Reward and Motivation Systems: A Brain Mapping Study of Early-Stage Intense Romantic Love in Chinese Participants

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Abstract: Early-stage romantic love has been studied previously in the United States and United Kingdom (Aron et al. [2005]: J Neurophysiol 94:327–337; Bartels and Zeki [2000]: Neuroreport 11:3829–3834; Ortigue et al. [2007]: J Cogn Neurosci 19:1218–1230), revealing activation in the reward and motivation systems of the brain. In this study, we asked what systems are activated for early-stage romantic love in Easterners, specifically Chinese participants? Are these activations affected by individual differences within a cultural context of Traditionality and Modernity? Also, are these brain activations correlated with later satisfaction in the relationship? In Beijing, we used the same procedure used by Aron et al. (Aron et al. [2005]: J Neurophysiol 94:327–337). The stimuli for 18 Chinese participants were a picture of the face of their beloved, the face of a familiar acquaintance, and a countback task. We found significant activations specific to the beloved in the reward and motivation systems, particularly, the ventral tegmental area and the caudate. The mid-orbitofrontal cortex and cerebellum were also activated, whereas amygdala, medial orbitofrontal, and medial accumbens activity were decreased relative to the familiar acquaintance. Self-reported Traditionality and Modernity scores were each positively correlated with activity in the nucleus accumbens, although in different regions and sides of the brain. Activity in the subgenual area and the superior frontal gyrus was associated with higher relationship happiness at 18-month follow-up. Our results show that midbrain dopamine-rich reward/motivation systems were activated by early-stage romantic love in Chinese participants, as found by other studies. Neural activity was associated with Traditionality and Modernity attitudes as well as with later relationship happiness for Chinese participants. *Hum Brain Mapp 32:249–257, 2011.*

Key words: ventral tegmental area; basal ganglia; striatum

INTRODUCTION

Romantic love is a powerful human experience that strongly influences many aspects of our lives (for review, see Aron et al. [2006]). It has been observed in nearly every culture [Jankowiak and Fischer, 1992], and evolutionary-oriented researchers [e.g., Buss, 2006; Fisher, 1998] suggest that it is a fundamental human experience.

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Romantic love is highly correlated with relationship satisfaction (for meta-analyses, see Acevedo and Aron [2009] and Masuda [2003]), with relationship quality and stability [e.g. Riehl-Emde et al., 2003], and is often a prerequisite for entering into marriage [e.g. Simpson et al., 1986]. Furthermore, romantic love and quality of the relationship is strongly linked with well-being, life satisfaction, and mental and physical health [e.g. Coan et al., 2006; Drigotas et al., 1999; Esch and Stefano, 2005; Gallo et al., 2003; Treboux et al., 2004].

However, romantic love has long been considered a Western invention [Capellanus, 1990], and cultural psychologists [e.g., Dion and Dion, 1993; Jackson et al., 2006] point to differences in how it is experienced and valued, particularly between collectivistic (Eastern) and individualistic (Western) cultures. Wu and Shaver [1992, 1993] found that Chinese participants tended to associate love with negative features (e.g. heartbreak) and spontaneously listed more negative items than Americans, who associated love with positive features (e.g. adoration). Gao [2001] found that American couples reported more passion in their romantic relationships than Chinese couples. Finally, Markus and Kitayama [1991] and Matsumoto [1993] found that Asians express emotions less than Westerners.

However, those studies reporting findings of cultural differences between Easterners and Westerners used self-report questionnaires, which can be distorted by language translations as well as by cultural differences in subjective beliefs about love (as opposed to differences in the actual experience itself). Thus, it is unclear whether Easterners actually *experience* romantic love differently or simply *report* their experiences differently. Because romantic love is such a significant part of our lives and may have a strong influence on health and relationship outcomes, it is important to find more reliable means to study the cultural aspects of romantic love. Our use of physiological measures such as neuroimaging helps avoid the potential confounds that exist in self-report questionnaire studies [Chiao and Ambady, 2007].

Three neuroimaging studies of romantic love have now been published, all in Western contexts [Aron et al. 2005, in the United States; Bartels and Zeki, 2000, in England; Ortigue et al. [2007] in the United States). A key result across studies is that viewing an image of an intensely beloved partner engages dopamine-rich reward regions of the brain. No studies to date have examined romantic love in an Eastern context. Thus, we undertook to fill this gap in the literature by using functional brain imaging to investigate romantic love and the reward system in Chinese participants. Specifically, we investigated early-stage intense romantic love following the procedures used with U.S participants by Aron et al. [2005].

We predicted that the regions of activation in our Chinese sample would be similar to those of participants from Western contexts, because there is a good deal of evidence that love's biological underpinnings are universal. Both mammalian and avian species share common behavioral systems for "selective attraction" to potential mates [Fisher, 1998]. For partner preference formation, the brain reward systems in humans appear very similar to monogamous voles [e.g. Curtis and Wang, 2005]. Finally, ethnographic studies of different human cultures have found romantic love to be similar [e.g., Jankowiak and Fischer, 1992].

However, we were also aware that we might find differences in the experience of early-stage intense romantic love among Chinese students, as neuroimaging research with humans has shown cultural differences between Easterners and Westerners. Specifically, research has found differences both in aspects of effect [e.g. Chiao et al., 2008; Komaki et al. 2006] and cognition [e.g. Han and Northoff, 2008; Hedden et al., 2008; Ketay et al., in press; Kitayama et al., 2003; Masuda and Nisbett, 2001; Nisbett et al., 2001].

With regard to the cross-cultural comparison, a strength of this study is that it replicates, in China with a Chinese sample, procedures that are virtually identical to those used in the United States with a U.S. sample in the Aron et al. [2005] study. However, this also necessarily limits the degree of precision in any cross-study comparisons due to the use of different scanners requiring different technical parameters. Thus, the cross-cultural comparison aspect of the study should be interpreted tentatively.

To further investigate the possible role of culture, we measured our sample's individual differences in Traditionality and Modernity, something not done in any of the previous neuroimaging studies of love [e.g. Aron et al., 2005; Bartels and Zeki, 2000; Ortigue et al., 2007]. We thought that if Easterners do experience love to a lesser degree or in a more negative manner as suggested by the behavioral studies cited earlier [e.g., Gao, 2001; Wu and Shaver, 1992, 1993], it may be explained by cultural attitude differences in terms of Modernity and/or Traditionality. We sought to see if any such differences may be reflected in regional brain activity.

We were also interested in examining the difference between implicit "liking" (e.g., affect and conscious pleasure) and "wanting" (e.g. motivation) in terms of early stage intense romantic love. Researchers have pointed to this general distinction [e.g. Berridge and Robinson, 2003], and, in particular, the ventral tegmental area (VTA) has been identified as an area associated with motivation ("wanting") rather than just pleasure ("liking") [e.g. Carter et al., 2009]. Some research directly concerning romantic love suggests that it functions primarily as a goal-oriented, motivational state ("wanting") rather than simply as an affect or state of pleasure ("liking") [e.g. Aron et al., 2005; Acevedo et al., under review[1]; Baumeister and Leary, 1995]. This distinction between wanting and liking has also been shown in the human brain. Aharon et al. [2001] found lateralization differences in the VTA such that right

[1] Acevedo BP, Aron A, Gross J, Xu X, Ralte Z (under review): Romantic love: Basic emotion or motivation?

VTA activation was associated with wanting (a face participants would work harder to see) and left VTA activation was associated with liking (an aesthetically pleasing face). Aron et al. [2005] further showed this distinction in American students experiencing early-stage intense romantic love such that right VTA activation was associated with the degree of self-reported passionate love experienced toward the partner, and left VTA activation was associated with the physical attractiveness of the partner (as judged independently by opposite-sex raters). We were therefore interested to see if this liking versus wanting VTA activation lateralization distinction would also show up in Chinese participants.

Finally, we were interested in the relationship between the brain's response to the partner during early stage love and the long-term quality of the relationship. To assess this, we recontacted participants 18 months after they were in the scanner and asked those who were still with their partner about their subjective relationship happiness. Thus, in addition to being the first neuroimaging study of its kind done on Chinese participants in China, this is the first study that looks at the associations between neuroimaging activations during early-stage intense romantic love and relationship satisfaction over time.

METHODS

We followed Aron et al.'s [2005] methods and used essentially identical stimuli, stimulus presentation, instructions, and data analysis procedures. We used a 3T Trio scanner at the Beijing MRI Center for Brain Research (Aron et al. used a 1.5T scanner). We were also able to recontact most of our participants 18 months after scanning (something not done by any other study on this topic), permitting us to examine for the first time whether activation patterns predicted subsequent relationship happiness. This study was approved by the IRBs at the Chinese Academy of Sciences in Beijing, China, and Stony Brook University.

Participants

Eighteen Han Chinese students (10 women) were recruited from Beijing Normal College, Peking University, and China Agricultural University (all in Beijing) by flyers sent to student listserves seeking participants who were currently in a relationship and very intensely in love. Participants' ages ranged from 19 to 25 years ($M = 21.61$, SD $= 1.75$) and relationship lengths ranged from 1.3 to 13 months ($M = 6.54$, SD $= 3.19$). Participants were not taking psychoactive medications, preferred their right hand, and did not report a history of claustrophobia. All provided informed written consent and received 80 Ren Min Bi (roughly 10 USD).

Questionnaires

Before scanning, participants completed the Chinese Individual Traditionality–Modernity Scale [Yang and Hchu, 1974], which assesses endorsement of traditional values ("Obeying authority and respecting the elderly are virtues that children should learn") and modern values ("If married life is too painful, divorce is perhaps a way to solve the problem") on a 1–6 scale (for a total possible score of 60 for each Scale). Participants averaged 29.28 (SD $= 7.28$) on the Traditionality Scale and 47.17 (SD $= 4.81$) on the Modernity Scale. Reliability for the original 10-item Traditionality scale was low in our sample ($\alpha = 0.68$); but after omitting two items, α rose to 0.81. All analyses were done with the remaining eight items. For Modernity, three items were dropped to obtain adequate reliability ($\alpha = 0.82$), and all analyses were done with the resulting seven items. A follow-up questionnaire was administered 18 months after the scanning. Participants were asked whether they were still with their partner and, if so, how happy they were in the relationship on a 1–7 (extremely unhappy to extremely happy) scale.

Stimuli

Before scanning, participants provided a photograph of their romantic partner (Positive Stimulus) and a familiar acquaintance (Neutral Stimulus) the same sex as their partner and for whom they had no romantic feelings. Photographs were cropped to show only the head and to ensure all head-shots were the same size. Picture quality of partner and neutral acquaintance photographs (rated independently by six Chinese students) did not differ significantly; nor did picture quality correlate significantly with relationship length, sex, Traditionality, or Modernity. Physical attractiveness ratings of positive and neutral stimuli (independently rated by three opposite-sex Chinese students) did not differ significantly and did not significantly correlate with picture quality, relationship length, sex, Traditionality, or Modernity.

Participants viewed photographs in the scanner via an angled mirror mounted on the RF coil, allowing the photographs to be projected on a screen placed directly outside the MRI tube, subtending a visual angle of 17°.

To prevent spillover of response to viewing facial stimuli, we interspersed the partner and neutral acquaintance stimuli with a serial count-back task (viewing a four-digit number and mentally counting backwards by 7 s).

Prescan Interview and Instructions

Before entering the scanner, each participant was interviewed by G.C. or T.F. and asked to recall pleasurable and rewarding events with the partner (e.g., "we had a phone conversation during the Spring Festival and used many loving words") and neutral events with the acquaintance (e.g., "we watched a television program together").

TABLE I. Regional activations and deactivations specific to the picture of the beloved compared to a picture of a familiar, neutral acquaintance

	Chinese sample[a]								American sample[b]							
	Left				Right				Left				Right			
Brain region	*x*	*y*	*z*	*P*	*x*	*y*	*z*	*P*	*x*	*y*	*z*	*P*	*x*	*y*	*z*	*P*
Activations																
Ventral tegmental area					2	−12	−10	0.05					2	−15	−9	0.03
Caudate tail	−32	−44	4	0.004	32	−44	12	0.004	−28	−40	10	0.01	28	−40	10	0.01
Orbitofrontal Cortex, mid					38	28	−12	0.05								
Cerebellum[c], vermis					4	−60	−24	0.04								
Deactivations																
Accumbens n., medial					9	10	−12	0.005								
Amygdala	−22	−12	−20	0.04	20	−1	−20	0.03				20	−3	−15	0.002	
Orbitofrontal cortex, medial					2	54	−14	0.005				2	54	−14	0.05	

Note: Region of interest analysis. Coordinates are at the maximum value for the cluster, which may be elongated in any direction. *P* values are for False Discovery Rate correction. MNI coordinates (*x*,*y*,*z*) for the highest intensity voxel in a cluster. Threshold was $P \leq 0.05$, corrected.
[a]Analyses of our Chinese sample using ROIs from Aron et al.'s American sample.
[b]Analyses of Aron et al.'s American sample using ROIs from our Chinese sample.
[c]Cerebellum was found in a U.K. sample by Bartels and Zeki (2000) and in a U.S. sample by Ortigue et al. [2007].

Participants were instructed to think about these respective events when viewing the corresponding photograph.

Experimental Design and Procedures

Four tasks were presented in an alternating block design. Participants (a) viewed the photo of the romantic partner (positive stimulus) for 30 s, (b) carried out the count-back task for 40 s (countback1), (c) viewed the photograph of their familiar acquaintance (neutral stimulus) for 30 s, and (d) carried out the count-back task for 20 s (countback2). The two countback tasks were of different durations as more countback time is necessary to prevent spillover effect after viewing positive stimuli, and less countback time is needed after viewing neutral stimuli. Starting image (positive or neutral) was counterbalanced across participants. The sequence was repeated six times; total duration was 720 s (12 min).

Image Acquisition

Blood oxygen level-dependent (BOLD) responses and in-plane anatomical data were recorded for each participant. Images were (a) anatomical, axial T1-weighted spin-echo scans: 92-ms TE, 3,700 ms TR, 90° flip angle, 24-cm FOV, 3-mm slice thickness, 0-mm gap, 256 × 256 matrix size, 30 slices; and (b) functional, T2* Gradient-Echo EPI scans: 30-ms TE, 2,000-ms TR, 90° flip angle, 24-cm FOV, 3-mm slice thickness, 0-mm gap, 64 × 64 matrix size (0 filled into 128 × 128 before FFT, and the resulting 128 × 128 images were averaged into 64 × 64 before analysis), 30 slices. Voxel size for functional images was 3.8 × 3.8 × 3.0 mm.

Analysis

Statistical Parametric Mapping software (SPM2; Wellcome Department of Imaging Neuroscience, London, UK) was used for fMRI data analyses. Functional images were normalized to the SPM EPI template brain and realigned and smoothed with a Gaussian kernel of 4 mm. Each stimulus type (positive, countback1, neutral, and countback2) was treated as a separate regressor and modeled as a boxcar function convolved with the canonical hemodynamic response function. We applied a high-pass filter with a cut-off of 128 s to remove low-frequency signal components. Motion covariates were removed. Contrast images for each comparison for each participant were created and analyzed across participants using a mixed-effects general linear model, treating participants as a random effect and conditions as a fixed effect.

All analyses for the main contrast Positive-versus-Neutral were planned comparisons. We applied a sphere as a region of interest (ROI) (sphere radius = 2–10 mm, $P \leq 0.05$, FDR corrected) to each of the areas significantly activated in Aron et al. [2005], and to each area Aron et al. [2005] predicted might be affected (Table I). For whole brain correlations (Traditionality and Modernity) performed by SPM2, we accepted $P < 0.005$ (uncorrected) for the single peak voxel in a cluster (with minimum 20 voxels). To investigate whether the left VTA correlation in Aron et al. [2005] for facial attractiveness would also be present in our sample, we placed the ROI sphere on the peak voxel coordinates found in that study. To investigate the possibility of sex differences, we compared activations for men and women at a threshold of $P < 0.001$, uncorrected. To evaluate relationship happiness scores at follow-up, we used *t*-tests and accepted $P \leq 0.005$.

We were interested in exploring cultural similarities and differences between our Chinese sample results and those found by Aron et al. [2005] to the extent possible, given the studies were done with different scanners with different parameters. Thus, as an exploratory procedure, for each ROI (sphere radius = 2–10 mm, $P \leq 0.05$ FDR corrected), we found to be significantly activated in our sample; we applied the ROI to the American data from Aron et al. [2005]. As noted earlier, we also applied each ROI tested or found in the Aron et al. [2005] American sample to our Chinese data set. In this way, we were able to get some indication of whether similar ROIs were significant in both samples (Table I) to provide some degree of direct comparison across cultures.

RESULTS

Positive-Versus-Neutral Stimulus Contrast (Activations)

We found activation in the right VTA and parts of the caudate nucleus (Fig. 1; Table I) as well as activation in the cerebellum (Table I), similar to the previous studies on this topic [Bartels and Zeki, 2000; Ortigue et al., 2007]. Unlike the other studies of romantic love, we also found activation in the middle orbitofrontal cortex. None of the ROI analyses showed sex differences nor did an exploratory whole brain analysis of sex differences ($P < 0.001$ uncorrected). Also, we did not find activation in areas associated with sexual arousal [Walter et al., 2008].

When applying ROIs from our results to Aron et al. [2005] data, we found significant activation in the VTA and caudate tail, but not in the middle orbitofrontal cortex nor in the cerebellum. Cerebellum activation was found in a U.K. sample by Bartels and Zeki [2000] and in a U.S. sample by Ortigue et al. [2007], so that it does not appear to be a culturally specific finding.

Differences between positive and neutral conditions could have been caused by eye movements while viewing the pictures. However, the frontal eye fields did not show an effect for this contrast, making it an unlikely explanation.

Positive-Versus-Countback

The countback tasks were included to provide a distraction between the positive and neutral stimuli and to minimize spillover response from the positive stimulus. We used the average of the two countback periods as a supplementary control condition for attention. Positive-versus-Countback activations included all the areas found in the Positive-versus-Neutral contrast (with additional areas activated since the stimuli being contrasted were so different—picture of a face vs. number on the screen).

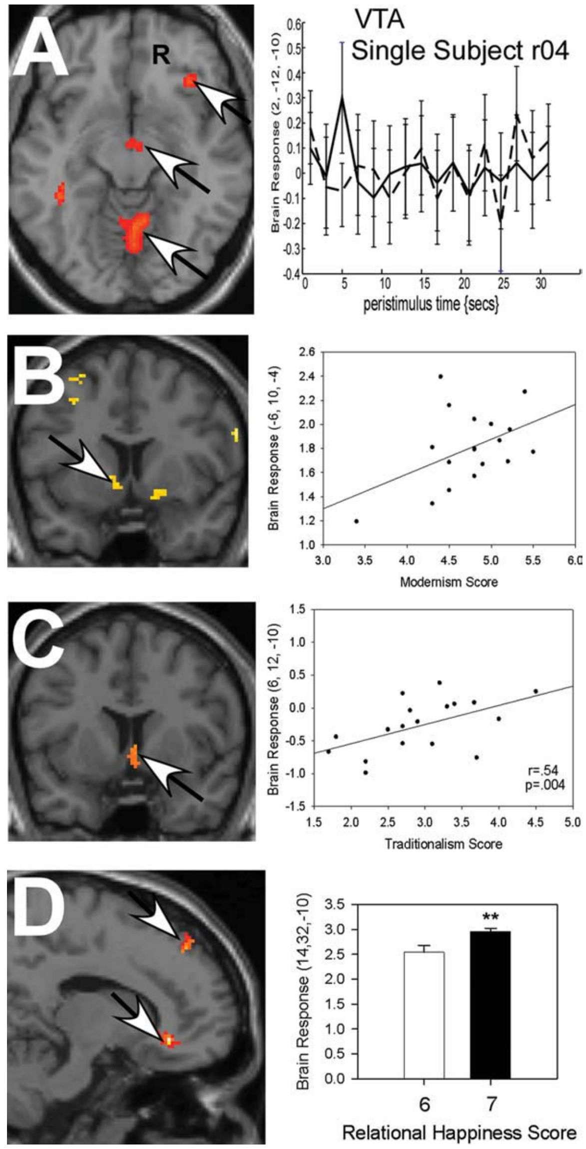

Figure 1.
Locations of activations, questionnaire score correlations with brain activity and follow-up score differences. **A:** Axial section showing the activations specific to the beloved in the middle orbitofrontal cortex (top arrow), ventral tegmental area (VTA; middle arrow), and cerebellum (bottom arrow). The graph to the right shows the timecourse of the BOLD response in the VTA of a single subject. **B:** Coronal section and graph showing the left accumbens core region (arrow) and its positive correlation with Modernity questionnaire scores from the group. **C:** Coronal section and graph showing the right medial accumbens region (arrow) and its positive correlation with Traditionality scores from the group. **D:** Sagittal section and graph showing the subgenual area (bottom arrow) and superior frontal gyrus (top arrow) where the BOLD response was greater at the time of the scan and relationship happiness scores were greater at 18 months after the scan.

TABLE II. Regional correlations of the BOLD signal for positive-versus-neutral

Brain region	Left					Right				
	x	*y*	*z*	*P*	*r*	*x*	*y*	*z*	*P*	*r*
Traditionality										
Accumbens n., medial (shell)						6	12	−10	0.004	0.54
Hypothalamus	−2	0	−11	0.01	0.41					
Modernity										
Accumbens n., (core)	−6	10	−4	0.004	0.46					
Caudate, head	−14	14	8	0.0001	0.60					
Subthalamic area	−10	−6	−3	0.001	0.36					
Inferior temporal gyrus	−56	−28	−18	0.0001	0.78					
Parietal lobe	−40	−57	37	0.0001	0.76					

Note: Coordinates are at the maximum value for the cluster, which may be elongated in any direction. MNI coordinates (x,y,z) are for the highest intensity voxel in a cluster. Threshold was $P \leq 0.005$, uncorrected.

Neutral-Versus-Positive (Deactivations)

Aron et al. [2005] reported a single significant deactivation, which was in the right amygdala. We found bilateral amygdala deactivation (see Table I). We also found right accumbens and right medial orbitofrontal deactivation (see Table I). When applying ROIs from our data to Aron et al. [2005], we found significant deactivation in the amygdala and a marginally significant deactivation in the right medial orbitofrontal cortex ($P = 0.05$; see Table I). Right accumbens deactivation was not significant when applying our ROI to the Aron et al. [2005] data.

Associations with Objectively Rated Attractiveness

We correlated facial attractiveness (independently rated) with the Positive-versus-Neutral contrast. Confirming Aron et al. [2005], BOLD responses in the *left* rather than the *right* VTA correlated with the independently rated attractiveness scores ($P < 0.005$; $r = 0.65$; MNI coordinates: −3, −13, and −11; Aron et al. [2005], $r = 0.74$; MNI: −6, −15, and −9).

Self-Reported Traditionality and Modernity

Traditionality was significantly correlated with greater activation (for the Positive-versus-Neutral contrast) in the right medial (shell) nucleus accumbens ($r = 0.54$, $P = 0.004$; Table II; Fig. 1). We lowered the statistical threshold to see if the hypothalamus, anatomically connected to the shell, was also correlated; it was (MNI coordinates: 0, 0, and −11). Modernity was significantly correlated with greater activation in the left dorsolateral (core) nucleus accumbens ($r = 0.46$ and $P = 0.004$). Areas associated with the accumbens core connections (the left caudate head and subthalamic nucleus) were also correlated with Modernity (Table II). The left inferior temporal gyrus and the left parietal lobe were also associated with Modernity (Table II). There were no significant correlations with Traditionality or Modernity for age, sex, objectively rated attractiveness of the partner, or other demographics. None of the areas significantly correlated with Traditionality or Modernity overlapped with areas significantly activated for the positive-versus-neutral contrast.

Eighteen-Month Follow-up Analyses: Relationship Happiness

Eighteen months after scanning, we recontacted all participants via email and/or phone, asking them if they were still with their partner, and if so, to rate their relationship happiness. Of the 18 participants, 13 completed the follow-up. There were no significant differences between those completing the follow-up and those who did not in terms of age, sex, relationship length, Traditionality, Modernity, or objective partner attractiveness.

Of the 13 who responded, 10 were still in the relationship. Of these 10, 4 rated their current relational happiness as a 6 (of 7), 6 rated it as a 7. Neither “staying together” nor the difference in relational happiness ratings were predicted by age, sex, other demographics, objective attractiveness, Traditionality, or Modernity. However, in spite of low power for testing these effects with such a small sample and with everyone rating their satisfaction quite high, degree of relational happiness 18 months later was clearly significantly associated with regional neural responses at the time of scanning. Greater relational happiness was significantly positively associated with more activity in the superior frontal gyrus and the subgenual area (see Table III; Fig. 1), and less activity (more deactivation) in the caudate tail, fusiform (face area), and the cerebellum (see Table III).

TABLE III. Regional Increases in the BOLD signal with self-reported relationship happiness score of six versus seven at 18-month follow-up

	Left				Right			
Brain region	*x*	*y*	*z*	*P*	*x*	*y*	*z*	*P*
Activations								
Subgenual area				14	32	−10	0.004	
Superior frontal gyrus				4	49	47	0.001	
Deactivations								
Caudate, tail	−22	−33	22	0.001				
Fusiform (face area)	−38	−63	−9	0.001				
Cerebellum	−20	−39	−25	0.001				

Note: Coordinates are at the maximum value for the cluster, which may be elongated in any direction. MNI coordinates (*x*,*y*,*z*) are for the highest intensity voxel in a cluster. Threshold was $P \leq 0.005$, uncorrected.

DISCUSSION

The findings of this study of early stage intense romantic love in China suggest that (a) highly similar patterns of reward system activation in response to one's beloved are found in Chinese as in the United States, (b) there is significant variation in the pattern of neural activation in response to the beloved as function of individual differences in endorsement of culturally relevant values of Traditionality and Modernity, (c) findings of laterality differences in VTA activation between "wanting" and "liking" found in two previous studies were replicated here, and (d) remarkably, degree of activation in reward areas in response to the beloved predicted degree of relationship happiness 18 months later.

Specifically, early-stage intense romantic love in Chinese students was associated with activation in the dopamine-rich regions of the VTA and caudate as found by Aron et al. [2005], Ortigue et al. [2007] for American students, and Bartels and Zeki [2000] for a London group. The VTA and caudate activations for the Positive-versus-Neutral contrast also overlapped with those of the Positive-versus-Countback task contrast in this study and in Aron et al. [2005], suggesting that the activations did not stem from attentional differences. Because we ran the analyses both ways (using ROIs from Aron et al.'s [2005] U.S. sample on our Chinese data as well as using ROIs from our sample on the Aron et al. [2005] data), there is some basis for concluding that VTA and caudate findings are common cross-culturally and not confounded by using different scanners with different strengths. Future research using the same scanner for two groups will be necessary to determine whether the degree of positive activation could be different, but the present results clearly show that positive activation in these same important areas occurs for both cultural groups.

Another important result was that independent ratings of the partner's attractiveness correlated with activation in the *left* VTA, whereas the *right* VTA was associated with early-stage love. This supports the idea that romantic love (conceptualized as "wanting") and aesthetic value (conceptualized as "liking") are constructs that are processed separately at some levels in the brain [Aron et al., 2005; Berridge and Robinson, 2003].

However, there were also important differences between this study, done with Chinese participants, and Aron et al. [2005], done with American participants. Several questionnaire studies have suggested that there are differences in the ways that romantic love is experienced in Western and Eastern cultures [e.g. Dion and Dion, 1993; Gao, 2001; Jackson et al., 2006; Matsumoto, 1993]. Wu and Shaver [1992, 1993] showed that Chinese participants associated love with negative features. Other studies show that the middle orbitofrontal cortex region and accumbens where we found changes are affected following *either* gains or losses [Camara et al., 2009; Tom et al., 2007]; the middle orbitofrontal region is also involved in learning from negative feedback [Cohen et al., 2008]. In the medial orbitofrontal cortex, where we found a change (deactivation), a meta-analysis showed associations with monitoring of reward value [Kringelbach, 2005; Kringelbach and Rolls, 2004]. Thus, it is possible that Chinese participants may engage orbitofrontal systems and afferents, weigh the relationship more carefully, and take negative aspects into account more readily than Western participants (orbitofrontal cortex activation was not found in US and UK samples: Aron et al. [2005], Bartels and Zeki [2000], or Ortigue et al. [2007], although since we used a more powerful scanner (3T) for this study than Aron et al. [2005], who used a 1.5T, it is possible that the differences we found between the Chinese and U.S. participants (especially those involving greater activation for the Chinese sample) were due to technical aspects of the studies. The medial orbitofrontal cortex deactivation cultural difference in particularly should interpreted tentatively. Although Aron et al. [2005] did not report deactivation in the medial orbitofrontal cortex, when we used an ROI from our sample and applied it to their data, we found a marginally significant deactivation ($P = 0.05$, Table I). Another difference between our sample and the American sample was activation in the cerebellum, which also should not necessarily be interpreted as a cultural difference since Bartels and Zeki [2000] found cerebellum in their London sample and Ortigue et al. [2007] found cerebellum in their U.S. sample.

Neural activity associated with Traditionality and Modernity questionnaire scores are a novel finding of this study. Traditionality and Modernity were correlated with more activation in the nucleus accumbens, although in different regions and on different sides of the brain. Modernity also correlated with more activation in the caudate head, subthalamic area, and several cortical areas. We can only speculate, however, based on anatomical connectivity differences between the two areas of the accumbens [Pennartz et al., 1994], Traditionality rewards associated with the beloved may use more of the midbrain dopaminergic system and neuroendocrine systems of the hypothalamus, whereas Modernity rewards associated with the beloved appear to be complex, based on an array of information from cortex, that uses several regions of the basal ganglia. The areas correlated with Traditionality and Modernity, however, did not overlap with areas activated for the positive-versus-neutral contrast. This suggests that the immediate experience of early-stage intense romantic love may not be influenced by the cultural aspects of Traditionality and Modernity, although the processing of the experience could be culturally influenced (as indicated by the Traditionality and Modernity activations).

A provocative new finding is that there were regions of the brain associated with relationship happiness at the 18 month follow-up. No previous neuroimaging study of love has included a follow-up. Of particular interest was activation in the subgenual area (see Fig. 1), an area related to reward and pleasant feelings [Rolls et al., 2008; Small et al., 2001], as well as activation in the superior frontal gyrus, an area associated with mirth that can elicit laughter when stimulated [Fried et al., 1998]. These findings suggest that the more intensely rewarding a relationship is in its early stages, the more likely it is to continue to be rewarding in the future.

Intriguingly, greater relationship happiness at the 18-month follow-up was also associated with more deactivation in part of the caudate tail, the cerebellum, and the fusiform (face area). We can only speculate as to the mechanisms of these deactivations. For the fusiform (face area), it may be possible that because participants were asked, while viewing their partner's face, to recall the experience of being in love, those participants who were better at immersing themselves in the experience of love rather than just focusing on the face had better relationship happiness outcomes at 18 months.

Regarding generalizability, we should caution that this study was conducted with college-age participants, and it is possible that older participants might show different results. Also, China is just one example of an Eastern culture, and our Chinese participants (from the capital city of Beijing) may have been more Westernized than people from other Chinese regions. Future studies could focus on a less Westernized cultural context or on a Western culture that endorsed more traditional values (e.g. a rural setting), so that it would become clear whether the patterns we observed with Traditionality and Modernity are unique to Chinese participants.

CONCLUSION

Early-stage, intense romantic love for Chinese students has neural correlates in the midbrain, particularly the VTA, and in the caudate, as well as in forebrain reward areas such as the accumbens, orbitofrontal, and prefrontal cortex that evaluate the complexities of rewards. Lateralization of VTA activity distinguished effects of attraction (liking) from early-stage love (wanting). Endorsement of cultural values of Traditionality and Modernity were associated with specific patterns of activation in forebrain reward regions. Finally, activation in reward regions of the brain at time of scanning predicted relationship happiness 18 months later.

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