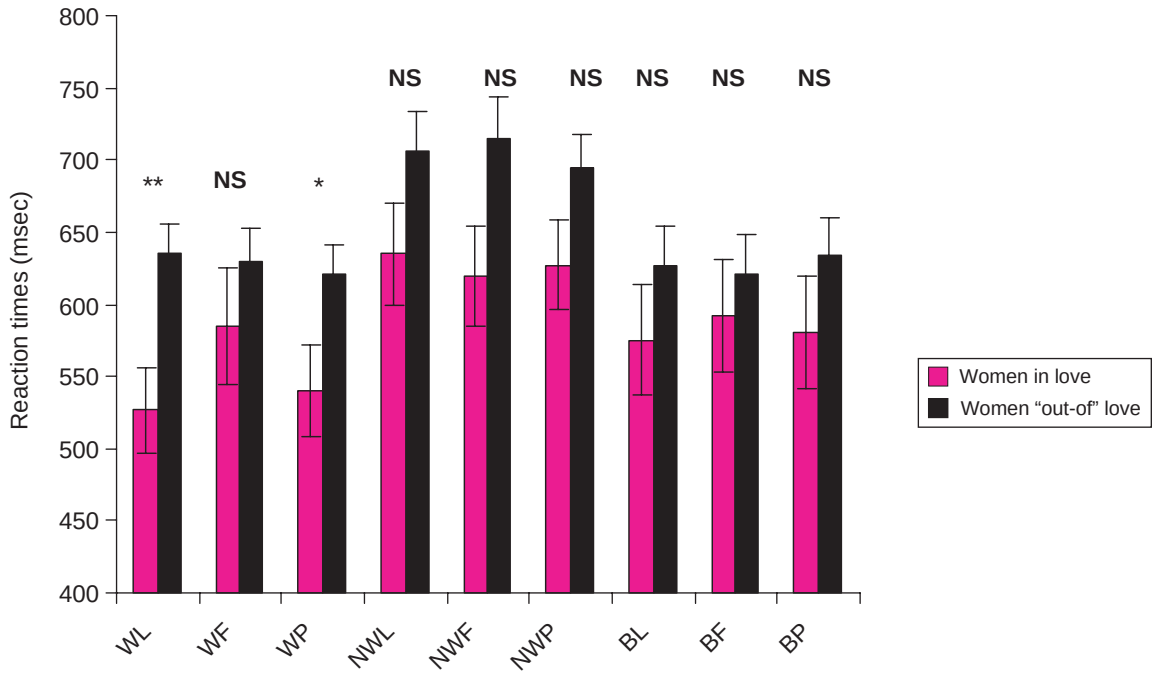

Figure 2. Mean reaction times from Experiment 2. Mean reaction times in a lexical decision task are reported for the detection of targets in the prior subliminal presentation of different primes for a name of the beloved (WL, for words, NWL for non-words and BL for blanks), a name of a friend (WF, for words, NWF for non-words and BF for blanks) and a name of a passion (WP, for words, NWP for non-words and BP for blanks). Mean reaction time from the six experimental blocks were calculated for each condition and were submitted to an $2 \times 3 \times 3$ factorial ANOVA with Prime type (beloved, friend, passion) and Target type (words, non-words, blanks) as within-subjects; and Group (in love and ''out-of'' love) as between-subjects. All statistical comparisons were associated with p values of less than .05 ($^{**}p < .005$, $^{*}p < .05$; NS = non-significant). Error bars correspond to the standard errors of the mean of each condition individually. Results indicate that only women in love benefited from both the subliminal love and passion priming during decision making.

pared to control) benefited from the facilitation effects of love primes during word detection, $t(34) = 3.03$, $p = .005$.

Interestingly, additional paired t-tests showed that both the women who were passionately in love and the women who were not passionately in love benefited from the subliminal presentation of a passion's descriptive noun [for women in passionate love: paired t-test between passion and friend primes: $t(17) = 2.59$, $p = .019$, $M_{\text{passion's descriptive noun}} = 540.28$ ms, $SE = 31.75$, $M_{\text{friend's name}} = 584.94$ ms, $SE = 40.55$; for women ''out-of'' passionate love: passion vs. love prime: $t(17) = 2.52$, $p = .02$, $M_{\text{passion's descriptive noun}} = 621.39$ ms, $SE = 19.43$, $M_{\text{beloved's name}} = 635.50$ ms, $SE = 20.56$]. Nevertheless, a t-test for independent samples showed that these facilitation effects of passion were more significant for women who were passionately in love than for women who were not passionately in love, $t(34) = 2.18$, $p = .036$. Paired t-test performed in women who were passionately in love also revealed similar facilitation effects between love and passion primes, $t(17) = 1.49$, $p = .16$.

A negative correlation was observed between PLS scores and reaction times obtained for emotional words when primed by a beloved's name (Pearson correlation, $r = -.502$, $p = .002$). No correlation was found for non-words primed by a beloved's name (Pearson correlation, $r = -.208$, $r = .223$). Surprisingly, a similar negative correlation was found for emotional words primed by a friend's name (Pearson correlation, $r = -.364$, $p = .029$). A negative correlation was also found between PLS scores and reaction times related to passion's descriptive nouns (Pearson correlation, $r = -.427$, $p = .009$).

As in Experiment 1, a negative correlation was also found between the percentage of daily thoughts for the partner and reaction times obtained for emotional words primed by a beloved's name (Pearson correlation, $r = -.555$,

$p < .0001$). No correlation was found for non-words primed by a beloved's name (Pearson correlation, $r = -.303$, $r = .073$). As in Experiment 1, no correlation was found for emotional words primed by a friend's name (Pearson correlation, $r = -.286$, $p = .091$). Interestingly, a negative correlation was found between percentage of thoughts and reaction times related to passion's descriptive nouns (Pearson correlation, $r = -.435$, $p = .008$).

Accuracy. Analysis of participant's accuracy did not reveal any interaction between prime and group, $F(2, 68) = 0.18$, $p = .84$, or between target and group, $F(2, 68) = 0.83$, $p = .44$, or between prime and target, $F(4, 136) = 0.78$, $p = .54$. Also, there was no significant three-way interaction (Prime $\times$ Target $\times$ Group), $F(4, 136) = 1.03$, $p = .39$.

Discussion

In Experiment 2, we tested the hypothesis that facilitation romantic love priming effects are sustained by common mechanisms with passion priming effects. The effects obtained support this hypothesis. First, we replicated the significant romantic love priming effects we observed in Experiment 1. As in Experiment 1, these effects were only present for women in love and for word detection. As in Experiment 1, no similar effect was observed for non-word (or blank) targets. Second, similar facilitation effects were observed with passion priming for all subjects. Because facilitation effects of passion were observed in all subjects regardless of whether they were passionately in love, our results suggest that one intense motive is enough to energize other goals. Interestingly, in respect to our hypothesis, women in love benefited similarly from love and passion primes during word detection. Moreover, women in love were significantly faster than women ''out-of'' love. Indeed, although women ''out-of'' love benefited in some way from passion priming as compared to a romantic love priming for word detection (slightly faster to detect words primed by a passion's descriptive noun), facilitation effects were much stronger (and opposite) in women in love. Our results thus depend on the internal state of the participants. Because facilitation passion priming effects parallel facilitation romantic love priming effects, we assume that love and passion share some common emotional–motivational mechanisms, as previously assumed (Aron et al., 2005; Fisher, 2004). Intense romantic love, as passion, is a motivated desire that coexists with cognition. More generally, our findings reinforced the assumption that intense romantic love, as an intense motivation, is a drive that energizes and directs behavior to acquire a particular biological need via the recruitment of dopaminergic-rich neural regions (Aron et al., 2005; Fisher, 2004; Fisher et al., 2005).

GENERAL DISCUSSION

Our results show that in women in love, subliminal affective priming including the name of their significant other (love prime) speeds their responses during a lexical decision task. Our findings reinforce the assumption that love is not simply a static state, but also a dynamic state sustained by great energy (Buss, 1988, 2003; Johnson, 1921). ''Love acts'' (Aron et al., 2005; Buss, 1988, 2003). To our knowledge, the present beneficial effect of romantic love priming on language has not been described before. On the basis of recent neuroimaging data, we assume that these results reflect an increase of cerebral brain activity within the dopaminergic system (Aron et al., 2005; Bartels & Zeki, 2000). In particular, the caudate nucleus, which is known to play a crucial role in reward detection, expectation, representation of goals, and integration of sensory inputs, could play a significant role in the preparation for action (Aron et al., 2005; Lauwereyns, 2006; O'Doherty, 2004).

Taken together, the present results are of particular interest because love primes and target words do not share any close emotional properties, but only distant conceptual–semantic characteristics. The fact that the facilitation effects occur only for meaningful words (as compared to non-words) indicates that women who are in passionate love are not inherently faster than women who are ''out of'' passionate love whatever the target stimulus but they are faster because of the mental associations they have unconsciously created in their minds in relation to their internal state of being in love. This indicates that subliminal romantic associations are sufficient to lead to automatic conceptual primings on the basis of associative relatedness. As such, our results are

consistent with theoretical accounts of priming effects that demonstrate not only evidence of automatic associative semantic priming (e.g., Dehaene et al., 1998; Ferguson & Bargh, 2004; Fitzsimons & Bargh, 2003; Naccache & Dehaene, 2001; Niedenthal & Halberstadt, 1995, 1997; Shah, 2003; Wig, Grafton, Demos, & Kelley, 2005), but also evidence of non-associative semantic priming (Niedenthal & Halberstadt, 1995, 1997; Spruyt et al., 2004). Our findings demonstrate that priming effects of intense romantic love thus correspond to an associative state rather than pure reflex emotional feelings, as it has been suggested for other facilitation priming effects (Dehaene et al., 1998; Eimer & Schlaghecken, 2003; Ferguson & Bargh, 2004; Fitzsimons & Bargh, 2003; Henson, 2003; Hulme, Roodenrys, Schweickert, Brown, & Mercer, 1995; Innes-Ker & Niedenthal, 2002; Shah, 2003).

In other words, we understand our results as reflecting a general effect of the state of being in love rather than a domain-specific effect having to do with emotions per se.

As such, we interpret these facilitation effects of subliminal romantic love as corresponding to cognitive top-down processes that occur from affective [romantic]-associations stored in long-term memory. In this sense, we assume top-down processes to occur within a love-enhanced neural network to visual word form areas.

The results that we obtained in Experiment 2 support this. These findings reinforce the assumption that love, like passion, is a goal-directed state that induces various emotions rather than a specific emotion without any motivational or reward components (Aron & Aron, 1986; Aron et al., 2005; Fisher, 1998, 2004). Because love primes have similar beneficial effects as passion primes (love primes and passion primes) in women in love, one might indeed conclude that facilitation priming effects are due to implicit automatic spreading of activation from both [emotional] romantic-associations stored in long-term memory and [motivational] passion-associations, at least in women in love. In this sense, the present study demonstrates a causal linkage between the state of being in love and human cognition.

Furthermore, the fact that only women intensively in love benefited from both passion and romantic love priming indicates that it is not only the type of prime that is important, but also the state of the participants. In other words, women in love seem to react to any stimuli that are salient for their state. Our findings give further support to the assumption that intense romantic love corresponds to a functionally specialized brain system, which is a modular system that converges onto cerebral regions storing motivating stimuli and memories dependent on the individual and the context (see Aron et al., 2005, for a review). In this respect, intense romantic love has an overall effect on cognition.

CONCLUSION

The present study stresses that the functional organization of the human brain can be modulated not only by elementary emotional states, but also by one of the most tremendous and conceptual emotional state of human endeavors, i.e., intense romantic love. Moreover, our findings reinforce the well-assumed involvement of love within an emotion-motivation system by demonstrating its overall effect on cognition (Aron & Aron, 1986; Aron et al., 2005; Fisher, 1998, 2004; Fisher et al., 2005). Our findings thus emphasize how a state related to social interactions can automatically influence behavior (e.g., Ferguson & Bargh, 2004; Fitzsimons & Bargh, 2003; Murphy & Zajonc, 1993), at least in women in love. Whereas the value of neuroscience for emotion (e.g., Cacioppo, 2004; LeDoux, 1996; Norris, Chen, Zhu, Small, & Cacioppo, 2004) and the psychology of love (e.g., Brehm et al., 2002; Buss, 2003; Fisher, 2004; Hatfield & Rapson, 1996; Sternberg, 1986; Sternberg & Barnes, 1988; Tennov, 1979) are widely accepted, our present findings reveal that the neuroscience of love might also offer a new avenue to a human being's behavioral cognition.

Manuscript received 18 December 2005
Manuscript accepted 11 June 2006
First published online 6 October 2006

REFERENCES

Aron, A., & Aron, E.N. (1986) *Love and the expansion of self: Understanding attraction and satisfaction*. New York: Hemisphere.

Aron, A., & Aron, E. N. (1991). Love and sexuality. In K. McKinney & S. Sprecher (Eds.), *Sexuality in close*

relationships (pp. 25–48). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

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*, 327–337.

Bargh, J. A., Chaiken, S., Govender, R., & Pratto, F. (1992). The generality of the automatic attitude activation effect. *Journal of Personality and Social Psychology*, *62*, 893–912.

Bargh, J. A., Chaiken, S., Raymond, P., & Hymes, C. (1996). The automatic evaluation effect: Unconditional automatic attitude activation with a pronunciation task. *Journal of Experimental Social Psychology*, *32*, 185–210.

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

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

Berscheid, E., & Meyers, S. A. (1996). A social categorical approach to a question about love. *Personal Relationships*, *3*, 19–43.

Bradley, M. M., & Lang, P. J. (1999). *Affective norms for English words (ANEW): Stimuli, instruction manual and affective ratings.* Technical report C-1, Gainesville, FL: The Center for Research in Psychophysiology, University of Florida.

Brehm, S. S., Miller, R., Perlman, D., & Miller Campbell, S. (2002). *Intimate relationships* (3rd ed.). New York: McGraw-Hill.

Buss, D. M. (1988). Love acts. The evolutionary biology of love. In J. S. Sternberg & M. L. Barnes (Eds.), *The psychology of love*. New Haven, CT: Yale University Press.

Buss, D. M. (2003). *The evolution of desire* (rev. ed). New York: Basic Books.

Cacioppo, J. T. (2004). Feelings and emotions: Roles for electrophysiological markers. *Biological Psychology*, *67*, 235–243.

Clark, M. S., & Mills, J. (1979). Interpersonal attraction in exchange and communal relationships. *Journal of Personality and Social Psychology*, *37*, 12–24.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*, 407–428.

Content, A., Mousty, P., Radeau, M. (1990). Brulex: Une base de données lexicales informatisées pour le français écrit et parlé. *L'année psychologique*, *90*, 551–566.

De Houwer, J., Hermans, D., & Eelen, P. (1998). Affective and identity priming with episodically associated stimuli. *Cognition & Emotion*, *12*, 145–169.

De Houwer, J., & Randell, T. (2002). Attention to primes modulates affective priming of pronunciation responses. *Experimental Psychology*, *49*, 163–170.

Dehaene, S., Naccache, L., Cohen, L., Bihan, D. L., Mangin, J. F., Poline, J. B., et al. (2001). Cerebral mechanisms of word masking and unconscious repetition priming. *Nature Neuroscience*, *4*, 752–758.

Dehaene, S., Naccache, L., Le Clec'H, G., Koechlin, E., Mueller, M., Dehaene-Lambertz, G., et al. (1998). Imaging unconscious semantic priming. *Nature*, *395*, 597–600.

Eimer, M., & Schlaghecken, F. (1998). Effects of masked stimuli on motor activation: Behavioral and electrophysiological evidence. *Journal of Experimental Psychology*, *24*, 1737–1747.

Eimer, M., & Schlaghecken, F. (2003). Response facilitation and inhibition in subliminal priming. *Biological Psychology*, *64*, 7–26.

Elliott, R., Friston, K. J., & Dolan, R. J. (2000). Dissociable neural responses in human reward systems. *Journal of Neuroscience*, *20*, 6159–6165.

Esch, T., & Stefano, G. B. (2005). The neurobiology of love. *Neuroendocrinology Letters*, *26*, 175–192.

Esposito, R. U., Porrino, L. J., Seeger, T. F., Crane, A. M., Everist, H. D., & Pert, A. (1984). Changes in local cerebral glucose utilization during rewarding brain stimulation. *Proceedings of the National Academy of Sciences, USA*, *81*, 635–639.

Fazio, R. H. (2001). On the automatic activation of associated evaluations: An overview. *Cognition & Emotion*, *15*, 115–141.

Fazio, R. H., Sanbonmatsu, D. M., Powell, M. C., & Kardes, F. R. (1986). On the automatic activation of attitudes. *Journal of Personality and Social Psychology*, *50*, 229–238.

Ferguson, M. J., & Bargh, J. A. (2004). How social perception can automatically influence behavior. *Trends in Cognitive Sciences*, *8*, 33–39.

Fisher, H. E. (1998). Lust, attraction and attachment in mammalian reproduction. *Human Nature*, *9*, 23–52.

Fisher, H. E. (2004). *Why we love.* New York: Henry Holt.

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*, 413–419.

Fisher, H. E., Aron, A., & Brown, L. L. (2005). Romantic love: An fMRI study of a neural mechanism for mate choice. *Journal of Comparative Neurology*, *493*, 58–62.

Fitzsimons, G. M., & Bargh, J. A. (2003). Thinking of you: Nonconscious pursuit of interpersonal goals associated with relationship partners. *Journal of Personality and Social Psychology*, *84*, 148–164.

Gonzaga, G. C., Keltner, D., Londahl, E. A., & Smith, M. D. (2001). Love and the commitment problem in romantic relations and friendship. *Journal of Personality and Social Psychology*, *81*, 247–262.

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

Hatfield, E., & Rapson, R. L. (1996). *Love and sex: Cross-cultural perspectives.* Boston: Allyn & Bacon.

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

Hatfield, E., & Walster, G. W. (1978). *A new look at love.* New York: Addison Wesley.

Henke, K., Landis, T., & Markowitsch, H. J. (1994). Subliminal perception of words and faces. *International Journal of Neuroscience*, *75*, 181–187.

Henson, R. N. A. (2003). Neuroimaging studies of priming. *Progress in Neurobiology*, *70*, 53–81.

Hermans, D., De Houwer, J., & Eelen, P. (1994). The affective priming effect: Automatic activation of evaluative information in memory. *Cognition & Emotion*, *8*, 515–533.

Hermans, D., De Houwer, J., & Eelen, P. (2001). A time course analysis of the affective priming effect. *Cognition & Emotion*, *15*, 143–165.

Hollerman, J. R., Tremblay, L., & Schultz, W. (2000). Involvement of basal ganglia and orbitofrontal cortex in goal-directed behavior. *Progress in Brain Research*, *126*, 193–215.

Hulme, C., Roodenrys, S., Schweickert, R., Brown, G. D. A., Mercer, R. (1995). The role of long-term memory in memory span. *British Journal of Psychology*, *86*, 527–536.

Innes-Ker, A., & Niedenthal, P. M. (2002). Emotion concepts and emotional states in social judgment and categorization. *Journal of Personality and Social Psychology*, *83*, 804–816.

Johnson, R. A. (1921). *We: Understanding the psychology of romantic love*. New York: Harper & Row.

Kampe, K. K. W., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Reward value of attractiveness and gaze reinforcing stimuli that serve basic survival. *Nature*, *413*, 589–602.

Kant, I. (1974). *Anthropology from a pragmatic point of view* (M. J. Gregor, Trans.). The Hague, Netherlands: Martinus Nijhoff. (Original work published in 1798.)

Kaplan, H. I., & Sadock, B. J. (1998). Human sexuality. In K. C. Millet (Ed.), *Synopsis of psychiatry* (8th ed., pp. 676–719). MD: Williams & Wilkins.

Kawakami, K., Dovidio, J. F., & Dijksterhuis, A. (2003). Effect of social category priming on personal attitudes. *Psychological Science*, *14*, 315–319.

Klauer, K. C., & Musch, J. (2001). Does sunshine prime loyal? Affective priming in the naming task. *Quarterly Journal of Experimental Psychology*, *54A*, 727–751.

Lauwereyns, J. (2006). Voluntary control of unavoidable action. *Trends in Cognitive Sciences*, *10*, 47–49.

LeDoux, J. (1996). *The emotional brain*. New York: Simon & Schuster.

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

Morris, J. S., Ohman, A., & Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating ''unseen'' fear. *Proceedings of the National Academy of Sciences, USA*, *96*, 1680–1685.

Murphy, S. T., & Zajonc, R. B. (1993). Affect, cognition, and awareness: Affective priming with optimal and suboptimal stimulus exposures. *Journal of Personality and Social Psychology*, *64*, 723–739.

Musch, J., & Klauer, K. C. (2003). *The psychology of evaluation*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Naccache, L., & Dehaene, S. (2001). Unconscious semantic priming extends to novel unseen stimuli. *Cognition*, *80*, 15–29.

Najib, A., Lorberbaum, J. P., Kose, S., Bohning, D. E., & George, M. S. (2004). Regional brain activity in women grieving a romantic relationship breakup. *American Journal of Psychiatry*, *161*, 2245–2256.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology*, *106*, 226–254.

Neumann, O., & Klotz, W. (1994). Attention and performance. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance* (pp. 123–150). Cambridge, MA: MIT Press.

Niedenthal, P. M., & Halberstadt, J. B. (1995). The acquisition and structure of emotional response categories. In D. L. Medin (Ed.), *The psychology of learning and motivation* (Vol. 33, pp. 23–64). New York: Academic Press.

Niedenthal, P. M., & Halberstadt, J. B. (1997). Emotional state and the use of stimulus dimensions in judgement. *Journal of Personality and Social Psychology*, *72*, 1017–1033.

Norris, C. J., Chen, E. E., Zhu, D. C., Small, S. L., & Cacioppo, J. T. (2004). The interaction of social and emotional processes in the brain. *Journal of Cognitive Neuroscience*, *16*, 1818–1829.

O'Doherty, J. P. (2004). Reward representations and reward-related learning in the human brain: Insights from neuroimaging. *Current Opinion in Neurobiology*, *14*, 769–776.

O'Doherty, J., Winston, J., Critchley, H., Perrett, D., Burt, D. M., & Dolan, R. J. (2003). Beauty in a smile: The role of medial orbitofrontal cortex in facial attractiveness. *Neuropsychologia*, *41*, 147–155.

Posner, M. I., & Snyder, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In P. Rabbitt & F. Dornic (Eds.), *Attention and performance* (Vol. V). New York: Academic Press.

Pulvermuller, F. (1996). Hebb's concept of cell assemblies and the psychophysiology of word processing. *Psychophysiology*, *33*, 317–333.

Reynvoet, B., Gevers, W., & Caessens, B. (2005). Unconscious primes activate motor codes through semantics. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *31*, 991–1000.

Rossell, S. L., & Nobre, A. C. (2004). Semantic priming of different affective categories. *Emotion*, *4*, 354–363.

Rubin, Z. (1970). Measurement of romantic love. *Journal of Personality and Social Psychology*, *16*, 265–273.

Shah, J. (2003). The motivational looking glass: How significant others implicitly affect goal appraisals. *Journal of Personality and Social Psychology*, *85*, 424–439.

Shaver, P. R., Morgan, H. J., & Wu, S. (1996). Is love a ''basic'' emotion. *Personal Relationships*, *3*, 81–96.

Shaver, P., Schwartz, J., Kirson, D., & O'Connor, C. (1987). Emotion knowledge: Further exploration of a prototype approach. *Journal of Personality and Social Psychology*, *52*, 1061–1086.

Spruyt, A., Hermans, D., De Houwer, J., & Eelen, P. (2004). Automatic non-associative semantic priming: Episodic affective priming of naming responses. *Acta Psychologica (Amst)*, *116*, 39–54.

Stapel, D. A., & Koomen, W. (2005). When less is more: The consequences of affective primacy for subliminal priming effects. *Personality and Social Psychology Bulletin*, *31*, 1286–1295.

Sternberg, J. S. (1986). A triangular theory of love. *Psychological Review*, *93*, 119–135.

Sternberg, J. S., & Barnes, M. L. (1988). *The psychology of love*. New Haven, CT: Yale University Press.

Taylor, J. L., & McCloskey, D. L. (1990). Triggering of preprogrammed movements as reactions to masked stimuli. *Journal of Neurophysiology*, *63*, 439–446.

Tennov, D. (1979). *Love and limerence: The experience of being in love*. New York: Stein & Day.

Troy, A. B. (2005). Romantic passion as output from a self-regulating, intimacy-seeking system: A model for understanding passionate love. *Psychological Reports*, *96*, 655–675.

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science*, *247*, 301–306.

Wentura, D. (2000). Dissociative affective and associative priming effects in the lexical decision task: Yes versus no responses to word targets reveal evaluative judgment tendencies. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *26*, 456–469.

Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *Journal of Neuroscience*, *18*, 411–418.

Wig, G., Grafton, S. T., Demos, K. E., & Kelley, V. M. (2005). Reductions in neural activity underlie behavioral components of repetition priming. *Nature Neuroscience*, *8*, 1228–1230.