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

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Juan Yang[1], Xiaofan Xu[1], Yu Chen[1], Zhenhao Shi[2] & Shihui Han[3]

Self-esteem has been associated with neural responses to self-re f ection and attitude toward social feedback but in di f erent brain regions. The distinct associations might arise from di f erent 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 f ndings suggest that trait self-esteem modulates the degree of both a f ective processes in the orbitofrontal cortex during self-re f ection and cognitive processes in the medial prefrontal cortex during evaluation of social feedback.

People i e o feel good abo hem el e , o eek o main ain hei elf-e eem, and hi i a f ndamen al h man na e[1,2]. F om he *a e* *a* pe pec i e, elf-e eem ha been ie ed a e al a ion of one' o n goodne o o h[3] o a pe onal a e men of ho ell one i doing in a ea ha he indi id al ega d a impo an [1]. An *e e* *a* pe pec i e, ho e e , gge ha people' ho gh and feeling abo hem el e e ec , in pa , ho he belie e he a e pe cei ed and e al a ed b o he [4]. e ociome e heo p opo e ha ocial feedback f om o he p od ce a onge ec on elf-e eem beca e he elf-e eem em i elf i a bjec i e moni o o ga ge of he deg ee o hich he indi id al i being accep ed b o he people[2,5].

I ha long been gge ed ha elf-e eem e ec he need fo bo h elf- e pec and e pec f om o he [6]. Beha io al e idence ha e ealed ha people i h high elf-e eem, ho belie e ha he a e ociall app o ed, a e hem el e mo e po i i el he ea ho e i h lo elf-e eem, ho do b hei ocial o h, a e hem-el e lo e on ociall al ed ai [3]. Ho e e , o da e, i emain nkno n he he and ho ne al ac i i ie ela ed o one' o n and o he ' opinion abo he elf a e a ocia ed i h di po i ional elf-e eem. On he one hand, Yang *e a* . (2012) fo nd ha le el of ai elf-e eem, e ima ed b he Ro enbe g elf-e eem cale[7], e e nega i el a ocia ed i h he ne al ac i i in he do al an e io cing la e co e (ACC) in e pon e o elf-e al a ion compa ed o o he -e al a ion[8]. On he o he hand, Ei enbe ge and colleag e fo nd ha ne al e pon e in he do al ACC, bila e al an e io in la and dmPFC o he a i de o a d ocial feedback abo he elf e e nega i el a ocia ed i h a e elf-e eem (hich a e ima ed b mea ing emo ional a e in e pon e o each feedback)[9].

Taken oge he , he e ob e a ion gge ha he ne al ac i i ie in di e en b ain egion ela ed o one' o n and o he ' opinion abo he elf a e epa a el a ocia ed i h hei elf-e eem. Ho e e , he p e io die emplo ed di e en a k and canned di e en c l al pop la ion , i i nclea he he he di inc a ocia ion be een elf-e eem and b ain ac i i a o e f om he di e en a k o bjec ample . Ne al ac i i in e pon e o pe onali ai ha a e de e mined a p io i o be po i i e o nega i e mainl e ec ed pa icipan ' ne al e pon e ela ed o he a k[10,11], hile ne al ac i i ela ed o pa icipan ' indi id ali ed e pon e o pe onali ai mainl e ec ed pa icipan ' ne al e pon e a ocia ed i h hei a i de[9,12]. e

[1]Faculty of Psychology, Southwest University, Chongqing, 400715, China. [2]The Annenberg Public Policy Center, University of Pennsylvania, Philadelphia, PA 19104-3806, USA. [3]Department of Psychology, PKU-IDG/McGovern Institute for Brain Research, Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, 100871, China. Correspondence and requests for materials should be addressed to J.Y. (email: valleyqq@swu.edu.cn) or S.H. (email: shan@pku.edu.cn)

e ec of di e en c l al ample i al o po ible gi en he b an ial e idence of c l al in ence on b ain ac i i in ol ed in m l iple cogni i e and a ec i e p oce e[13,14]. To cla if he e, he p e en d ec i ed he ame c l al ample (i.e., Chine e) and emplo ed he ame e al a ion a k. We e ed he he and ho one' elf-e eem i a ocia ed i h he ne al ac i i d ing e al a ion of one' o n pe onali ai and e al a ion of o he ' opinion abo one' o n pe onali i . D ing fMRI canning, pa icipan e e a ked o e ec on he elf o a celeb i and o e ec on ocial feedback o he elf o o a celeb i b e ponding on a 4-poin cale. Ne al ac i i nde l ing he e ec ion a k a e ima ed b con a ing e ec ion on he elf e o he o b con a ing e ec ion on ocial feedback abo he elf o a celeb i . Ne al ac i i ela ed o a i de a de ned b eg e ing b ain ac i i o pa icipan ' e pon e d ing elf- e ec ion and d ing j dgmen on ocial feedback. i de ign allo ed o e amine he he ai elf-e eem can be a ocia ed i h ne al ac i i ela ed o bo h elf-e al a ion and ocial feedback. Mo eo e , a ai elf-e eem a de ned a he endenc o e al a e one elf po i i el a he han nega i el [15], e e e al o in e e ed in he a ocia ion be een elf-e eem and he ne al ac i i ela ed o bo h e al a ion of po i i e ai of he elf and a i de o a d he po i i e ai of he elf.

Self-e eem i con ide ed o be a ela i el end ing cha ac e i ic ha po e e bo h a ec i e and cogni- i e componen [16]. e a people ep e en hem el e in compa i on i h o he , and he ole of a ec i e p oce e in ch ep e en a ion a e ma e of igni can in e e o a ocial cogni i e and a ec i e ne o ci- ence of ai elf-e eem[11]. On he one hand, e ea ch on elf-e eem ha foc ed on a ocia ed in ape onal e pe ience (elf-e al a ion) de ned elf-e eem a one' feeling abo he elf[17]. Self-e eem, a i oo , i an a ec i e, op-do n, in e nal e pe ience. a i , people feel ei he good o bad abo he elf (a ec), hich hen g ide e al a ion (cogni ion), and d i e ac ion (beha io)[16]. On he o he hand, he e i al o a long hi o of acco n ing fo elf-e eem' in e pe onal in ence [18]. F om hi pe pec i e, people p oce ed o he ' eac ion

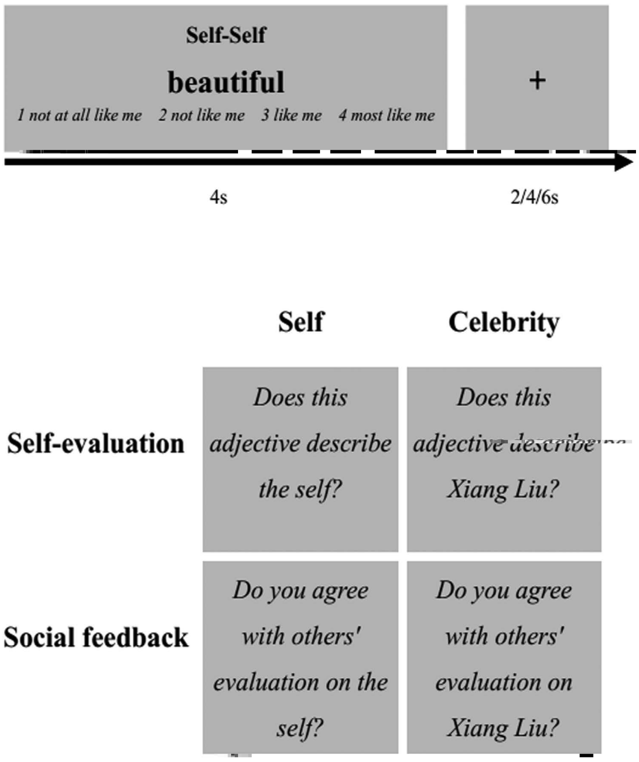

Figure 1. Experimental procedure (top) and experimental conditions (bottom) used in the fMRI study. e condi ion a ied acco ding o he Ta ge of he e al a ion (elf e Celeb i) and o he Ta k of he e al a ion (elf-e al a ion e ocial feedback).

fMRI Data Acquisition. Image e e acq i ed in a 3T Siemen TRIO MRI canne . F nc ional da a com-p i ed 1680 ol me acq i ed i h T2*- eigh ed g adien echo plana imaging (EPI) eq ence . We ob ained 32 echo plana image pe ol me en i i e o blood o genа ion le el-dependen (BOLD) con a (TR = 2000 m ec; TE = 30 m ec; 3 mm × 3 mm in-plane e ol ion; Field of Vie [FOV] = 192 mm × 192 mm). Slice e e acq i ed in an in e lea ed o de and o ien ed pa allel o he AC-PC plane, i h hickne of 3 mm, 0.99 mm gap. High- e ol ion T1- eigh ed 3D fa eld echo (FFE) eq ence e e ob ained fo ana omical efe -ence (176 lice , TR = 1900 m ec; TE = 2.52 m ec; lice hickne = 1 mm; FOV = 250 mm × 250 mm; o el i e = 1 mm × 1 mm × 1 mm).

fMRI Data Analysis. Da a e e anal ed ing B ain Vo age QX 2.3 (B ain Inno a ion, e Ne he land). F nc ional can e e ealigned i hin and ac o n o co ec fo head mo ion, and co- egi e ed i h each pa icipan ' ana omical da a. F nc ional da a e e hen no mali ed in o anda d e eo ac ic Talai ach pace, e liced in o a o el i e of 3 × 3 × 3 mm^3 and moo hed i h an 8 mm Ga ian ke nel o inc ea e ignal- o-noi e a io. E en - ela ed e ec e e e ima ed ing he gene al linea model and emplo ing a canonical hemod -namic e pon e f nc ion con ol ed i h he e pe imen al de ign. Fi ed e ec anal e e e pe fo med o e ima e e ec a each o el and o compa e egionall peci c e ec in indi id al pa icipan ing linea con a . G o p anal e e e hen cond c ed ing andom-e ec model o enable pop la ion infe ence . Infe ence of a i ical igni cance ed nco ec ed al e < 0.005, in egion encompa ing a lea 20 o el [20].

M de g f ef- e a ed c a d g he ef-e a a a . B ain ac i a ion a ocia ed i h e al a ion of one' o n ai a e ima ed b con a ing (EPS + ENS) e (EPC + ENC). e con a of (EPS EPC) e (ENS ENC) a calc la ed o de ne b ain egion in ol ed in e al a ion of po i i e ai of he elf. Mo eo e , o iden if he he pa icipan ' ai elf e eem can mod la e hei b ain ac i a ion ela ed o e al a ion of one' o n ai , elf e eem co e de i ed f om he RSE q e ionnai e e e en e ed a a eg e - o in a hole b ain eg e ion anal i o a e i a ocia ion i h he con a al e of (EPS + ENS) e (EPC + ENC) o (EPS EPC) e (ENS ENC), e pec i el .

F he , b ain ac i a ion ela ed o pa icipan ' a i de abo he elf e e e ima ed b eg e ing pa - icipan ' a ing of each ai adjec i e on a 4 poin cale (1 = ongl di ag ee, 4 = ongl ag ee). B ain ac i- a ion ha ho ed linea ela ion hip i h inc ea ing a ing in e al a ing ai of he elf e e calc la ed. e con a of (EPS + ENS) e (EPC + ENC) o (EPS EPC) e (ENS ENC) e e cond c ed o a e b ain ac i a ion ela ed o a i de o a d he elf o a i de o a d he po i i e ai of he elf, e pec i el . Mo eo e , o iden if he he people' ai elf e eem co ld mod la e he b ain egion ha ho ed a linea ela ion hip i h inc ea ing a ing in e al a ing ai of he elf o po i i e ai of he elf, he elf e eem co e de i ed f om he RSE q e ionnai e e e en e ed a a eg e o in a hole b ain eg e ion anal i o a e i a ocia ion i h he con a al e of (EPS + ENS) e (EPC + ENC) o (EPS EPC) e (ENS ENC), e pec i el .

M de g f e f e a ed c a d g he c a feedbac a . B ain ac i a ion ela ed o e al a ion of o h- e ' feedback on he elf a e ima ed b con a ing (EPFS + ENFS) e (EPFC + ENFC). e con a of (EPFS EPFC) e (ENFS ENFC) a calc la ed o de ne b ain egion engaged in e al a ion of o he ' po - i i e feedback on he elf. Mo eo e , o iden if he he pa icipan ' ai elf e eem can mod la e hei b ain ac i a ion in ol ed in e al a ion of ocial feedback on he elf o po i i e ocial feedback on he elf, a hole b ain eg e ion anal i of he con a al e of (EPFS + ENFS) e (EPFC + ENFC) o he con a al e of (EPFS EPFC) e (ENFS ENFC) e e cond c ed i h elf e eem co e a a eg e o .

F he , b ain ac i a ion ela ed o pa icipan ' a i de abo ocial feedback e e e ima ed b eg e ing pa icipan ' a ing of each ai adjec i e on a 4 poin cale (1 = ongl di ag ee, 4 = ongl ag ee). e con- a of (EPFS + ENFS) e (EPFC + ENFC) a hen cond c ed o a e b ain ac i a ion ela ed o a i de o a d he ocial feedback on he elf. In addi ion he con a of (EPFS EPFC) e (ENFS ENFC) a ed in he eg e ion anal e o e amine b ain ac i a ion ela ed o a i de o a d po i i e ocial feedback on he elf. Mo eo e , o iden if he he people' ai elf e eem co ld mod la e hei b ain egion ha ho ed a

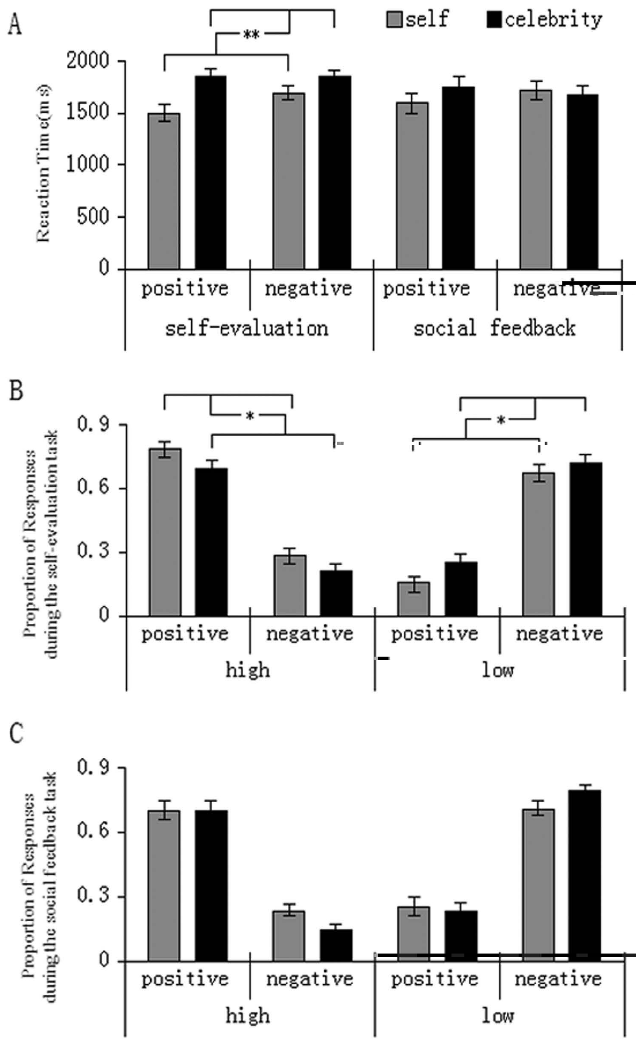

Figure 2. Participants' reaction times (**A**), p opo ion of e pon e d ing he elf-e al a ion a k (**B**) and p opo ion of e pon e d ing he ocial feedback a k (**C**).

contrasts	Anatomical region	BA	L/R	X	Y	Z	*k*	*r*
(EPS + ENS) (EPC + ENC)	middle f on al g	10	L	−41	57	8	31	0.68
	infe io f on al g	47	L	−38	23	1	58	0.66
	p ec ne	31	L	−15	−50	29	21	0.68
	c ne	19	L	−9	−88	37	21	0.64
	pa ahippocampal co e		L	−26	−45	3	23	0.67
	middle empo al g	21	L	−64	−33	−10	34	0.65
	pe io empo al g	22	L	−58	−51	20	144	0.68
	middle occipi al g	19	L	−27	−93	22	39	0.67
(EPS EPC) (ENS ENC)	middle f on al g	9	L	−44	31	36	68	0.69
	infe io empo al g	20	L	−60	−11	−19	29	0.65
	middle empo al g	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), igh middle empo al g (34/−79/23, = 4.42, = 35) and middle occipi al g (23/−94/9, = 4.28, = 24) (Table 2). Ho e e , people ai elf e eem did no co ela e i h he ne al ac i i ela ed o ocial feedback on one elf.

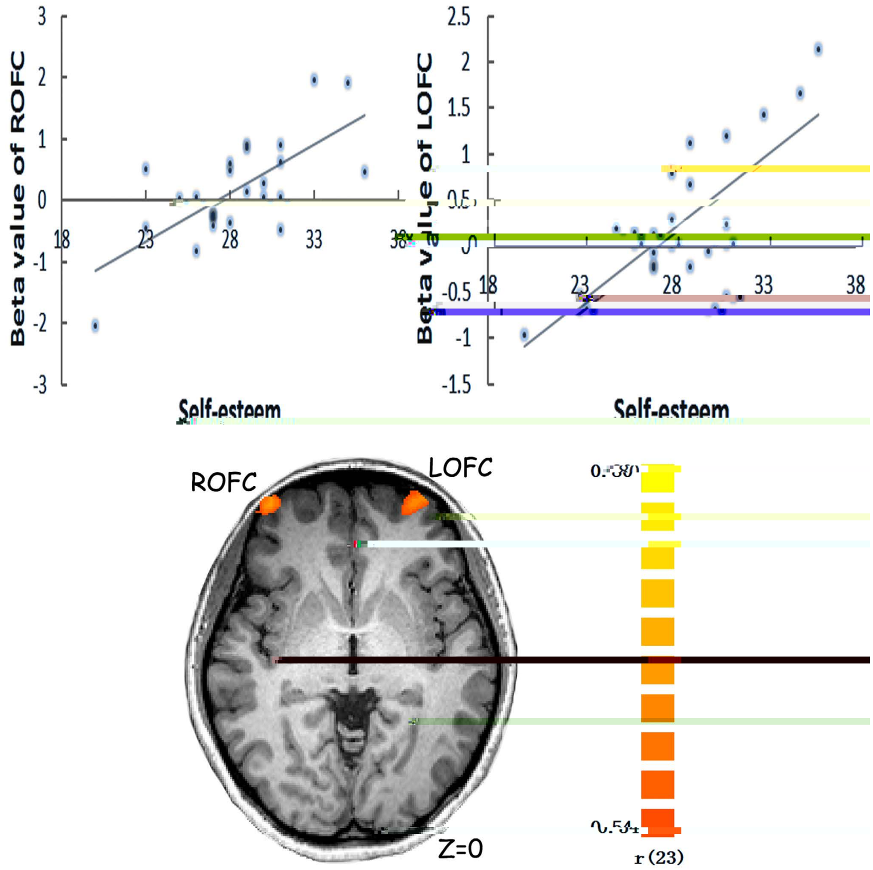

Figure 3. Prediction of self-esteem by attitude-related neural activity showed significant activations in the bilateral OFC in responses to evaluation of positive traits of the self compared to the celebrity (Z = 0).

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 f on al g⊠	10	L	−33	38	21	24	4.41
	PCC	30	R	1	−54	6	60	4.02
	P ec ne	7	L	−15	−71	46	279	4.71
	P ec ne	7	R	14	−69	49	88	4.11
	Middle empo al g⊠	19	R	34	−79	23	35	4.42
	Middle occipi al g⊠	18	R	23	−94	9	24	4.28

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

F he , a hole b ain eg e ion anal⊠ i of he ne al ac i i ⊠ in e pon e o he e al a ion of ocial feed-back o he elf e he celeb i ⊠ e ealed a igni can ac i a ion in he igh ca da e (22/−14/29, = 3.49, = 20). Mean hile, a hole b ain eg e ion anal⊠ e of a i de ela ed ne al ac i i ⊠ i h elf e eem a -ing co e a a eg e o e ealed igni can ac i a ion in he en al medial p ef on al co e (mPFC: 9/53/3, = 0.66, = 25), PCC (−36/31/24, = 0.63, = 24) and occipi al co e (6/−92/−5, = 0.63, = 73) in e pon e o e al a ion of po i i e ocial feedback o he elf e he celeb i ⊠ (Fig. 4).

Discussion

e e ha been le han pe fec ag eemen i hin he p ⊠chological li e a e on he na e of elf e eem in e m of in ape onal e in e pe onal pe pec i e[1,4], and a ec i e e cogni i e p oce e[16,21 23]. e c en o k e amined he he and ho ne al ac i i ⊠ ela ed o elf e al a ion and ocial feedback can be ela ed o one' ai elf e eem and he he and ho ai elf e eem can be a ocia ed i h he ne al ac i i ⊠ ela ed o bo h a k and a i de. Con i en i h o h⊠po he i , people' ai elf e eem a po i i el⊠ co ela ed i h he in ape onal p oce ing in OFC hich ha been ho n o ppo a ec i e p oce e ; and con i en i h o econd h⊠po he i , hei ai elf e eem a po i i el⊠ co ela ed i h he in e pe onal

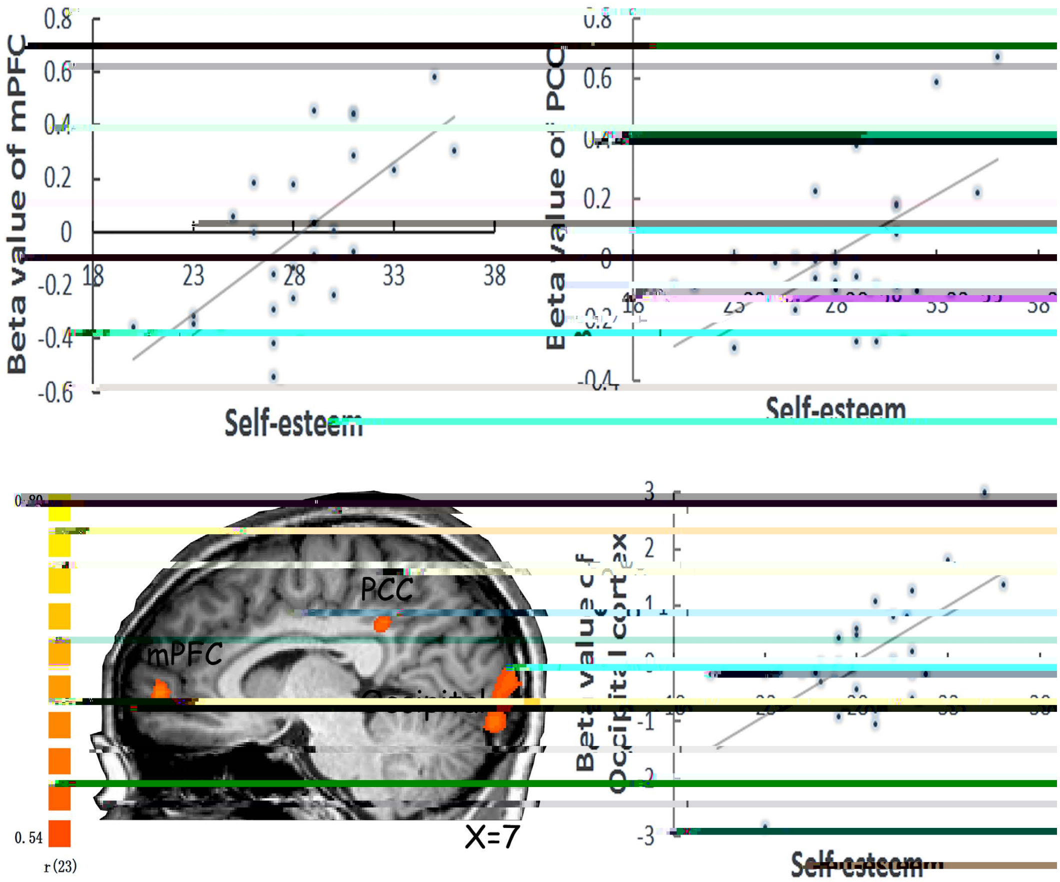

Figure 4. Prediction of self-esteem by attitude-related neural activity showed significant activations in the medial prefrontal cortex (mPFC), PCC and occipital cortex in responses to evaluation of positive social feedback to the self compared to the celebrity (X = 7).

p oce ing in mPFC/PCC hich ppo cogni i e p oce e . Mo eo e , o fMRI e l gge ed ha ai elf e eem p edic ed he a k ela ed ne al ac i i in he middle f on al g , infe io empo al g and middle empo al g in e pon e o e al a ion of one' o n po i i e ai compa ed o ho e of a celeb i .

In e e ingl one' elf e eem a po i i el a ocia ed i h he a ec i e ela ed ne al ac i i in bila e al OFC, hich a in ol ed in e al a ion of po i i e ai of he elf. e o bi of on al co e (OFC) i an impo - an pa of he ne o k in ol ed in emo ional p oce ing beca e of i ne oana omical connec i i i h a ec- i e egion ch a he am gdala, cing la e co e , and in la[24-26]. Some die ha e en gge ed ha OFC can be ie ed a pa of a global o k pace fo e al a ing he a ec i e alence of im li[27,28]. N me o die ha e ho n OFC ac i a ion d ing a ec i e p oce ing, ch a hen ecei ing plea an and painf l o che[29]. OFC ac i a ion a al o co ela ed i h he amo n of mone ecei ed/lo in a p obabili ic i al a ocia ion a k[30]. Damage o he OFC in h man ma p ecl de he gene a ion of helpf l emo ional info ma ion[31], hich ma be a ocia ed i h impai men in emo ional and ocial beha io cha ac e i ed b ocial inapp op ia ene and i e pon ibili . Self e eem i an a ec i el laden elf e al a ion f om he *a e' a ie*[5] and a i co e, elf e eem efe ' o ho e feel abo o el' e and i inhe en l oo ed in a ec i e p oce e f om he *a ec- e* model of elf e eem[17,32]. Ra he han being ba ed olel on cogni i e elf e al a ion , elf e eem in ol e a ec i e p oce e ha ma o ma no be ela ed o peci c, con cio elf e al a ion[5]. e efo e, he ac i a ion of OFC ma be al o in ol' ed in a ec i e p oce ing and a a ocia ed i h people' elf e eem d ing he elf e al a ion a k.

O d al o ho ed e idence ha ai elf e eem can be al o po i i el ela ed o he cogni i e ela ed ne al ac i i in he medial p ef on al/po e io cing la e co e d ing e al' a ion of po i i e ocial feedback abo he elf. Acc m la ing da a gge ha concei ing a ie poin of o he (heo of mind), a a ela ed fo m of elf p ojec ion, in ol e b ain ne o k a ocia ed i h he cogni i e p oce ing, incl ding f on al lobe em ha a e adi ionall a ocia ed i h planning, a ell a medial empo al pa ie al lobe em ha a e a' ocia ed i h memo [33]. ' e ociome e heo p opo e ha elf e eem i e en iall a p chological me e , o ga ge, ha moni o ' he q ali of people' ela ion hip i h o he [34]. I i a pe on' in e nal, bjec i e inde o ma ke ega ding he deg ee o hich he indi id al i being incl ded e e cl ded b o he people[4]. elf e eem encompa e a cogni i e p oce ing in moni o ing he ela ion hip i h o he' , f om he *e e- a pe pec i e*. Mo eo e , ai elf e eem a al o a ocia ed i h ac i i ie in he occipi al co ice d ing

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