Correlation between insula activation and self-reported quality of orgasm in women

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Current multidimensional models of women's sexual function acknowledge the implicit impact of psychosocial factors on women's sexual function. Interaction between human sexual function and intensity of love has been also assumed, even if love is not an absolute condition. Yet, whereas great insights have been made in understanding the central mechanisms of the peripheral manifestations of women's sexual response, including orgasm, the cerebral correlates sustaining the interaction between women's sexual satisfaction and the unconscious role of the partner in this interpersonal experience remain unknown.

Using functional imaging, we assessed brain activity elicited when 29 healthy female volunteers were unconsciously exposed to the subliminal presentation of their significant partner's name (a task known to elicit a partner-related neural network) and correlated it with individual scores obtained from different sexual dimensions: self-reported partnered orgasm quality (ease, satisfaction, frequency), love intensity and emotional closeness with that partner.

Behavioral results identified a correlation between love and self-reported partnered orgasm quality. The more women were in love/emotionally close to their partner, the more they tended to report being satisfied with the quality of their partnered orgasm. However, no relationship was found between intensity of love and partnered orgasm frequency.

Neuroimaging data expanded these behavioral results by demonstrating the involvement of a specific left-lateralized insula focus of neural activity correlating with orgasm scores, irrespective of dimension (frequency, ease, satisfaction). In contrast, intensity of being in love was correlated with a network involving the angular gyrus.

These findings strongly suggest that intimate and sexual relationships are sustained by partly different mechanisms, even if they share some emotional-related mechanisms. The critical correlation between self-reports of orgasm quality and activation of the left anterior insula, a part of the partner-related neural network known to play a pivotal role in somatic processes, suggests the importance of somatic information in the integration of sexual experience. On the other hand, the correlation between activation of the angular gyrus and love intensity reinforces the assumption that the representation of love calls for higher order cognitive levels, such as those related to the generation of abstract concepts. By highlighting the specific role of the anterior insula in the way women integrate components of physical satisfaction in the context of an intimate relationship with a partner, the current findings take a step in the understanding of a woman's sexual pleasure.
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Introduction

Throughout the ages, philosophers, anthropologists, writers, anatomists, psychiatrists and sexologists have tried to decipher the sense, nature and function of a woman's sexual pleasure (such as orgasm, e.g., Kaplan, 1974, 1979; Kinsey et al., 1953; Lloyd, 2005; Mah and Binik, 2001; Masters and Johnson, 1966; Symons, 1979). However, the underlying mechanisms of a woman's sexual pleasure remain poorly understood. This is an important issue given the high number of women and couples who have concerns about the female orgasm (e.g., for a review, see Ortigue and Bianchi-Demicheli, 2006). Five to ten percent of adult women in the United States have never experienced orgasm by any means of partner stimulation (Spector and Carey, 1990). Moreover, many inter- and intra-individual differences exist in terms of number of orgasms, frequency and preferred partner (Bianchi-Demicheli and Ortigue, 2007; Darling et al., 1991; Ladas et al., 1982; Levin, 1981; Levin and Wagner, 1985; Mah and Binik, 2001; Masters and Johnson, 1966; Meston et al., 2004; Ortigue and Bianchi-Demicheli, 2006). These inter- and intra-individual differences clearly highlight the potential implicit role that cognitive and

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emotional factors can play during sexual relationships (Bancroft, 1989; Bancroft et al., 2003; Basson, 2000, 2005; Kaplan, 1974, 1979; Mah and Binik, 2005; Masters and Johnson, 1966; Whipple and Brash-McGreer, 1997).

Recently several efforts have been made to better understand the numerous psychosocial factors that may interact with the complexity of a woman's sexual pleasure (e.g., Mah and Binik, 2001, 2005). Current models of women's sexual function incorporate the importance of a variety of interpersonal, contextual and psychological factors, such as emotional intimacy, relationship satisfaction, sexual stimuli and previous sexual experiences (e.g., Bancroft, 1989, 2003; Basson, 2000, 2001, 2002, 2005; Bianchi-Demicheli and Ortigue, 2007; Kaplan, 1974, 1979; Masters and Johnson, 1966; Mah and Binik, 2001, 2005; Whipple and Brash-McGreer, 1997). Bancroft et al. (2003) found in a national survey of 987 women, that emotional well-being and the quality of a relationship with a partner had more effects on sexuality than aging. Similarly, a close interaction between the intensity/satisfaction of love (as a major source of heightened emotional experience) and human sexual function is often assumed, even if love is not an absolute condition to reach orgasm (e.g., Brehm et al., 2002; Buss, 2003; Fisher, 2004; Komisaruk and Whipple, 1998; Mah and Binik, 2005). Does it mean that sexual pleasure and love intensity share the same neural basis? Although sexual pleasure and love may be experienced in concert, they are fundamentally distinct subjective experiences (e.g., Fisher, 2004). As an abstract concept, love is often considered as a higher order cognitive representation of the mind that may include both cognitive (e.g., planification of actions; Buss, 2003; Bianchi-Demicheli et al., 2006) and autonomic manifestations (e.g., the so-called butterflies in the stomach; Bianchi-Demicheli et al., 2006; Fisher, 2004). On the other hand, sexual pleasure is mainly based on somatic phenomena (Bianchi-Demicheli et al., 2006; Ortigue and Bianchi-Demicheli, 2006). In light of this, the neural substrates of love intensity and orgasm may not be the same, even if these mechanisms may interact in some ways. Yet, the neural basis underlying the interaction between love intensity and a woman's sexual experience remain unknown.

Only recently has the complexity of female orgasm become a focus for neuroscience (Bianchi-Demicheli and Ortigue, 2007; Komisaruk et al., 2004; Levin and van Berlo, 2004; Mah and Binik, 2001, 2005; McKenna, 1999; Meston et al., 2004; Ortigue and Bianchi-Demicheli, 2006; Rowland, 2006). To date, only one published fMRI study has reported preliminary evidence for a specific neural network of women's orgasm while participants were submitted to passive cervical self-stimulations during scanner sessions (Komisaruk et al., 2004). In Komisaruk et al.'s study (2004), induced orgasmic response was characterized over time by an overwhelmingly activation of a distributed neural network known to be involved in a wild variety of cognitive functions, such as those sustaining some psychosocial dimensions. Most critically, the early stages of the induced orgasmic experience were characterized by the activation of brain areas known to play a pivotal role in the integration of emotional somatic experiences (e.g., insula; Komisaruk et al., 2004). Such results tend to suggest some functional interactions between bodily states (as represented in somatosensory areas) and higher order cognitive processes (Damasio, 1994). However, the cerebral network sustaining the implicit link between cognitive/emotional factors and subjective woman's orgasm quality ratings remains poorly understood. A more definitive test of a psychosocial theory of women's sexual function would involve assessing women's orgasm in the context of a socio-emotional task, irrespective of orgasm-related motor confounds (such as general online arousal, direct sensory inputs or motor activity that may be induced during online rhythmic contractions).

Here we used an event-related fMRI design to assess the brain activity elicited when 29 healthy female volunteers who were in a stable relationship with a partner were unconsciously exposed to a behavioral task known to identify a partner-related neural network (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007), and we correlated it with individual scores obtained from a standard female sexual functioning questionnaire (Rosen et al., 2000). Based on the somatic marker hypothesis, which suggests that an emotional experience can guide future behaviors (Damasio, 1994, 1996), we hypothesize that the neural mechanisms taking place in the early stages of an orgasm experience may also influence future sexual-related experiences, such as orgasm quality ratings (as assessed by self-report questionnaires about satisfaction, frequency and ease). In other words, we assume the neural correlates of self-report orgasm quality ratings to be partly similar to those sustaining orgasm experience.

In order to better understand the implicit link between self-reported orgasm quality ratings and love intensity/emotional intimacy within this population, individual scores about love intensity (standard passionate love scale; Hatfield and Sprecher, 1986) and satisfaction of emotional closeness with the partner during sexual activity were also considered (Rosen et al., 2000). In this framework of a partner-related network, we thus assessed the potential overlapping substrates for subliminal partner-related neural responses, women's representation of orgasm quality ratings (as assessed by self-report questionnaires about satisfaction, frequency and ease), intensity of love and satisfaction of emotional closeness with their partner. Even if it is of course clear that being in a stable relationship or being in love is not a prerequisite to reach orgasm, a growing body of evidence suggests that a partner-related cerebral network may involve brain areas that have been also reported to be recruited in the orgasm-related cerebral network (Aron et al., 2005; Bartels and Zeki, 2000; Bianchi-Demicheli and Ortigue, 2007; Komisaruk et al., 2004; Ortigue et al., 2007). Thus, we hypothesize that a significant relationship may exist between the cerebral correlates of self-report partnered orgasm quality ratings, and at least one of the brain regions located within the putative partner-related neural network.

Materials and methods

Participants

Twenty-nine healthy heterosexual women (aged 20.41±3.42 (SD) years) participated in the present study. All participants were recruited from the Dartmouth College student population on the basis of advertisements indicating that experimenters were seeking individuals who were currently intensively in love with one partner. All participants were dating, engaged or married to their partner for an average of 16.4 months. They were right-handed (Edinburgh Handedness Inventory, Oldfield, 1971) and had normal or corrected-to-normal vision, no antidepressant medication and no chemical dependency. All participants were without any symptoms of psychiatric disorders, as ascertained by a structured clinical interview (Brief Psychiatric Rating Scale; Overall and Gorham, 1962) carried out by a clinical neuropsychologist (SO). Moreover, the anamnesis did not reveal any history of psychiatric disorders, traumatic brain injury with loss of consciousness, epilepsy, neuro-

logical impairment or degenerative neurological illness. All participants provided written informed consent to participate in the experiment, which was approved by the Committee for Protection of Human Subjects at Dartmouth College.

Procedure

Questionnaires

The measure of the subjective feelings of love was assessed with the standard Passionate Love Scale (PLS), a 9-point Likert scale self-report questionnaire (Hatfield and Sprecher, 1986). All participants were in love with their partner as assessed by the PLS (score = 7.6 ± 1.28 (SD)).

To assess the women's subjective experience about orgasm with their partner, we asked participants to complete standard questions about whether (and to what degree) they reached orgasm with their partner (Female Sexual Functioning Index, FFSI; Rosen et al., 2000). These questions were part of the standardized Female Sexual Functioning Index, a self-report measure of sexual functioning that has been validated on a clinically diagnosed sample of 259 women with female arousal disorder (Rosen et al., 2000; Meston, 2003). These questions investigate women's orgasm experience according to three dimensions: i.e., the ease with which a woman experiences orgasm during intercourse or masturbation with the partner (orgasm ease); the frequency of orgasm (orgasm frequency); and how satisfied a woman is with her ease of achieving orgasm with a partner (orgasm satisfaction). On average, participant's FSFI scores were in the normal range (mean: 4.03 ± 1.88 (SD)).

Participants also completed an FSFI question assessing their degree of satisfaction with their emotional closeness (EC) with their partner. On average, participant's FSFI scores were in the normal range (mean: 4 ± 1.6 (SD)).

fMRI recordings

During the scanner session, participants were instructed to perform one of our standard tasks known to assess the unconscious mental representation of their partner (Bianchi-Demicheli et al., 2006; Ortigue et al., 2007). During this visual lexical decision task, which is embedded in a subliminal priming paradigm, participants were asked to indicate as rapidly and as accurately as possible whether or not an English word was presented on that trial. Responses were made by pressing one of two response buttons on a keyboard with fingers of the right hand (response "yes" with the index to words and response "no" with the middle to non-words or blanks). The visual stimulus on each trial was composed of a sequence of three frames, following a standard subliminal priming paradigm (Fig. 1A). First, a prime word was presented for 26 ms, followed by a mask of ########## symbols for 150 ms and then a target stimulus for 26 ms. Stimulus onset asynchrony (SOA; i.e., the interval between the onset of the prime and the onset of the target) was 176 ms. Trials were separated by an inter-stimulus interval randomly chosen between 1500 ms and 6000 ms. All stimuli were presented using Cogent 2000 running in Matlab 7.0.1 under Windows XP, which provides millisecond control of display durations and accurate recordings of reaction times. Stimuli appeared in lowercase 43-point Courier New font, in white on a black background.

Each trial was composed of one of three primes together with one of 40 words, or 1 of 40 non-words, or one of 40 'blank' trials, giving a total of 360 possible trials (Fig. 1B; Bianchi-Demicheli et al., 2006). Each of the possible trials was then randomly assigned to one of six blocks by means of a Latin hypercube sampling, which ensures that each block contained an equal number of each prime, and an equal number of words, non-words and blanks. A different suit of random trial order was used for every participant. A target stimulus was not presented twice in the same block in order to avoid any effects of familiarization. In addition, trial order within a block was pseudo-randomized with the constraint of no more than three consecutive trials with the same target type. Each participant performed six blocks with 60 trials in each block, for a total of 360 trials, which took up to 40 min including breaks between each block.

Stimuli

The 80 target letter-string stimuli (three to eleven characters long) included 40 positive emotional English nouns and a set of 40 pronounceable non-words (following the same consonant/vowel structure as words; Bianchi-Demicheli et al., 2006). Emotional words were selected from the Affective Norms for English Words (Bradley and Lang, 1999) and the Kucera and Francis linguistic database (Kucera and Francis, 1967; Coltheart, 1981; for further details see Bianchi-Demicheli et al., 2006). Three types of primes were used—a beloved partner's name (love prime); two control stimuli: a neutral acquaintance's name (acquaintance prime); and a noun describing their favorite hobby in life (hobby prime). No difference in name length between love, acquaintance and hobby primes was observed ($F(2,70) = 2.69$; $p = 0.08$). To ensure the validity of the control condition, we imposed the condition that the participant did not feel any emotional, physical or intellectual attraction for the selected name of the acquaintance that corresponded to a person of similar age, sex and duration of knowledge as their beloved partner.

The presence of the primes was not mentioned to the subjects. To ensure that participants were not aware of the type of prime stimuli, 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.

Magnetic resonance imaging

Imaging was performed with a 3T Philips MRI scanner using an 8-channel phased array head coil. For each functional run, an echo planar gradient echo imaging sequence sensitive to blood oxygenation-level-dependent contrast was used to acquire 30 slices per TR (4 mm thickness, 0.5 mm gap), with a TR of 1976 ms, TE of 35 ms, flip angle of 90°, field of view of 240 mm and 80 × 80 matrix. One hundred fifty-seven whole brain images were collected in each run. After all the functional runs, a high-resolution T1-weighted image of the whole brain was acquired using a spoiled gradient recalled 3D sequence (TR = 9.9 ms; TE = 4.6 ms; flip angle = 8°; FOV = 240 mm; slice thickness = 1 mm; matrix = 256 × 256).

Functional image processing

Data processing was carried out in SPM2 (http://www.fil.ion.ucl.ac.uk/spm). Structural MRI images were only used to visually detect any individual anatomical anomaly. Functional images were realigned to correct for head movement. Then, data were co-
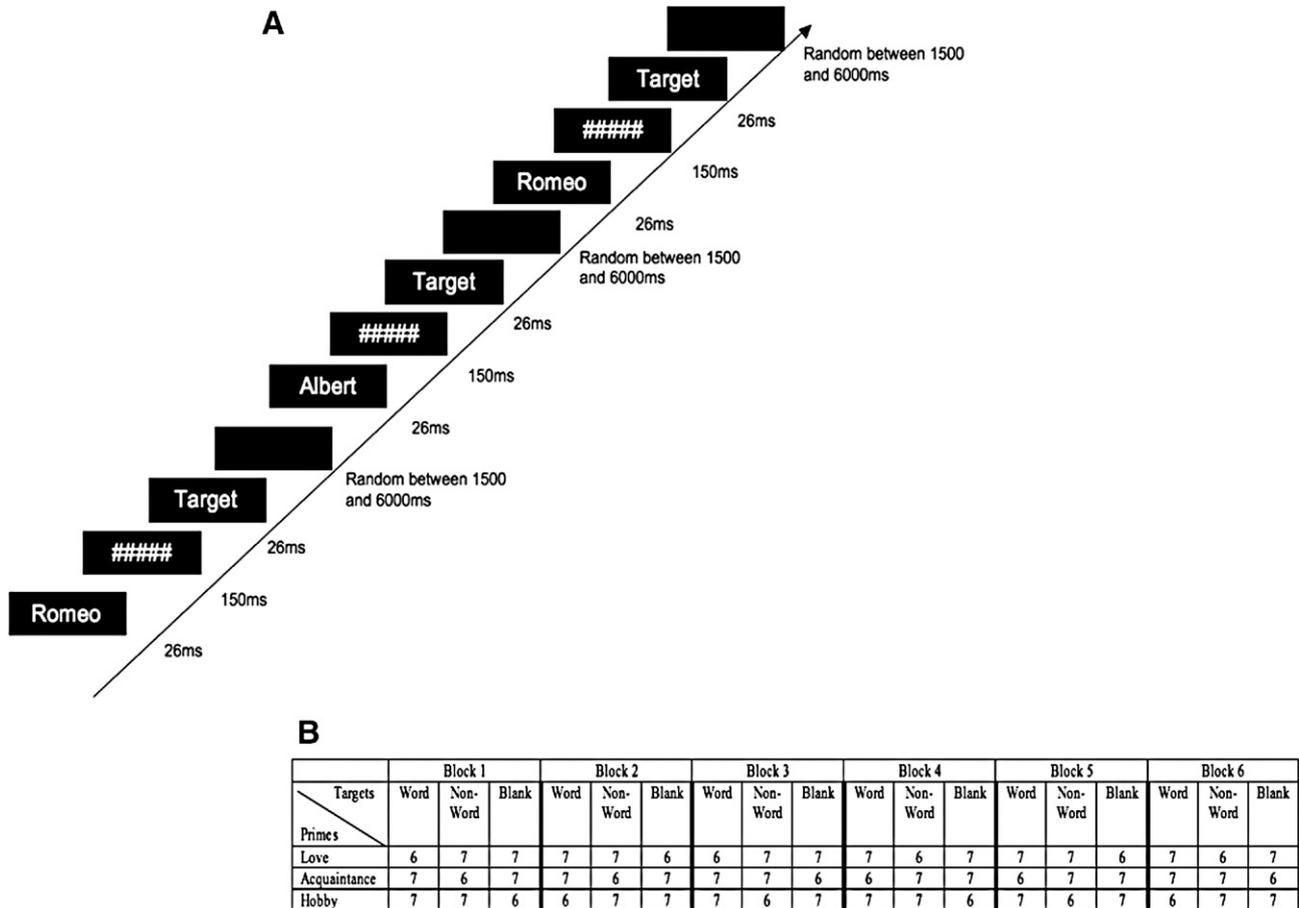
Fig. 1. (A) Experimental design. Stimulus sequence. The visual stimulus on each trial was composed of a sequence of three frames. First, a prime word (a beloved's name, e.g., Romeo; and two control stimuli: an acquaintance's name, e.g., Albert, and a hobby descriptor, e.g., Piano) was presented for 26 ms, followed by a mask of ######### symbols for 150 ms and then the target word (words, non-words, blanks) for 26 ms. Subjects were not informed of the presence of the prime. (B) Factorial design. All the trials in our factorial design were evenly distributed over the six blocks by means of a Latin hypercube sampling. A different suit of random trial order was used for every participant. Each participant performed six blocks with 60 trials in each block, for a total of 360 trials. A target stimulus was not presented twice in the same block in order to avoid any effects of familiarization. In addition, the order of experimental trials was random with the constraint of no more than three consecutive trials with the same target type.

registered to the SPM2 EPI template and normalized to a standardized Montreal Neurological Institute (MNI) stereotaxic space to give images with $2 \times 2 \times 2$ mm voxels.

A design matrix was fitted for each subject with the stimulus in each cell of a factorial design modelled by a standard hemodynamic response function (HRF) and its temporal derivative. Each trial was modelled as a single event with zero duration, starting at the onset of the prime stimulus. The design matrix weighted each raw image according to its overall variability to reduce the impact of movement artefacts (Diedrichsen and Shadmehr, 2005). The design matrix was fit to the data for each participant individually. After estimation, betas were smoothed (10 mm full-width half-maximum) and taken to the second level or random effect analysis.

Second level analysis

Our analysis aimed to identify which brain areas within a neural network associated with the beloved partner were preferentially correlated with subjective orgasm scores. To do this, we first identified the brain regions involved in the partner-related network, as assessed with the primed lexical decision task. We calculated a T-map from a simple contrast "subliminal presenta-

tion-no presentation". This contrast of all primes>rest was thresholded at $p < 0.001$ uncorrected. Then, we performed an inclusive masking procedure in which we masked the contrast "beloved partner's name-neutral acquaintance's name" by the T-map "subliminal presentation-no presentation" at $p < 0.01$. Accuracy of anatomical labeling was ascertained with the standard Duvernois (1991) atlas. This procedure elicited a broad insulo-striato-limbic, temporo-parieto-frontal and cerebellum partner-related network that served to define regions of interest in the present study. We used a masking approach to restrict the likelihood of false positives rather than a region of interest approach because the lack of previous studies of subliminal priming for love and orgasm means that we cannot make 'a priori' predictions for our results.

Within this partner-related network, we calculated correlations by integrating each participant's mean orgasm score as a regressor of interest at the group level into a design matrix. We corrected our correlations for multiple comparisons and only report results at a significant threshold of $p < 0.001$. The same procedure was performed for PLS's and EC's scores. Then, Pearson correlations were also calculated across the significant brain regions.

Results

Correlations between the different behavioral scales

In order to better understand our behavioral data, we calculated a coefficient of correlation between the different behavioral scales (orgasm scale, OS, emotional closeness scale, ECS and passionate love scale, PLS; Table 1).

First, our results showed that PLS scores were highly correlated with ECS scores (Pearson correlation, $r=0.49$, $p=0.006$; Table 1). The more participants reported being in love, the more they reported being satisfied with their emotional closeness with their partner.

Second, a significant correlation was found between PLS scores and the composite measure of orgasm (as calculated by combining the individual measures of the three orgasm scores; Pearson correlation, $r=0.38$, $p=0.04$; Table 1). A significant correlation was also observed between this composite measure of orgasm and ECS scores (Pearson correlation, $r=0.65$, $p<0.001$; Table 1).

Finally, a significant correlation was observed between PLS scores and two orgasm dimensions, respectively (orgasm ease, Pearson correlation, $r=0.43$, $p=0.02$; orgasm satisfaction, Pearson correlation, $r=0.39$, $p=0.04$; Table 1). The more participants reported being in love with their partner, the more they reported to achieve orgasm with facility and the more they tended to report being satisfied with their orgasm experiences.

However, no correlation was found between PLS scores and orgasm frequency (Pearson correlation, $r=0.23$, $p=0.206$; Table 1), suggesting that no predictable effect between intensity of love and orgasm frequency can be drawn.

fMRI data analyses

In comparison with a control neutral stimulus (such as an acquaintance's name), the subliminal presentation of a beloved partner's name identified a partner-related network, which was in line with previous studies (Bartels and Zeki, 2000; Aron et al., 2005). Critically, response were observed in the following brain regions: insula, caudate nucleus, brain stem/midbrain, bilateral fusiform regions, parahippocampal gyri, angular and supramarginal gyri, left dorsolateral middle frontal gyrus, left inferior temporal gyrus, left anterior prefrontal cortex, right superior temporal gyrus, occipital cortex and cerebellum (partner-related network; Table 2).

Within this partner-related network, a between-subject random effect analysis correlating Blood oxygenation level-dependent (BOLD) responses and participant's PLS scores revealed that participants who scored higher at being in love showed stronger activations in a large portion of the defined partner-related network involving critically in the left angular gyrus (−56, −58, 42 x, y, z mm coordinates $r=0.61$, $p<0.0001$; Table 2). That is, participants who self-reported higher levels of love than others exhibited greater activation than others in this cerebral network. The left angular gyrus exclusively correlated with PLS scores (Table 2).

This method also revealed a positive correlation between participant's scores of satisfaction for emotional closeness and BOLD responses in the left anterior prefrontal cortex ($r=0.55$; $p=0.002$; −16, 62, 54; x, y, z mm coordinates of a larger part of the frontal lobe within the partner-related network; Table 2), a brain area correlating with the angular gyrus as demonstrated by a correlation analyses across brain regions ($p<0.01$ corrected; Table 3).

A similar between-subject random effect analysis correlating BOLD responses and participant's individual differences in orgasm's scores (as characterized with the composite measure of FSFI's orgasm scores) showed a significant positive correlation with activity in one specific site: the left insula (−34, 8, −6; x, y, z mm coordinates of a larger part of the insular lobe within the partner-related network; $r=0.65$; $p<0.001$; Fig. 2). Participants who scored higher on the composite measure of FSFI's orgasm scores showed stronger activations in this specific neural substrate (Fig. 2). This specific correlation with the left anterior insula was independent of reported orgasm type (with or without sexual intercourse). As assessed with a directed interview at the beginning of the experimental session, 21 women out of the 29 participants reported to have experienced orgasms during sexual intercourse with their partner only, although 8 women out of the 29 participants reported to have experienced orgasms with their partner after clitoral stimulation only (i.e., without sexual intercourse). Thus, the present neuroimaging results showed a strong correlation between FSFI's orgasm scores and insula activation, irrespective of reported orgasm type (without sexual intercourse: $T=7.42$; $p<0.001$; peak at −30, 10, −10; x, y, z mm coordinates of a larger part of the insular lobe; *with sexual intercourse*: $T=4.31$; $p<0.001$; peak at −40, 14, −8; x, y, z mm coordinates of a larger part of the insular lobe). Because there is no objective measure to identify the exact nature of a self-reported sexual intercourse (i.e., with vaginal stimulation only or vaginal and concurrent clitoral stimulation), no further analysis was possible to dissociate more precisely the neural correlates of each type of orgasm. Further studies should investigate this question.

Table 1
Pearson's r correlation coefficient between each behavioral scale (PLS and FSFI's orgasm scores; and FSFI's scores of satisfaction of emotional closeness with the partner)

Pearson's r correlation coefficient	PLS	Satisfaction of closeness	Orgasm frequency	Orgasm ease	Orgasm satisfaction	Composite
PLS	1					
Satisfaction of emotional closeness	0.49 [S**]	1				
Orgasm frequency	0.23 [NS]	0.60 [S**]	1			
Orgasm ease	0.43 [S*]	0.65 [S***]	0.87 [S***]	1		
Orgasm satisfaction	0.39 [S*]	0.58 [S**]	0.82 [S***]	0.83 [S***]	1	
Composite	0.38 [S*]	0.65 [S***]	–	–	–	1

S: Significant, *$p<0.05$; **$p<0.01$, ***$p<0.001$.
NS: non-significant, $p>0.05$.
PLS: Passionate love scale.
Composite averages the individual measures of the three FSFI's orgasm scores.

Table 2
MNI coordinates of cerebral activations peaks

Regions	Coordinates				Partner-related network	Orgasm composite	Orgasm ease	Orgasm satisfaction	Orgasm frequency	PLS	Emotional closeness satisfaction
	x	y	z	T value	T value	Pearson's r coefficient					
Thalamus	6	−8	10	6.14							
Caudate nucleus	6	12	0	5.34	4.39						
Brain stem/Midbrain	6	−22	−22	4.90	3.21						
Insula	36	−4	2	3.73	3.54						
Insula/claustrum/putamen	−26	20	−4	4.97	3.75	0.65***	0.67***	0.55**	0.64***		
Local maxima: Insula	−30	20	−4	4.62							
Putamen	−20	20	−4	3.74							
Occipitotemporal/ Fusiform region	36	−88	−18	5.33	2.56						
	−48	−50	−24	4.65	3.33						
	64	−52	16	4.25							
	56	−70	−2	3.47							
Parahippocampal gyrus	34	−18	−28	5.03	4.06			0.53**		0.63***	
	−40	−8	−34	4.91	2.79						
AG	−64	−50	22	4.35	2.59					0.61***	
SMG/AG	66	−44	32	4.33	2.45						
Anterior prefrontal cortex	−18	62	16	3.24	1.84		0.60**	0.51**		0.57**	0.55**
Dorsolateral middle frontal gyrus	−46	26	26	4.51	3.09					0.60**	
	52	38	22	3.78							
Superior temporal gyrus	66	−14	−8	4.18	1.8			0.57**			
Inferior temporal gyrus	−44	−26	−20	4.39	2.70						
	−64	−22	−10	4.52							
Occipital cortex	−18	−96	−8	6.00	2.59						
	18	−94	−8	5.22							
Precuneus	16	−76	20	4.32							
Lingual gyrus	−12	−68	−2	4.05							
Cingulate gyrus	10	−40	20	3.97							
	−6	−42	8	3.25							
Precentral gyrus	64	2	24	3.66							
Cerebellum	12	−48	−38	5.17	2.76						
	−36	−78	−52	4.04	4.3						

**Correlation is significant at the 0.01 level (two-tailed); ***correlation is significant at the 0.001 level (two-tailed).
Partner-related network as assessed with beloved-neutral friend contrast; orgasm composite averages the scores obtained from the three orgasm scales (i.e., ease, satisfaction, frequency). The lack of correlation indicates that the correlation was not significant.
AG=angular gyrus, SMG=supramarginal gyrus.

To better understand the present correlation between insula activation and the composite measure of FSFI's orgasm scores, we performed a between-subject random effect analysis correlating BOLD responses and each FSFI's orgasm dimension (orgasm ease, orgasm satisfaction, orgasm frequency), respectively. As expected, imaging results demonstrated that the composite measure of orgasm correlates with the left anterior insula activation, as does each orgasm dimension (Table 2). Moreover, in line with the

Table 3
Pearson's r correlation coefficient between each brain areas of interest

Pearson's r correlation coefficient	Insula	PF	PH	AG
Insula	1			
PF	0.39 NS	1		
PH	0.38 NS	0.62 S**	1	
AG	0.19 NS	0.59 S*	0.63 S**	1

S: Significant, *$p<0.01$, **$p<0.001$.
NS, non-significant.
PF: prefrontal cortex (left-sided).
PH: parahippocampal gyrus (right-sided).
AG: angular gyrus (left-sided).

behavioral results (Table 1), both ease and satisfaction of orgasm ratings also correlated with an extended neural network that was also observed for emotional feelings (as described above for PLS scores and FSFI's scale of satisfaction of emotional closeness with the partner) and correlated with the angular gyrus (Table 3). Interestingly, these ratings of emotional feelings (PLS scores and satisfaction of emotional closeness) did not correlate with insula response (Table 2). In line with the behavioral results, orgasm frequency ratings exclusively correlated with a left anterior insula response (Pearson's coefficient, $r=0.64$, $p<0.001$; −38, 12, −8; x, y, z mm coordinates, Table 2).

Taken together, these results underline the high degree of functional specificity in the information that may be transmitted among two distinct parallel neural systems: one centered on the left anterior insula and another one correlating with the left angular gyrus.

Discussion

In the present study, we show a behavioral correlation between emotional feelings (love and satisfaction of emotional closeness with a partner) and orgasm scores. The more participants reported being in love/emotionally close with their
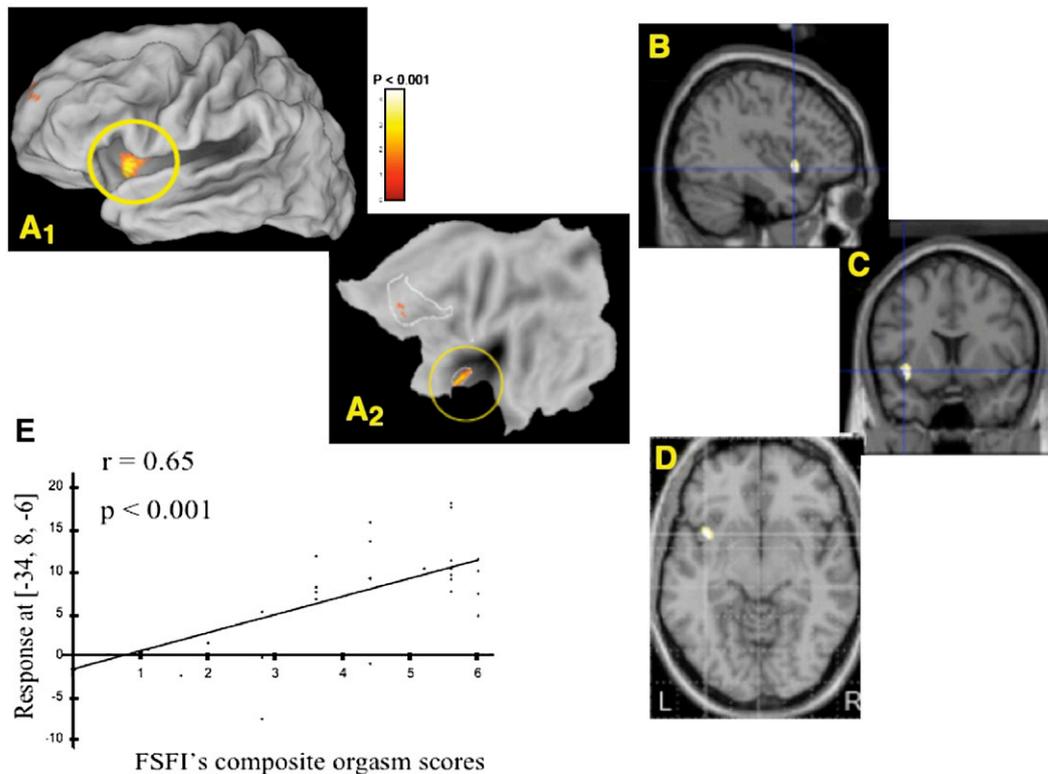
Fig. 2. Blood oxygenation level-dependent (BOLD) responses within the left anterior insula during partner-related conditions (beloved-acquaintance) are significantly correlated with individual mean orgasm scores as measured by the Female Sexual Functioning Index (FSFI; Rosen et al., 2000). Correlations are significant on the $p < 0.001$ level, corrected for multiple comparisons. (A) Peak of activation in the anterior insula correlating with FSFI orgasm scores shown on lateral views of the inflated (A_1) and flat (A_2) left brain (circle). (B) Sagittal, (C) coronal and (D) axial section through the insula from the MNI T1 template; (E) graph of the correlation between BOLD responses and FSFI orgasm's scores for the left anterior insula. The line represents the linear best fit.

partner, the more they reported to achieve orgasm with facility and to be satisfied with their orgasm experience with that partner. However, no correlation was observed between intensity of love and orgasm frequency. These findings strongly suggest that intimate and sexual relationships are sustained by partly different mechanisms, even if they probably share some emotional-related mechanisms. In other words, intimate and sexual relationships may be sustained by parallel neural networks, instead of competing networks.

Functional neuroimaging results extended our behavioral results by demonstrating two dissociable neural networks: a left anterior insula-related network correlating exclusively with quality of orgasm scores and a left angular-related network correlating with love intensity. This dissociation suggests that there may be a degree of functional parcellation of information between these two neural systems.

The anterior insula, as a crucial orgasm-related neural substrate

As expected, the present self-report orgasm quality ratings correlate with the left anterior insula, a brain area that increasingly became the focus of attention for its role in body representation and subjective emotional experience on the basis of somatic manifestations (Damasio, 1994; Isnard et al., 2004; Isnard and Mauguiere, 2005; Shelley and Trimble, 2004). In particular, Damasio has proposed that the insula region plays a role in mapping visceral states that are associated with emotional experience (somatic marker hypothesis, Damasio, 1994). This is in essence a

neurobiological formulation of the ideas of William James, who first proposed that subjective emotional experience arise from our brain's interpretation of bodily states that are elicited by physical emotional events.

According to the somatic marker hypothesis, reinforcing stimulations occurring during sexual emotional experiences induce physiological affective associations that are stored as somatic markers (Damasio, 1994). The present correlation between subjective quality ratings of orgasm and insula activation is consistent with the key aspect in the somatic marker hypothesis suggesting that somatic-marker associations are reinstated physiologically and may bias cognitive processing, reasoning and decision making during future experiences. In this framework, it might be proposed that the specific correlation between left anterior insula response and self-reports of partnered orgasm quality, irrespective of dimension (ease, satisfaction, frequency) or type (with or without sexual intercourse) calls for some recollection of sexual memory that have been encoded during previous physical partnered orgasm experiences (sexual memory, Spiering, 2004; Spiering et al., 2003). This assumed role of the insula in sexual memory is in line with a growing body of evidence demonstrating a clear involvement of this brain area in a variety of bodily and/or emotion experiences that may occur during online sexual relationships, such as cardiovascular, gastrointestinal, vestibular, olfactory, gustatory, somatosensory, motor modulations and positive sensations (Damasio, 1994, 1996; Fisher, 2004; Flynn et al., 1999; Isnard et al., 2004; Isnard and Mauguiere, 2005; Ortigue and Bianchi-Demicheli, 2006; Shelley and Trimble, 2004; Persinger,

2001). Our assumption is also consistent with Komisaruk et al.'s (2004) recent findings demonstrating an activation of the insula during online solo cervical-stimulation induced orgasm in spinal-cord damaged women. In line with this, recent fMRI findings in men and EEG data in epileptic patients also showed that an orgasm results from a spread of neural activation within multiple brain areas, of which the insula might play a particular role (Bianchi-Demicheli and Ortigue, 2007; Calleja et al., 1988; Chuang et al., 2004; Currier et al., 1971; Fadul et al., 2005; Freemon and Nevis, 1969; Janszky et al., 2002, 2004; McKenna, 2002; Ortigue and Bianchi-Demicheli, 2006; Shelley and Trimble, 2004). Along these lines, our results thus suggest that the insula serves as an integration cortex for multimodal and conceptual convergence of information that may play a role in second-order representations of bodily states (such as those involved in subjective quality ratings of orgasm) based on, for instance, recollections of sexual sensations, sexual fantasies and knowledge about sexual rewards or costs (sexual memory; Spiering, 2004; Spiering et al., 2003).

An additional way of conceptualizing the current results makes reference to the recent pivotal position the insula took in incentive motivation and also in anticipation of primary and non-primary reward mechanisms by receiving sensory inputs and sending outputs to the orbitofrontal cortex and the striatum (Amodio and Frith, 2006; Chikama et al., 1997; Komisaruk et al., 2004; Knutson et al., 2003; O'Doherty et al., 2001; O'Doherty, 2004; Shelley and Trimble, 2004; Tanaka et al., 2004). In this framework, one might suggest that the correlation between insula activation and each dimension of orgasm reflects anticipation of future reward (e.g., Amodio and Frith, 2006; Shelley and Trimble, 2004; Komisaruk et al., 2004; Knutson et al., 2003; O'Doherty, 2004; Tanaka et al., 2004). This is consistent with the fact that during erotic situations, other emotions may have been experienced in addition to sexual excitement; for example, those connected with a tendency to approach the partner, desires and expectations (Janssen and Everaerd, 1993). Along these lines, variations of responses in the left anterior insula could play an important role in inter- and intra-individual differences of "motive for sexual intercourse". Such assumption also reinforces current psychosocial models of sexual function suggesting that women often apprehend a novel sexual experience with a partner as a result of contextual and other reward and motivational factors that are encoded with that partner (Bancroft et al., 2003; Basson, 2000; Mah and Binik, 2001, 2005; Whipple and Brash-McGreer, 1997). However, the latency between the completion of self-report questionnaires and orgasm experience is too long to allow any direct inference on anticipation of future reward. For a better understanding of anticipation of reward mechanisms in human intimate relationships, further studies should investigate this question by introducing an online orgasm experimental condition and two control conditions (a rewarding non-sexual task, such as the Markov decision task, Tanaka et al., 2004; and a non-rewarding sexual condition).

Taken together, our results let us assume that the present insula activation reflects a level of information processing more closely related to sexual-reward based memory and somatic marker associations than a love reaction to a partner per se (e.g., Komisaruk et al., 2004, Bianchi-Demicheli and Ortigue, 2007). The present lack of significant correlation between PLS/ECS and insula reinforces our assumption by suggesting the involvement of other neural substrates in the correlation with love intensity and emotional closeness.

An angular-centered network for love

The present functional neuroimaging results revealed an exclusive correlation between PLS scores and activation of the left angular gyrus. This result reinforced the assumed role of the left angular gyrus in love intensity (Ortigue et al., 2007). Interestingly, the temporo-parietal junction, and notably the angular gyrus, is an associative brain area considered to be pivotal in carrying out cross-modal information (Calvert et al., 2000; Bremmer et al., 2001), episodic memory retrieval, conceptual knowledge and metaphors (Ashby and O'Brien, 2005; von Bubnoff, 2005, Jackson et al., 2006; Ortigue et al., 2007; Saxe and Kanwisher, 2003). Thus, the present correlation between this brain region and love intensity reinforces that such higher order mechanisms can take place in the abstract concept of love (e.g., Aron et al., 2005; Bianchi-Demicheli et al., 2006; Brehm et al., 2002; Buss, 2003; Fisher, 2004; Sternberg and Barnes, 1988). In addition, the temporo-parietal junction is also important in (a) integration of abstract representations of the self, others (Arzy et al., 2006; Blanke et al., 2002; Feinberg and Keenan, 2005; Jackson et al., 2006; Lou et al., 2004) and/or (b) social cognition related to the ability to reason about the contents of mental states, such as desire (Saxe and Kanwisher, 2003). This is of particular importance for the concept of love, which is often assumed, according to theories in social psychology, to call for mechanisms underlying an expansion of the self (e.g., Aron and Aron, 1986, 1996; Bataille, 1962).

Finally, the present correlation between activation in the left angular gyrus and brain areas correlating with orgasm ease and satisfaction ratings (Tables 2 and 3) suggests that higher-order mechanisms also take place for these components. Taken together, the present results highlight the cognitive role this angular-related neural network may play in psychosocial dimension (e.g., Ochsner et al., 2005; Sternberg and Barnes, 1988).

There are some factors which restrict our interpretation of the data in the present study and which could be examined more closely in the future. Because there are not many previous studies of the neural basis of sexual and emotional relationships, our study constitutes a first step and includes some limitations.

Even if the present approach constitutes a sophisticated tool to investigate the psychosocial link between sexual and emotional relationships without any orgasm-related confounds (such as general online arousal, direct sensory inputs or motor activity that may be induced during rhythmic contractions as observed in previous studies using self-stimulation), the analysis is limited to correlations with limited causal inference.

If the present FSFI's orgasm-related questions are standardized and specific to each dimension of a partnered orgasm experience, their small quantity ($n=3$) reduced our range of assessment. The link between sexual experience and emotional relationships would benefit from the use of a larger panel of questionnaires evaluating the different types and intensities of orgasm in the framework of different types of emotional relationships. This would be helpful to better understand the neural modulation of this personal experience with respect to interpersonal and contextual factors.

Finally, our study specifically focused on understanding the cerebral mechanisms underlying the implicit psychosocial factors that may interact with subjective quality ratings of a partnered orgasm. Moving this research forward involves opportunities that are not isolated to partnered sexual activities or to the implicit factors interacting with a woman's sexual pleasure.

Conclusion

Our results let us propose that the specific involvement of the left anterior insula and its widely distributed functional connections imbue the notable complexity of women's orgasm experience that may be encoded in memory. The functional localization is also consistent with the somatic marker hypothesis. More critically, we suggest that the orgasm-related function of this insular representation may constitute a basis for women's ability to elaborate subjective shared representation of feelings based on the integration of autonomic and bodily responses experienced during orgasm, and to predict the likely associated reward consequences. By highlighting the role of the anterior insula in the way women integrate their intimate relationships, the current findings take a step in the understanding of a woman's sexual pleasure.

Acknowledgments

References

Amodio, D.M., Frith, C.D., 2006. Meeting of minds: the medial frontal cortex and social cognition. Nat. Rev., Neurosci. 7, 268–277.

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. J. Neurophysiol. 94, 327–337.

Ashby, F.G., O'Brien, J.B., 2005. Category leaning and multiple memory systems. Trends Cogn. Sci. 9, 83–89.

Aron, A., Aron, E.N., 1986. Love and the Expansion of Self: Understanding Attraction and Satisfaction. Hemisphere Publish Corporation, New York.

Aron, A., Aron, E.N., 1996. Love and expansion of the self: the state of the model. Pers. Relatsh. 3, 45–58.

Arzy, S., Seeck, M., Ortigue, S., Spinelli, L., Blanke, O., 2006. Induction of an illusory shadow person. Nature 443, 287.

Bancroft, J., 1989. Human Sexuality and Its Problems. Churchill Livingstone, New York.

Bancroft, J., Loftus, J., Long, J.S., 2003. Distress about sex: a national survey of women in heterosexual relationships. Arch. Sex. Behav. 32, 193–208.

Bartels, A., Zeki, S., 2000. The neural basis of romantic love. NeuroReport 11, 3829–3834.

Basson, R., 2000. The female sexual response: a different model. J. Sex Marital Ther. 26, 51–65.

Basson, R., 2001. Female sexual response: the role of drugs in the management of sexual dysfunction. Obstet. Gynaecol. 98, 350–353.

Basson, R., 2002. A model of women's sexual arousal. J. Sex Marital Ther. 28, 1–10.

Basson, R., 2005. Women's sexual dysfunction: revised and expanded definitions. CMAJ 172, 1327–1333.

Bataille, G., 1962. Eroticism. (M. Dalwood, Trans.). London: Calder.

Bianchi-Demicheli, F., Ortigue, S., 2007. Toward an understanding of the cerebral substrates of woman's orgasm. Neuropsychologia (May 04).

Bianchi-Demicheli, F., Grafton, S.T., Ortigue, S., 2006. The power of love on the human brain. Soc. Neurosci. 1, 90–103.

Blanke, O., Ortigue, S., Landis, T., Seeck, M., 2002. Stimulating illusory own-body perceptions. Nature 19, 269–270.

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., Perham, D., Miller, C.S., 2002. Intimate Relationships, 3rd ed. McGraw-Hill Humanities.

Bremmer, F., Schlack, A., Duhamel, J.R., Graf, W., Fink, G.R., 2001. Space coding in primate posterior parietal cortex. NeuroImage 14, S46–S51.

Buss, D.M., 2003. The Evolution of Desire. Basic Books, New York.

Calleja, J., Carpizo, R., Berciano, J., 1988. Orgasmic epilepsy. Epilepsia 29, 635–639.

Calvert, G.A., Campbell, R., Brammer, M.J., 2000. Evidence from functional magnetic resonance imaging of crossmodal binding in the human hetero-modal cortex. Curr. Biol. 10, 649–657.

Chikama, M., McFarland, N.R., Amaral, D.G., HAber, S.N., 1997. Insular cortical projections to functional regions of the striatum correlate with cortical cytoarchitectonic organization in the primate. J. Neurosci. 17, 9686–96705.

Chuang, Y.C., Lin, T.K., Lui, C.C., Chen, S.D., Chang, C.S., 2004. Toothbrushing epilepsy with ictal orgasms. Seizure 13, 179–182.

Coltheart, M., 1981. The MRC psycholinguistic database. Q. J. Exp. Psychol. 33A, 497–505.

Currier, R.D., Little, S.C., Suess, J.F., Andy, O.J., 1971. Sexual seizures. Arch. Neurol. 25, 260–264.

Damasio, A., 1994. Descartes' Error: Emotions, Reason, and the Human Brain. Avon Books, New York.

Damasio, A., 1996. The somatic marker hypothesis and the possible functions of the prefrontal cortex. Philos. Trans. R. Soc. Lond., Biol. Sci. 351, 1413–1420.

Darling, C.A., Davidson Sr., J.K., Jennings, D.A., 1991. The female sexual response revisited: understanding the multiorgasmic experience in women. Arch. Sex. Behav. 20, 527–540.

Diedrichsen, J., Shadmehr, R., 2005. Detecting and adjusting for artifacts in fMRI time series data. NeuroImage 27, 624–634.

Duvernois, H., 1991. The Human Brain. Springer, New York.

Fadul, C.E., Stommel, E.W., Dragnev, K.H., Eskey, C.J., Dalmau, J.O., 2005. Focal paraneoplastic limbic encephalitis presenting as orgasmic epilepsy. J. Neuro-oncol. 72, 195–198.

Feinberg, T.E., Keenan, JP., 2005. Where in the brain is the self? Conscious. Cogn. 14, 661–678.

Fisher, H., 2004. Why We Love? Henry Holt and Company, New York.

Flynn, F.G., Benson, D.F., Ardila, A., 1999. Anatomy of the insula functional and clinical correlates, 13, 55–78.

Freemon, F.R., Nevis, A.H., 1969. Temporal lobe sexual seizures. Neurology 19, 87–90.

Hatfield, E., Sprecher, S., 1986. Measuring passionate love in intimate relationships. J. Adolesc. 9, 383–410.

Isnard, J., Mauguiere, F., 2005. The insula in partial epilepsy. Rev. Neurol. (Paris) 161, 17–26.

Isnard, J., Guenot, M., Sindou, M., Mauguiere, F., 2004. Clinical manifestations of insular lobe seizures: a stereo-electroencephalographic study. Epilepsia 45, 1079–1090.

Jackson, P.L., Brunet, E., Meltzoff, A.N., Decety, J., 2006. Empathy examined through the neural mechanisms involved in imagining how I feel versus how you feel pain. NeuroImage 44, 752–761.

Janssen, E., Everaerd, W., 1993. Determinants of male sexual arousal. Annu. Rev. Sex Res. 4, 211–245.

Janszky, J., Szucs, A., Halasz, P., Borbely, C., Hollo, A., Barsi, P., et al., 2002. Orgasmic aura originates from the right hemisphere. Neurology 58, 302–304.

Janszky, J., Ebner, A., Szupera, Z., Schulz, R., Hollo, A., Szucs, A., et al., 2004. Orgasmic aura—A report of seven cases. Seizure 13, 441–444.

Kaplan, H.S., 1974. The new sex therapy: active treatment of sexual dysfunctions. New York.

Kaplan, H.S., 1979. Disorders of Sexual Desire and Other New Concepts and Techniques in Sex Therapy. Brunner/Hazel, New York.

Kinsey, A.C., Pomeroy, W.B., Martin, C.E., Gebbard, O.H., 1953. Sexual behaviour in the human female. Philadelphia.

Knutson, B., Fong, G.W., Bennett, S.M., Adams, C.M., Hommer, D., 2003. A region of mesial prefrontal cortex tracks monetarily rewarding

outcomes: characterization with rapid event-related fMRI. NeuroImage 18, 263–272.

Komisaruk, B.R., Whipple, B., 1998. Love as sensory stimulation: physiological consequences of its deprivation and expression. Psycho-neuroendocrinology 23, 927–944.

Komisaruk, B.R., Whipple, B., Crawford, A., Liu, W.C., Kalnin, A., Mosier, K., 2004. Brain activation during vaginocervical self-stimulation and orgasm in women with complete spinal cord injury: fMRI evidence of mediation by the vagus nerves. Brain Res. 1024, 77–88.

Kucera, H., Francis, W.N., 1967. Computational Analysis of Present-day American English. Brown University Press, Providence, RI.

Ladas, A., Whipple, B., Perry, J.D., 1982. The G spot and other recent discoveries about human sexuality. New York City.

Levin, R.J., 1981. The female orgasm—A current appraisal. J. Psychosom. Res. 25, 119–133.

Levin, R.J., van Berlo, W., 2004. Sexual arousal and orgasm in subjects who experience forced or non-consensual sexual stimulation—A review. J. Clin. Forensic Med. 11, 82–88.

Levin, R.J., Wagner, G., 1985. Orgasm in women in the laboratory-quantitative studies on duration, intensity, latency, and vaginal blood flow. Arch. Sex. Behav. 14 (5), 439–449.

Lloyd, E.A., 2005. The Case of the Female Orgasm: Bias in Science of Evolution. Harvard Univ. Press, Yale.

Lou, H.C., Luber, B., Crupain, M., Keenan, J.P., et al., 2004. Parietal cortex and representation of the mental Self. Proc. Natl. Acad. Sci. U. S. A. 101, 6827–6832.

Mah, K., Binik, Y.M., 2001. The nature of human orgasm: a critical review of major trends. Clin. Psychol. Rev. 21, 823–856.

Mah, K., Binik, Y.M., 2005. Are orgasms in the mind or the body? Psychosocial versus physiological correlates of orgasmic pleasure and satisfaction. J. Sex Marital Ther. 31, 187–200.

Masters, W.H., Johnson, V., 1966. Human sexual response. Boston.

McKenna, K.E., 1999. The brain is the master organ in sexual function: central nervous system control of male and female sexual function. Int. J. Impot. Res. 11, S48–S55.

McKenna, K.E., 2002. The neurophysiology of female sexual function. World J. Urol. 20, 93–100.

Meston, C.M., 2003. Validation of the Female Sexual Function Index (FSFI) in women with female orgasmic disorder and in women with hypoactive sexual desire disorder. J. Sex Marital Ther. 29, 39–46.

Meston, C.M., Hull, E., Levin, R.J., Sipski, M., 2004. Women's orgasm. In: Lue, T.F., Basson, R., Rosen, R., Giuliano, F., Khoury, S., Montorsi, F. (Eds.), Sexual Medicine: Sexual Dysfunctions in Men and Women. Health Publications, Paris, pp. 783–850.

O'Doherty, J.P., 2004. Reward representations and reward-related learning in the human brain: insights from neuroimaging. Curr. Opin. Neurobiol. 14, 769–776.

O'Doherty, J., Kringelbach, M.L., Rolls, E.T., Hornak, J., Andrews, C., 2001. Abstract reward and punishment representations in the human orbitofrontal cortex. Nat. Neurosci. 4, 95–102.

Ochsner, K.N., Beer, J.S., Robertson, E.R., et al., 2005. The neural correlates of direct and reflected self-knowledge. NeuroImage 28, 797–814.

Ortigue, S., Bianchi-Demicheli, F., 2006. The neurophysiology of the female orgasm. Rev. Méd. Suisse 2, 784–786.

Ortigue, S., Bianchi-Demicheli, F., Hamilton, A.F., Grafton, S.T., 2007. The neural basis of love as a subliminal prime: an event-related fMRI study. Journal of Cognitive Neuroscience (July).

Overall, J.E., Gorham, D.R., 1962. The brief psychiatric rating scale. Psychol. Rep. 10, 799–812.

Persinger, M.A., 2001. Shifting gustatory thresholds and food cravings during pregnancy as expanding uterine-induced steady potential shifts within the insula: an hypothesis. Percept. Mot. Skills 92, 50–52.

Rosen, R., Brown, C., Heiman, J., Leiblum, S., Meston, C., Shabsigh, R., et al., 2000. The Female Sexual Function Index (FSFI): a multi-dimensional self-report instrument for the assessment of female sexual function. J. Sex Marital Ther. 26, 191–208.

Rowland, D.L., 2006. Neurobiology of sexual response in men and women. CNS Spectr. 11, 6–12.

Saxe, R., Kanwisher, N., 2003. People thinking about thinking people. The role of the temporo-parietal junction in "theory of mind". NeuroImage 19, 1835–1842.

Shelley, B.P., Trimble, M.R., 2004. The insular lobe of Reil-its anatomico-functional, behavioural and neuropsychiatric attributes in humans-a review. World J. Biol. Psychiatry 5, 176–200.

Spector, I.P., Carey, M.P., 1990. Incidence and prevalence of the sexual dysfunctions: a critical review of the empirical literature. Arch. Sex. Behav. 19, 389–408.

Spiering, M., 2004. Conscious processing of sexual information: mechanisms of appraisal. Arch. Sex. Behav. 33, 369–380.

Spiering, M., Everaerd, W., Janssen, E., 2003. Priming the sexual system: implicit versus explicit activation. J. Sex Res. 40, 134–145.

Sternberg, J.S., Barnes, M.L., 1988. The Psychology of Love. Yale Univ. Press, New Haven.

Symons, D., 1979. The Evolution of Human Sexuality. Oxford University, New York.

Tanaka, S.C., Doya, K., Okada, G., Ueda, K., Okamoto, Y., Yamawaki, S., 2004. Prediction of immediate and future rewards differentially recruits cortico-basal ganglia loops. Nat. Neurosci. 7, 887–893.

von Bubnoff, A., 2005. Stroke patients shed light on metaphors [electronic version; news@nature.com] Nature (Retrieved 26 May).

Whipple, B., Brash-McGreer, K., 1997. Management of female sexual dysfunction. Sexual Function in People With Disability and Chronic Illness. A Health Professional's Guide. Aspen Publishers, Gaithersburg, MD, pp. 509–534.