

SCIENTIFIC REPORTS

OPEN

Trait self-esteem and neural activities related to self-evaluation and social feedback

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Received: 02 June 2015

Accepted: 21 December 2015

Published: 04 February 2016

Self-esteem has been associated with neural responses to self-reflection and attitude toward social feedback but in different brain regions. The distinct associations might arise from different tasks or task-related attitudes in the previous studies. The current study aimed to clarify these by investigating the association between self-esteem and neural responses to evaluation of one's own personality traits and of others' opinion about one's own personality traits. We scanned 25 college students using functional MRI during evaluation of oneself or evaluation of social feedback. Trait self-esteem was measured using the Rosenberg self-esteem scale after scanning. Whole-brain regression analyses revealed that trait self-esteem was associated with the bilateral orbitofrontal activity during evaluation of one's **own positive traits but with activities in the medial prefrontal cortex, posterior cingulate, and occipital cortices** during evaluation of positive social feedback. Our findings suggest that trait self-esteem modulates the degree of both affective processes in the orbitofrontal cortex during self-reflection and cognitive processes in the medial prefrontal cortex during evaluation of social feedback.

People like to feel good about themselves, or seek to maintain their self-esteem, and this is a fundamental human nature^{1,2}. From the perspective of self-esteem has been identified as a function of one's own goodness or one's own personal achievement of his or her doing in areas that he or she identifies as important¹. Another perspective is, however, that people's thoughts and feelings about themselves, in part, are based on the beliefs they are perceived and evaluated by others⁴. The outcome of their proposed social feedback from others produces a range of emotional self-esteem, which is affected by a subjective monitoring of the degree to which he or she identifies as being accepted by others^{2,5}.

I have long been engaged in self-esteem research. The need for both self-reflection and reflection from others⁶. Behavioral evidence has revealed that people with high self-esteem, however, are actually approached, rather than more popular, here, however, the high self-esteem, however, do both their social or, rather, the emotional or socially adjusted³. However, it remains unknown whether and how the relationship between one's own and others' opinion about self-esteem is a dual process of self-esteem. On the one hand, Yang *et al.* (2012) found that the level of self-esteem, as measured by the Rosenberg self-esteem scale⁷, is negatively related to the neural activity in the dorsal anterior cingulate cortex (ACC) in response to self-evaluation compared to other-evaluation⁸. On the other hand, Ejnberger and colleagues found that the neural response in the dorsal ACC, bilateral anterior insula and dmPFC to the actual social feedback about self-esteem is negatively related to high self-esteem (which is measured by means of emotional aspects in response to each feedback)⁹.

Taken together, the above-mentioned studies have neural activity in different brain regions related to one's own and others' opinion about self-esteem, especially in the self-esteem. However, the previous studies employed different tasks and cannot directly clarify the relationship between self-esteem and brain activity from the different tasks or, by consequence, the neural activity in response to personally relevant information. The above-mentioned studies have not examined a priori to be positive or negative in the evaluation of participating in the neural response related to the self-esteem^{10,11}, while the neural activity related to participating in the neural response to personally relevant information is mainly related to participating in the neural response to self-evaluation in the self-esteem^{9,12}.

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effect of direct verbal, ample individual, possible given the biological evidence of verbal influence on brain activity in olfactory multiple cognitive and affective processes^{13,14}. To clarify this, the present study recruited the same verbal, ample (i.e., Chinese) and employed the same evaluation task. We tested whether and how one's self-esteem is associated with the neural activity during evaluation of one's own personality traits and evaluation of others' opinion about one's own personality. During fMRI scanning, participants were asked to rate the self or a celebrity and to rate social feedback of the self or a celebrity by responding on a 4-point scale. Neural activity underlying the reaction to a negative image by comparing reaction on the self or other or by comparing reaction on social feedback about the self or a celebrity. Neural activity related to a decrease in blood flow during brain activity of participants' response during self-reaction and during judgment on social feedback. This design allowed to examine whether self-esteem can be associated with neural activity related to both self-evaluation and social feedback. Moreover, a rating self-esteem was designed to the end of evaluation of one's self or others' traits than negative¹⁵, therefore also included in the social interaction between self-esteem and the neural activity related to both evaluation of positive traits of the self and a decrease of the positive traits of the self.

Self-esteem is considered to be a relatively enduring characteristic that has both affective and cognitive components¹⁶. For a people represent themselves in comparison with others, and the role of affective processes in which representation are major of individual can influence social cognitive and affective neuroscience of rating self-esteem¹¹. On the one hand, research on self-esteem has focused on a social interaction experience (self-evaluation) of self-esteem as one's feeling about the self¹⁷. Self-esteem, a trait, is an affective, opinion, internal experience. That is, people feel either good or bad about the self (affect), which then guides evaluation (cognition), and drive action (behavior)¹⁶. On the other hand, there is also a long history of accounting for self-esteem in interpersonal influence¹⁸. From this perspective, people processed others' reaction

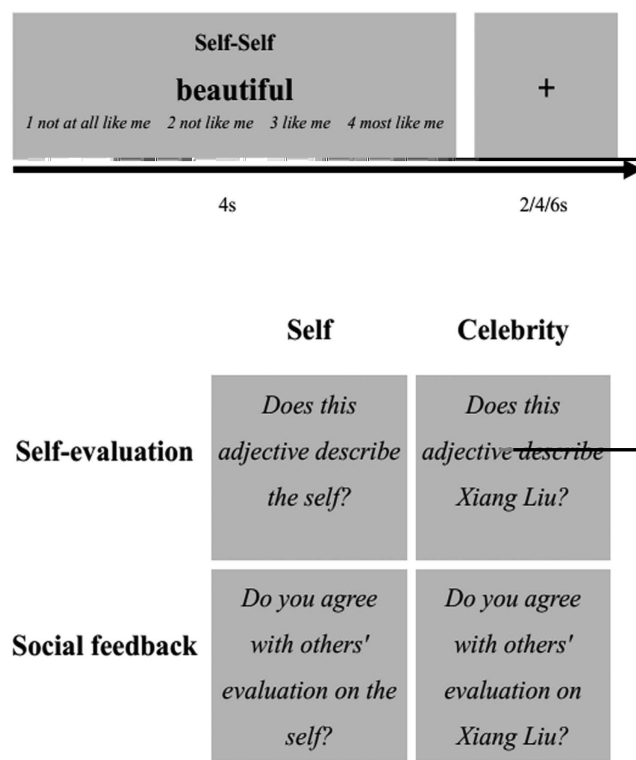


Figure 1. Experimental procedure (top) and experimental conditions (bottom) used in the fMRI study.

The condition varied according to the Target of the evaluation (Self or Celebrity) and to the Task of the evaluation (Self-evaluation or Social feedback).

fMRI Data Acquisition. Images were acquired in a 3T Siemens TRIO MRI scanner. Functional data comprised 1680 volumes acquired with T2*-weighted gradient echo planar imaging (EPI) sequence. We obtained 32 echo planar images per volume in the blood oxygenation level-dependent (BOLD) contrast. (TR = 2000 ms; TE = 30 ms; 3 mm × 3 mm in-plane resolution; Field of View [FOV] = 192 mm × 192 mm). Slices were acquired in an interleaved order and oriented parallel to the AC-PC plane, with thickness of 3 mm, 0.99 mm gap. High-resolution T1-weighted 3D fast field echo (FFE) sequence were obtained for anatomical reference (176 slices, TR = 1900 ms; TE = 2.52 ms; slice thickness = 1 mm; FOV = 250 mm × 250 mm; voxel size = 1 mm × 1 mm × 1 mm).

fMRI Data Analysis. Data were analyzed using Brain Voyager QX 2.3 (Brain Innovation, The Netherlands). Functional scans were realigned to the individual anatomical template and coregistered with each participant's anatomical data. Functional data were then normalized to the standard stereotaxic Talairach space, resliced into a voxel size of 3 × 3 × 3 mm³ and smoothed with an 8 mm Gaussian kernel. To increase signal-to-noise ratio, event-related effects were modeled using the general linear model and employing a canonical hemodynamic response function convolved with the experimental design. First-level analyses were performed on the individual data for each voxel and to compare regionally specific effects in individual participants using linear contrasts. Group analyses were then conducted using random-effects model to enable population inference. Inference of statistical significance was conducted at the $p < 0.005$, in region encompassing a least 20 voxels²⁰.

Modeling self-evaluation and self-evaluation of others. Brain activation associated with the evaluation of oneself or others was modeled by contrasting (EPS + ENS) vs. (EPC + ENC), the contrast of (EPS - EPC) vs. (ENS - ENC) and calculated to define brain regions involved in the evaluation of positive ratings of the self. Moreover, to identify the her participants' ratings self-esteem can model the relationship between the evaluation of oneself or others, self-esteem, core derived from the RSE questionnaire entered as a regressor in a whole brain regression analysis. To assess the association with the contrast of (EPS + ENS) vs. (EPC + ENC) or (EPS - EPC) vs. (ENS - ENC), respectively.

Further, brain activation related to participants' self-debasing self-evaluation by regressing participants' ratings of each rating adjective on a 4-point scale (1 = strongly disagree, 4 = strongly agree). Brain activation has also linear relationship with increasing ratings in the evaluation of the self were calculated. The contrast of (EPS + ENS) vs. (EPC + ENC) or (EPS - EPC) vs. (ENS - ENC) were conducted on the brain activation related to the self-debasing self-evaluation of the positive ratings of the self, respectively. Moreover, to identify the her people's ratings self-esteem could model the brain regions has showed a linear

relationship in increasing rating in each rating of the self or position of the self, the self-esteem core derived from the RSEQ questionnaire were entered as a regressor in a whole brain regression analysis of the contrast of the contrast of (EPFS + ENFS) \times (EPC + ENC) or (EPFS - EPC) \times (ENFS - ENC), respectively.

Mediation of the effect of social feedback on self-esteem. Brain activation related to each condition of other's feedback on the self was examined by contrasting (EPFS + ENFS) \times (EPFC + ENFC) with the contrast of (EPFS - EPFC) \times (ENFS - ENFC) as calculated to determine brain regions engaged in each condition of other's position in the feedback on the self. Moreover, to identify whether participants' rating of the self-esteem could modulate their brain activation in order to each condition of social feedback on the self or position of social feedback on the self, a whole brain regression analysis of the contrast of (EPFS + ENFS) \times (EPFC + ENFC) or the contrast of (EPFS - EPFC) \times (ENFS - ENFC) were conducted in the self-esteem core as a regressor.

Further, brain activation related to participants' rating of each rating of other's social feedback was examined by regressing participants' rating of each rating as a covariate on a 4-point scale (1 = strongly disagree, 4 = strongly agree). The contrast of (EPFS + ENFS) \times (EPFC + ENFC) was then conducted to examine brain activation related to each condition of other's social feedback on the self. In addition, the contrast of (EPFS - EPFC) \times (ENFS - ENFC) was added in the regression analysis to examine brain activation related to each condition of other's social feedback on the self. Moreover, to identify whether people's rating of the self-esteem could modulate their brain regions related to

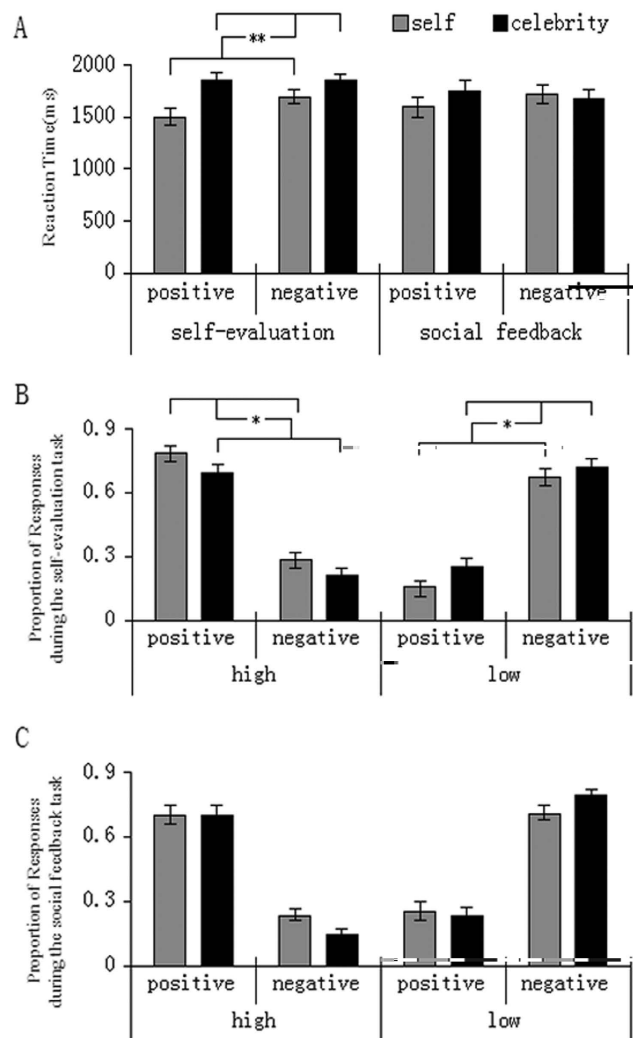


Figure 2. Participants' reaction times (A), proportion of responses during the self-evaluation task (B) and proportion of responses during the social feedback task (C).

contrasts	Anatomical region	BA	L/R	X	Y	Z	k	r
(EPS + ENS) (EPC + ENC)	middle frontal gyrus	10	L	-41	57	8	31	0.68
	inferior frontal gyrus	47	L	-38	23	1	58	0.66
	precuneus	31	L	-15	-50	29	21	0.68
	cuneus	19	L	-9	-88	37	21	0.64
	parahippocampal cortex		L	-26	-45	3	23	0.67
	middle temporal gyrus	21	L	-64	-33	-10	34	0.65
(EPS - EPC) (ENS - ENC)	superior temporal gyrus	22	L	-58	-51	20	144	0.68
	middle occipital gyrus	19	L	-27	-93	22	39	0.67
	middle frontal gyrus	9	L	-44	31	36	68	0.69
	inferior temporal gyrus	20	L	-60	-11	-19	29	0.65
	middle temporal gyrus	21	L	-53	-29	-9	29	0.63

Table 1. Association between self-esteem and the neural activity related to the self during the self-evaluation task.

= 88), right middle temporal gyrus (34/-79/23, $z = 4.42$, $p = .35$) and middle occipital gyrus (23/-94/9, $z = 4.28$, $p = .24$) (Table 2). However, people's trait self-esteem did not correlate with the neural activity related to social feedback on oneself.

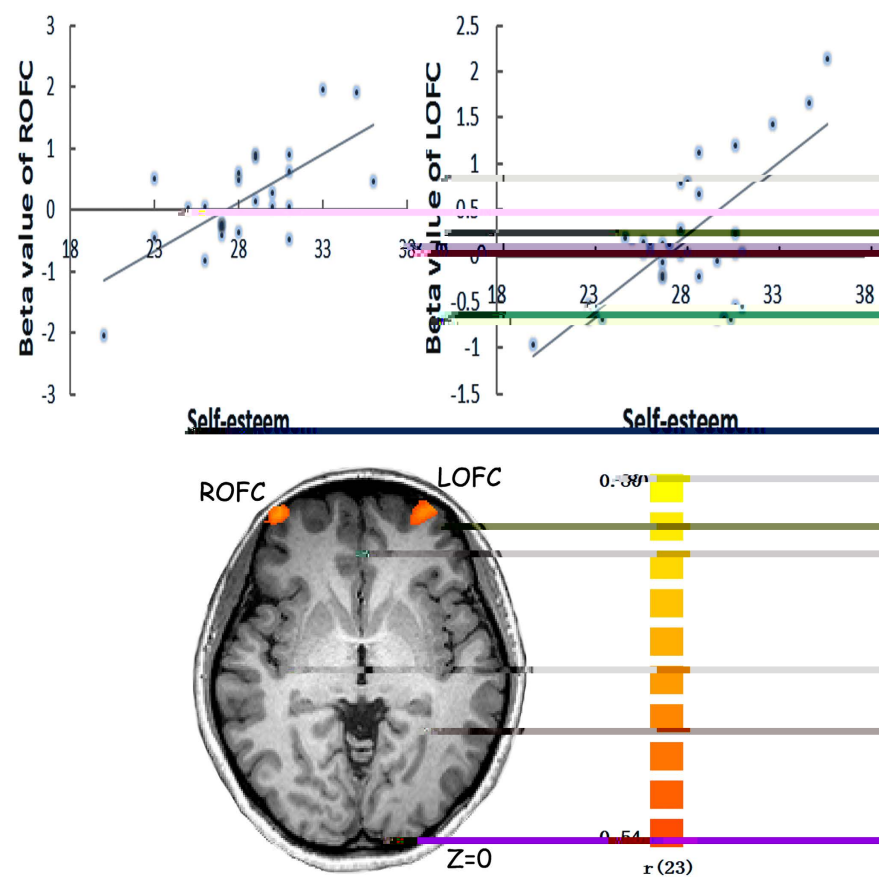


Figure 3. Prediction of self-esteem by attitude-related neural activity showed significant activations in the bilateral OFC in responses to evaluation of positive traits of the self compared to the celebrity ($Z = 0$).

contrasts	Anatomical region	BA	L/R	X	Y	Z	k	t
(EPFS + ENFS) (EPFC + ENFC)	ACC	24	L	−7	36	4	221	5.22
(EPFS EPFC) (ENFS ENFC)	ACC	32	L	−9	40	4	22	2.89
	Middle frontal gyrus	10	L	−33	38	21	24	4.41
	PCC	30	R	1	−54	6	60	4.02
	Precuneus	7	L	−15	−71	46	279	4.71
	Precuneus	7	R	14	−69	49	88	4.11
	Middle temporal gyrus	19	R	34	−79	23	35	4.42
	Middle occipital gyrus	18	R	23	−94	9	24	4.28

Table 2. Neural activity related to self during the social feedback task.

Further, a whole brain regression analysis of the neural activity in response to the evaluation of social feedback of the self versus the celebrity revealed significant activation in the high-calorie ($22/−14/29$, $z = 3.49$, $p = .0006$). Meanwhile, a whole brain regression analysis of the relationship between self-esteem ratings and core affect revealed significant activation in the ventral medial prefrontal cortex (mPFC: $9/53/3$, $z = 0.66$, $p = .51$), PCC ($−36/31/24$, $z = 0.63$, $p = .53$) and occipital cortex ($6/−92/−5$, $z = 0.63$, $p = .53$) in response to the evaluation of positive social feedback of the self versus the celebrity (Fig. 4).

Discussion

There have been less than perfect agreements in the psychological literature on the nature of self-esteem in terms of its representational, experiential, and personal perspectives^{1,4}, and a deeper cognitive process^{18,21–23}. The current work examined whether and how the relationship between self-esteem and social feedback can be related to one's trait self-esteem and whether and how trait self-esteem can be associated with the neural activity related to both high and low self-esteem. Consistent with our hypothesis, people with high self-esteem showed a positive correlation with the experiential processing in OFC, which has been hypothesized as a deeper process; and consistent with our second hypothesis, their trait self-esteem was positively correlated with the experiential

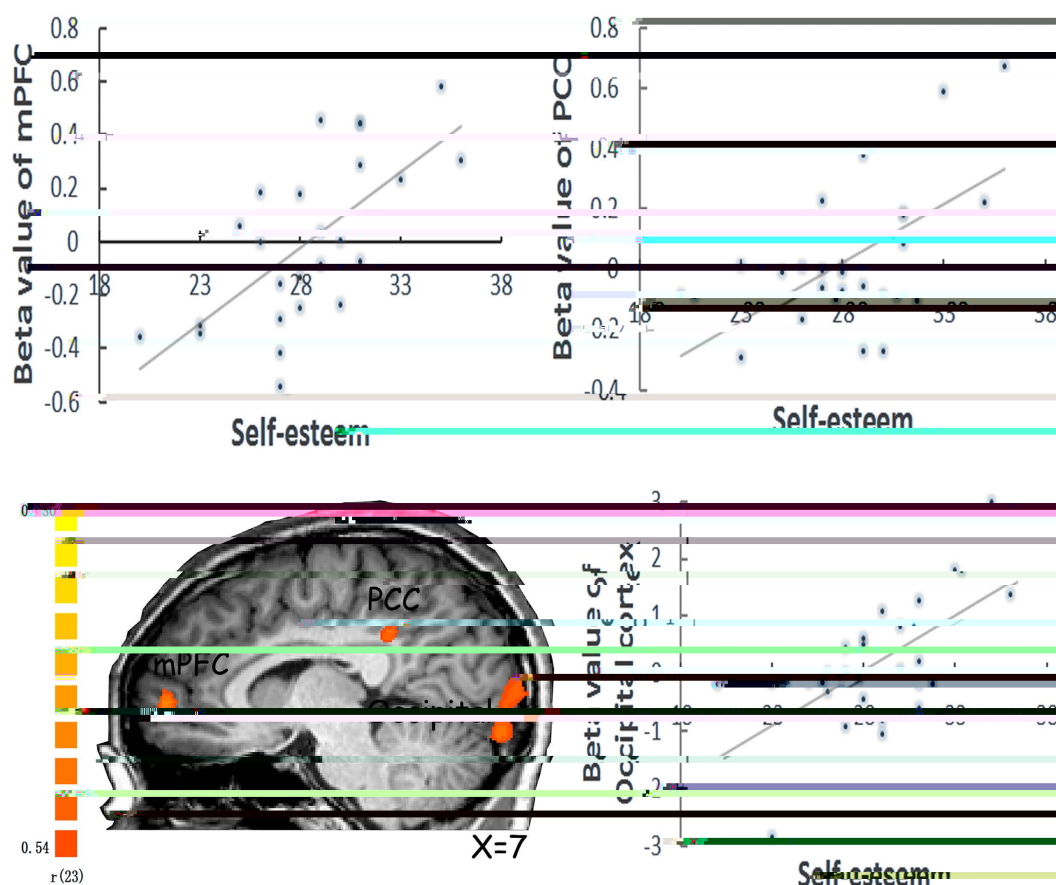


Figure 4. Prediction of self-esteem by attitude-related neural activity showed significant activations in the medial prefrontal cortex (mPFC), PCC and occipital cortex in responses to evaluation of positive social feedback to the self compared to the celebrity ($X=7$).

processing in mPFC/PCC which supports cognitive processing. Moreover, our fMRI results suggest that self-esteem predicted the activation of the middle frontal gyrus, inferior temporal gyrus, and middle temporal gyrus in response to evaluation of one's own picture compared to that of a celebrity.

In the present study, self-esteem was positively related to the activation of the bilateral OFC, which is involved in the evaluation of positive feedback to the self. The orbitofrontal cortex (OFC) is an important part of the network involved in emotional processing because of its anatomical connections with a wide range of other brain regions, including the amygdala, cingulate cortex, and insula²⁶. Some studies have suggested that the OFC can be considered a part of a global workspace for evaluating the salience of stimuli^{27,28}. Nemeroff et al. (2009) have shown that OFC activation during a decision-making task when receiving pleasurable and painful feedback is related to the amount of money received/lost in a probabilistic task²⁹. OFC activation is also correlated with the amount of money received/lost in a probabilistic task³⁰. Damage to the OFC in humans may predict the generation of helpful emotional information³¹, which may be associated with impairments in emotional and social behavior characterized by socially inappropriate and inappropriate behavior. Self-esteem is an individual's self-evaluation from the perspective of a core self-esteem, which refers to how one feels about oneself and is inherent in the self-esteem process from the perspective of a model of self-esteem^{17,32}. Rather than being based solely on cognitive self-evaluation, self-esteem is also a self-esteem process that may or may not be related to specific cognitive self-evaluation⁵. Therefore, the activation of OFC may be involved in the self-esteem process and is associated with people's self-esteem during the self-evaluation task.

Our results also have evidence that self-esteem can be a positive relationship between cognitive and neural activation in the medial prefrontal/posterior cingulate cortex during evaluation of positive social feedback about the self. According to the self-concept theory, the point of view of others (the "other" of mind), a related form of self-projection, in the brain network is associated with the cognitive processing, including frontal lobe, temporal lobe, and parietal lobe³³. The self-concept theory also suggests that the self-esteem is a psychological mechanism that monitors the quality of people's relationship with others³⁴. It is a person's internal, subjective and internal marker regarding the degree to which the individual is being included or excluded by other people⁴. Self-esteem encompasses a cognitive processing in monitoring the relationship with others, from the perspective of a person. Moreover, our results suggest that self-esteem is also associated with activation in the occipital cortex during

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Acknowledgements

All authors would like to thank Dr. Karolina Dedovic for proof reading of the manuscript. This research was supported in part by the Humanities and Social Sciences Foundation of Ministry of Education of China (15XJC190002) and the Social Science Foundation Project of CQ (2015QNSH13) of J.Y. and National Natural Science Foundation of China grants (31421003, 31470986, and 91332125) of S.H.

Author Contributions

J.Y. and S.H. designed the study. X.X. and Y.C. collected the data. J.Y., Z.S. and S.H. wrote the paper. All authors reviewed the manuscript.