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# Neural representation of self-concept in sighted and congenitally blind adults

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D a P c , P < U , B 100871, P ' R b c C a

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**The functional organization of human primary visual and auditory cortices is influenced by sensory experience and exhibits cross-modal plasticity in the absence of input from one modality. However, it remains debated whether the functional architecture of the prefrontal cortex, when engaged in social cognitive processes, is shaped by sensory experience. The present study investigated whether activity in the medial prefrontal cortex underlying self-reflective thinking of one's own traits is modality-specific and whether it undergoes cross-modal plasticity in the absence of visual input. We scanned 47 sighted participants and 21 congenitally blind individuals using functional magnetic resonance imaging during trait judgements of the self and a familiar other. Sighted participants showed medial prefrontal activation and enhanced functional connectivity between the medial prefrontal and visual cortices during self-judgements compared to other-judgements on visually but not aurally presented trait words, indicating that medial prefrontal activity underlying self-representation is visual modality-specific in sighted people. In contrast, blind individuals showed medial prefrontal activation and enhanced functional connectivity between the medial prefrontal and occipital cortices during self-judgements relative to other-judgements on aurally presented stimuli, suggesting that visual deprivation leads to functional reorganization of the medial prefrontal cortex so as to be tuned by auditory inputs during self-referential processing. The medial prefrontal activity predicted memory performances on trait words used for self-judgements in both subject groups, implicating a similar functional role of the medial prefrontal cortex in self-referential processing in sighted and blind individuals. Together, our findings indicate that self-representation in the medial prefrontal cortex is strongly shaped by sensory experience.**

**Keywords:** a a c ; ; c a a c a c a ; da a c ; b d
**Abbreviation:** BA = B d a a a; MRI = a c a c a

## Introduction

c a a a d a d c c b c . T cc a c a c d a N a a c ab a b a c a c a c d a ac a d b a d d / d a c c d c d (B *et al.*, 2002; G *et al.*, 2009) a d b B a ad ada a (Ba a d N , 2002; b d d d a (Sada *et al.*, 1996; B c *et al.*, 1998; Pa c a-L *et al.*, 2005). S d a a a d- B *et al.*, 2002). M , cc a ac a d a a c a d c d a b d d d a dc b a a a c a d

R c d J 1, 2010. R d S b 2, 2010. Acc d S b 5, 2010. Ad a c Acc b ca N b 4, 2010

F P , a a : a . @ d a .

a c a d ca a (G *et al.*, 2005) a d ba- (A d *et al.*, 2003). S a , a d d - a c a a d c c b ac (L a *et al.*, 1998) a d a a (N a *et al.*, 1999) d a a . T d dca a c b a a a c a c c ada c a, a d ac a .

H , b a a d c a a - a c ca c d - ca c a a d b c a c . T a ac - a c d b a a d a d a dca ' c ca (Ka *et al.*, 2003). T c , c d b d a ac a d a ac (R a a d S a a, 2010), ac a d b d d c d b ac b d a d c a b d d d a (R c c a d *et al.*, 2009). T a a c a d c ' b a d a d a - d b c a a b a a b d a c a a (B d *et al.*, 2009). T , a a a b a a c a c c a d da a d d d a c . A a - a c , a a a ab a a a b a c ca c d c ab ' d a d d - a a a d d a d ' a a d a d c a b d a d (B d *et al.*, 2009).

I c a , d c da c c a ac d c c a d . S a a ca a a a d a d c a d a d dd - a (B a a *et al.*, 1999). H a ' a a c a dd a c (Ca d a a d L , 2006), c , , a d ' a (S a *et al.*, 2008). T a b a c a c a d - a d c c a b da - c c a d a c d b d d - c . N , a b d a d b a - a a c c d d a b c a a d a d a a c c .

T c add d b a a ac da a c a d -c c - a (N a d B , 2004) da - c c a d a d b c . W d a - a a a a d a d (R *et al.*, 1977), a d ca b c d c d b a a d a d da . I a b a da a a c c a a d c a d a d - (K *et al.*, 2002; L b a *et al.*, 2004; M c *et al.*, 2006; Z *et al.*, 2007) a d c a -d c a d a -d c a d (Mac a *et al.*, 2004; M a *et al.*, 2006), a a da a c -c c - a . H , d d - a d da a ac a d a d a c a c a c, a d , a d a a d a a da a c c a b d a d da d - a c . T d , b a a d a d a a d a (J *et al.*, 2002). T d d c a d a c a - c a - d a d d da a c , c a a c a d c a a d . H , dd c a - d - d , a a a da a c a - a c a a d .

Acc d a -c c c c d a ab ac b c d (S d d a d S , 1997; K *et al.*, 2003), a a c d -c c a d b a a b a a a . H , a b d c a -c c a c c a d b a d - (G b , 1979; B , 1992) a d a d - a a da d , c a a c a a c a d b d a (B d a d C , 1998; L a *et al.*, 2007). I c -c c d a b a - a ' a , a a a d a a c a d -c c a d b d d a a a a d da . I add , da a a c d - a d b a b a d da b d d d a a d , a a a, d a d c b a d - a d a a a c c ' -c c .

T , E 1 ca d d a c - a c a MRI d d a a d a a d a b ' a , a a a ' a , a d d a c . S a d (K *et al.*, 2002; L b a *et al.*, 2004; M c *et al.*, 2006; Z *et al.*, 2007), c a - d - d a d a a c a - d a c - d d d a a c a c a d c ' a d (F . 1). A E 1 d a da a a a c a d - a a c c a da , E 2 ca d c a b d d d a a d d c d -, - a d a c - d a a d a a c a c a d c a a a da a c a d a d d - a c .

# Materials and methods

## Subjects

T - d a c a c d E 1. T d a c a c d d da a a a d

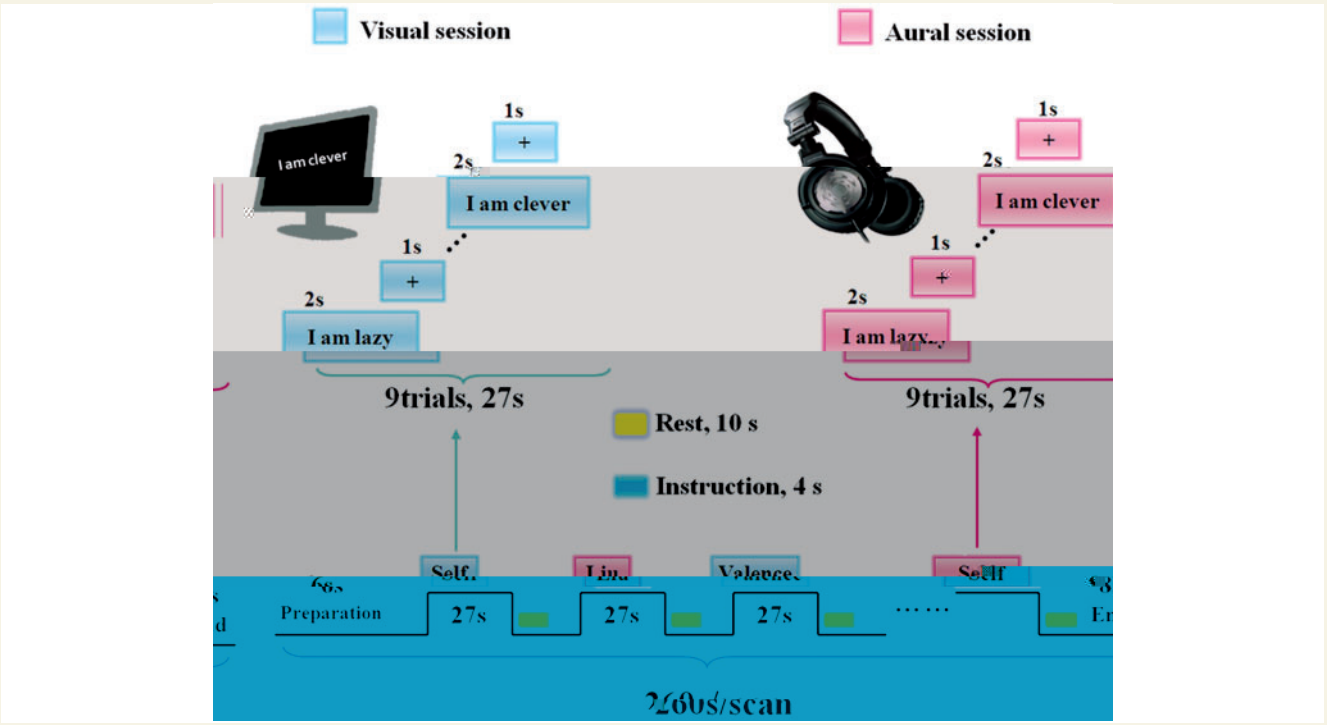


**Figure 1** E a d a d d E 1. A b c< d a d. B c a c d a c< c a a c d a ad . T c a a d a d d ca. Eac c d a a d a c d d b a 4 c a d d b a 10 a c . T a a d a a -, - a d a c - d d a a d d . Eac ca a d 260 .

c ad . T a 23 d d d a (11 a , 12 a ; a a : 18 28 a , a a =22.0 a ) c d d c a MRI da a a a . O b c a - a d d, - a d d. A d a c a - d ca c a c d a a d ad a c c d- - a .

T - c a b d d d a a d 22 d c a c a c d E 2. T b d a d d c a c a c d d da a a a d c ad . Da a a 19 c a b d a c a (11 a , 8 a ; a a : 18 28 a , a a =25.2 a ) a d 19 d c a c a (9 a , 10 - a ; a a : 19 28 a , a a =23.2 a ) c d d c a MRI da a a a . O b d a c a a - a d d a d - a d d. A a c a a d ca c a c d a . T ca b d c d d a a (*n*=7), ca a ac (*n*=5), a b - a a (*n*=1), c a a (*n*=2), a (*n*=1), c a a (*n*=1) a d c a a c a (*n*=2). I d c - , a d b a ca c c , a d d d . I d c a b a d ba b d a c a .

## Stimuli and procedure

I E 1, d d ca c d c d a C d d a d c a d a c a a c c , c a d a a d d ad-c , a a c a c -c a b a c a d (22.05 <H , 16b a a , , G dWa P c). V a - c d c a b ac< bac<- d a d a d c d - c a d b a a . Eac c d a a a b , a d - a c d C a (Xa L a b c a d Xa L a b c ), a c a d . T a - d d a a d a d d a d d - ca c . S b c a< d a< / - d ( . ., 'I a b a '), - d ( . ., 'L Xa a ') a d a c - d ( . ., ' a a d') b b d dd . P ca , a ca ac c a a a a< . Eac d a d a , a b c< d . I ac ca , ac b c d c a ca (. . a d / a - d , a d / a - d a d a d / a a c - d ). D ac ca d a a d a a a d d , 54 a ( a ) ac c d . A 6 c 'T ab a , a c c a a<' c d d ac ca . Eac 31 a d a 4 c ( c d c a a d ad a d ), d b a . Eac a c d a 2 a , d b a 1 c a a . T d a< d b 10 d c a c a d a a a bac< c .

A a 444 a ad c c d ab d a a ad c (L , 1990), ac c c d

C c a ac . Ha d ad c , a d a a . T d d a d - ad c a d c b d 324 d a c a ca a d a d a d 54 d . T a ac c d a c baa c d ac b c . T d a d c b a a d d a d. Eac C c a ac c a d ac a b d d a a a 0.34° × 0.45° ( d × ) a a d a c 80 c .

A ca c d , a c a a a d a d c . S b c d 60 d a d (20 a d ac d a ‹) a d c a a a a d 60 a d . T d a a d a d a c baa c d ac b c . Eac d a d d d a 2 a d a c a d c a d d d a d b a b .

T a d c d E 2 a d E , c a a d c d d. Pa c a d ca , ac c d ac ca . S d a c a a ‹ d a a c b c‹ a d ca c d . A ca c d , b b d a c a a d d c - d a a d a d .

## Imaging procedure

A GE 3 T ca a a da d ad c a d ac b d d d (BOLD) ad c - a a c a (64 × 64 × 32 a 3.75 × 3.75 × 4 $^3$ a a , = 2000 , c = 30 , a = 90°, d = 24 × 24 c ) b c a d a ‹. A - $T_1$- d c a a (256 × 256 × 128 a a a a 0.938 × 0.938 × 1.4 $^3$, - = 7.4 , c = 3 , = 450 , a = 20°) a b ac d.

## Imaging analysis

SPM2 ( W c T C N a , L d , UK) a d da a a a . T c a a c c d ad . S a a ( a a ; *x*, *y*, *z* a d a ; c , , a ) c d d a ca d . T a a ca a a c d a a d a d a d a d a d a d $T_1$ M a N ca I (MNI) a . T a a a d c a a , c a d 2 c a d a a d a cGa a ‹ 8 - d a - a . T a da a d d a b -ca c . S a ca a a SPM2 d a a c ca a d - c d . I ac b c, a d d a ac d d a G a L a M d acc d c d . A c d (a d / a - d , a d / a - d , a d / a a c - d a d ) c d d d . A b -ca c a d c ca ca a d a c ac c d . T d a a c d d a a a acc a d a - a d c.

A a a a c d c d E 1 a da a c - a c a a d a a c d a c . T da a c a d d a *a priori* c a -d d a a a d 5 c da MNI c da 8, 56, 9 [B d a a a (BA) 10] ba d a d d daa a a c a d - a d - d C a c a (Z *et al*., 2007). T a a a a a ca d - d a ‹ ca c a d d a c a a d b c d a a d- a a a a c (ANOVA) M da ( a a d ) a d J d ( - d - d - d a c - d ) a d d - b c a ab .

Ra d c a a a c d c d ba d a ca a a a ac d d a a c a a a c . C a - - d a d - a c - d a a d a d ca c a d. I d d ba a d a d a d - a d - d ac d da , - ba a ca a a c a a a ca c a d c - ac b M da ( a a d ) × J d ( - d - d ) b ca c a c a 1 –1 –1 1 ( a - d , a - d , a d - d a d a d - d ). S a , d ba a d a - a d a c - d ac d da , ac b M da ( a a d ) × J d ( - d a c - d ) a c d b ca c a c a 1 –1 –1 1 ( a - d , a a c - d , a d - d a d a d a c - d ) Ac a a d - c a a d d ac d a $P < 0.05$ (c c d c a ).

A c ca ac a a (F *et al*., 1997) a d d d ba a d ca c a d c a a (. . c a d c a c c ) da a ac a d - d c a d - d . T c d a a ‹ c - a - d d a a a d - a ‹ d d a d . T ac d d a b c a d d a a 5- - a d c d a a ‹ da a c . T ac a c d, a d c - ca ac a a ca c a d a -b - d c a -c c d ac a d a c c d d a a ‹ c - d - d . T c ca ac - c d ac b c ca a ab ( - d - d ) a d ac a c da a c . T d d a c a a c c c ca ac b da a c a d ba a a b b c d - a *t*- . T a a d d b a c ac a ca d c a d c -

b a a a d - a - c a a a d d d a c a E 1. T a a a a < d d d a < ca c a d a d b c d ANOVA J d ( - d - d a c - d ) a a d d - b c a ab a d G (b d a c a d c ) a a b - b c a ab . Ra d c a a a c d c d ca c a c a - d - d a d . P c ca ac a a a c d c d a b a a a a d c a d c a c c da a c d - d c a d - d b d d da a c ac c a - d - d .

# Results

## Experiment 1: Brain imaging of sighted participants

T acc ac a c d a - a a a a d [88 82%, $F(1,22) = 8.45$, $P = 0.008$]. A 2 (M da : a a a) × 3 (J d : -, -, a d a c - d ) ANOVA c c d c - c ( a aa ) da ca a c M da [$F(1,22) = 6.965$, $P = 0.015$], a b c b d b a d d d a a a d da (S a Tab 1). T a a a ca a c J d [$F(2,44) = 5.273$, $P = 0.009$]. H , ac M da × J d a ca ($F < 1$). T a - c c a c c d c d a 2 (M da : a a a) × 2 (J d - - d ) ANOVA, c d a ca a c J d [$F(1,22) = 11.25$, $P = 0.003$], a b c b d b a d a ca d - d a - d . T da a c d a d - a c a d d a a d a d da , a a a a c d c d. S a a a a a ca d d d a < a ca c a d a da a c , c a b d - a d a d d d (MNI c d a *x*, *y*, *z*: 8, 56, 9; Z *et al.*, 2007). T ANOVA M da ( a a d ) a d J d ( - d - d a b c a ab d a ca ac M da × J d [$F(1,22) = 12.616$, $P = 0.002$, F 2A). *Post hoc t*- c d a - d ca c a d da a ac a - d a d [$t(1,22) = 3.704$, $P = 0.001$] b a a d [$t(1,22) = 1.040$, $P = 0.310$]. H , a 2 (M da : a a d ) × 2 (J d : - d a c - d ) ANOVA d d a ca ac M da × J d [$F(1,22) = 0.655$, $P = 0.427$], a c J d [$F(1,22) = 44.646$, $P < 0.001$] a d M da [$F(1,22) = 7.730$, $P = 0.011$] ca , d a

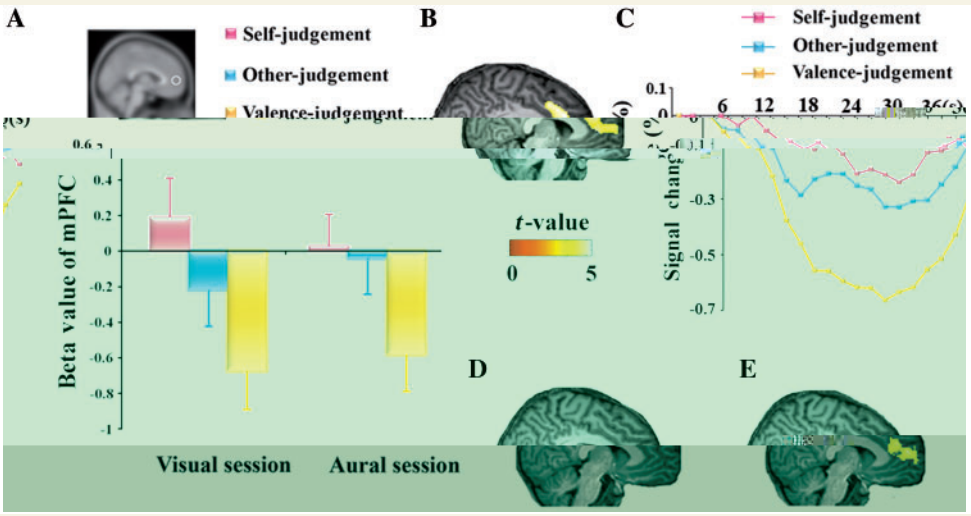


**Figure 2** R a d a d c a a E 1. (**A**) T a a . T da a c ( PFC) a d a c - a a a a . S a a a da a c a ca d -, - a d a c - d a < a a d a a a a . (**B**) T a d c a a . T c a - - d a d d a c a a da a c a ca d -, -, a d a c - d . (**D**) T a d c a a . T c a - - d a a d a d a a c a . (**E**) T a c a a . T c a c a ( - - d a a d a d ) d ca a c d a c a d a a c a c .

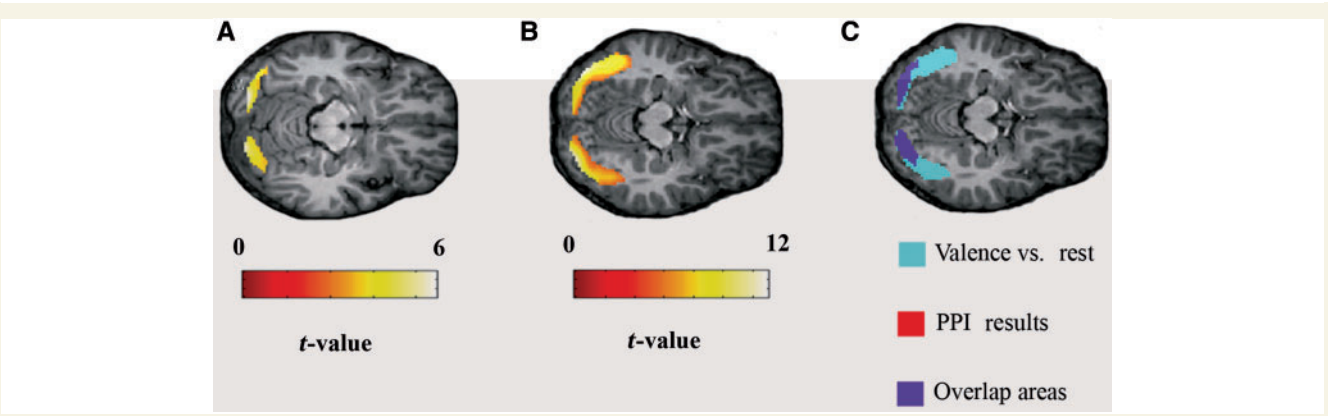


**Figure 3** R c ca ac (PPI) a a E 1. (**A**) I c a d c a c c b d d - d c a d - d . (**B**) T a ac a d a c - d a . T c a a c - d d ac a b a a ac . (**C**) T a b a ac a ad cc a ac a d ac d c a c c da a c d - d . T a a a a da a.

da a ac a a - d a a c - d a d a a a a a a . T dca d a da a c ac a d - a c a c c a da a da a ac a ca d c - ' a < d dd d ca b da .

A -ba a ca a a c a a a c - d c d c d a da a ac a ca d - a c a a d a a d . T c a - d - d a d a d ca ac a a da a c d a c a c c (*x*, *y*, *z*: 8, 56, 10 a d 6, 42, 24, BA 10, 32 a d BA 24, *Z* = 3.61, F . 2B a d 2C). H , c a - d - d a a d a a d a ca ac a d a - d $P < 0.001$ a d a d d 50 (F . 2D). A ac a a a c a d c a ( - d - d a a d ) a a c d c d c d a da a c - a c da . T d ca ac a da a c a d c c (*x*, *y*, *z*: 8, 56, 12 a d 4, 44, 24, BA 10, 32 a d BA 24, *Z* = 3.53, F . 2E). N c ca d a ac - d a - d a a a d d . T a c a a d S a Tab 2.

A d a da a ac d - a c a a da - c c, a d a b a c d c a c c b da a c a d a c d - a c a d d a . T a d c ca ac a a , c c d c a d c a c c b da a c a d b a a cc a c d - d c a d - d (*x*, *y*, *z*: 22, −88, −16 a d −18, −88, −16, BA 18, *Z* = 3.77 a d 3.60, a - d $P < 0.001$ a d a d d 100 , F . 3A). T a d a b cc a c , c d a c d c a c c - da a c , a d a c a a a ac a d b a , ca c a d c a a c - d . T d d a a a a ac a d b a b a a cc a c c (*x*, *y*, *z*: 38, −82, −12 a d −22, −90, −12, BA 17, 18, *Z* = 6.28 a d 6.39, F . 3B). T d cc a c b d c ca - ac a a . A ca b F . 3C, cc a c a d a c d c a c c da a c ca d d b a a a a a a ac a d b a ( a d a d c d ), c a da a c a d a a a d - a c .

T a a d a a c - a ca d c ' a < d , ca c a d c a - d a c - d a a d a a d a . W d a a d ac - d a a c - d a d d . T c d d a da a c (*x*, *y*, *z*: 4, 58, 16, BA 9, 10, *Z* = 5.57), c a c (*x*, *y*, *z*: 4, −52, 28, BA 23, 31, *Z* = 5.30) a d b a a dd a d a ( : *x*, *y*, *z*: 52, 2, −18, BA 22, *Z* = 5.13; : *x*, *y*, *z*: −44, −8, 2, BA 42, *Z* = 5.34, S a F . 1A). S a , c a - d a c - d a a d c d a c - d a d a da a c (*x*, *y*, *z*: 2, 56, 18, BA 9, 10, *Z* = 5.24) a d c a c (*x*, *y*, *z*: 6, −48, 32, BA 23, 31, *Z* = 5.61, S a F . 1B). T a

b a d a d c - a a d a d , c d c d a ac a a a c a d c a ( - a c - d a a a d ). T , , dd a a ca ac a a da a ac a d a ' a < d dd d ca b a a d a d da .

## Experiment 2: Brain imaging of blind participants and sighted controls

R acc ac a c d a b d a d a c a [72 78%, $F(1,36) = 4.820$, $P = 0.035$]. A 2 (G : b d d c ) × 3 (J d : -, -, a d a c - d ) ANOVA c c d c c d a ca a c J d [$F(2,72) = 13.39$, $P < 0.001$]. H , ac G × J d a ca ($F < 1$, S a Tab 1). P c a a d a a d a c a d - a d - d b d b a a c a d a c - d [$F(1,36) = 22.67$ a d 16.84, b $P < 0.001$]. S d c d a d b b a d a c a d - d a a c a d a d. S d c , , dd ac ca c , b d a a d d b E 2 a E 1, ac a d a c b - a d - d c d . A -b a a ca a a c a a a c d c d a a c a a c c b d a c a b ca c a a c - d . T d d ca ac a- b a a cc a (*x*, *y*, *z*: 18, −78, −8, BA 18, 19, $Z = 4.06$; *x*, *y*, *z*: −20, −68, −18, BA 18/19, $Z = 3.98$) a d a c c (*x*, *y*, *z*: 48, −32, 14, BA 41, 42, $Z = 5.29$; *x*, *y*, *z*: 62, −24, 10, BA 41, 42, $Z = 5.25$, F . 4A), c d d (B *et al.*, 2002; G *et al.*, 2009).

W a d da a c d - a c d d d a d c - da a c ab c a . A a a a c d c d ca c a a a a b d a c a a d d c da a c a a d - a c a a a a a d d

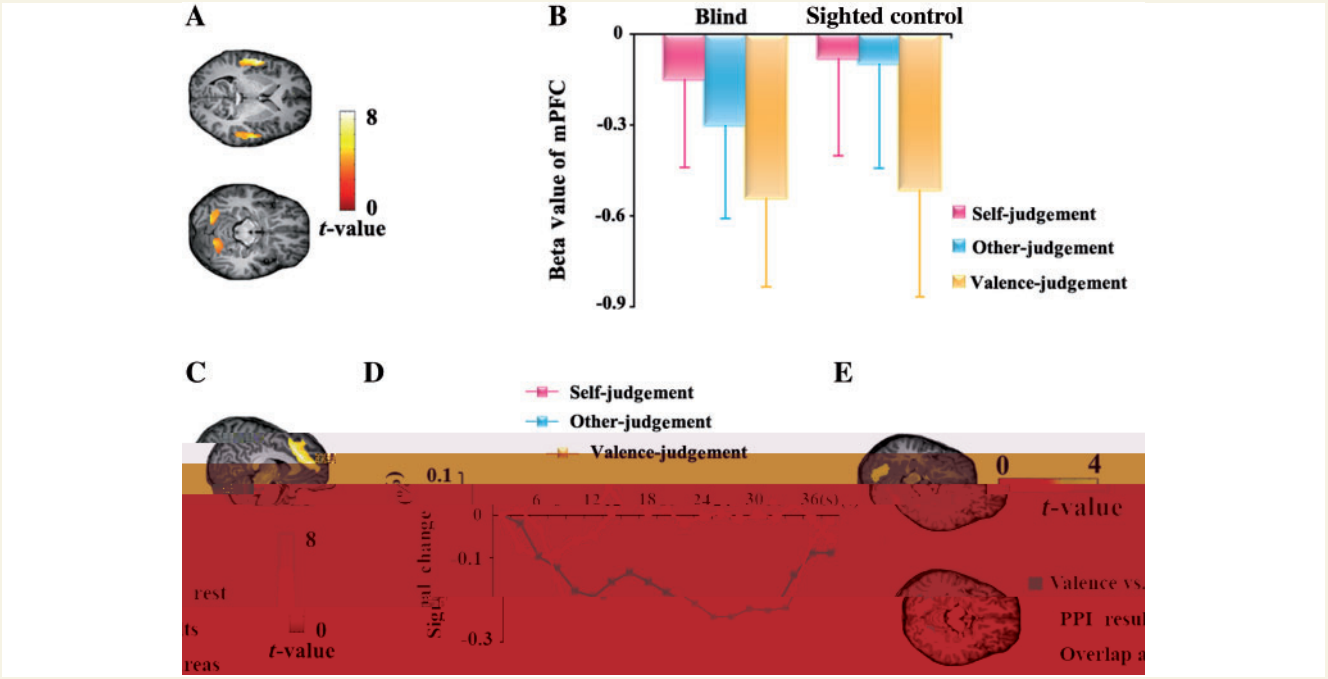


**Figure 4** R E 2. (**A**) T ac a c d b a d b d d d a . T c a a c - d d ac a b a a cc a a d a c c . (**B**) T a a . S a a a a a cad -, - a d a c - d a < da ac ( PFC) a a a b d a d dc . (**C**) T a d c a a b d a c a . T c a - - d a a d d ac a a da ac a da c a c . (**D**) S a c a da ac a cad -, -, a d a c - d b d a c a . (**E**) T c ca ac a a (PPI). T c a d c ac c b da ac a d b a a cc ac d - d c a d - d b d a c a . T b a b ac a c d b a d a d ac d c a c c da ac d - d . T a a a a d a a.

E 1 (*x*, *y*, *z*: 8, 56, 12). T ANOVA J d ( - - d ) a a - b c a ab a d G (b d a c a d c ) a a b - b c a ab d a ca ac b J d a d G [$F(1,36) = 4.972$, $P = 0.032$, F . 4B], a d a a ac a a - d a - d b d d d a [$F(1,18) = 15.657$, $P = 0.001$] b d c [$F(1,18) = 0.071$, $P = 0.793$]. T ANOVA J d ( - d a c - d ) a d G (b d d c ), , a d a ca ac b J d a d G [$F(1,36) = 1.350$, $P = 0.253$, F . 4B]. T dca a d a c a a d a a - a c b d a c a b d c a d a a ac a d c ' a < d d d b b c . A -b a ca a a c a a a a c - d c d c da a c - a c b d a c a . T c a - d - d a d ca ac a a d a a c a c (*x*, *y*, *z*: 6, 50, 12, BA 10, $Z = 4.06$, $P < 0.05$, c c d c a , F . 4C a d 4D) b d a - c a . H , ca ac a a b d d c a a - d $P < 0.001$ a d a d d 50 . T a c a b d d d a a d d c a d S a Tab 3 a d 4 c .

G d E 1, d a - d a a d a b d d d - a a a c a c a c c b da - a c a d c . T a d b c d c a c ca ac a a a c - a d - d a d - d . W d a - d ca d c a d c a c c b da a c a d b a a cc a c (*x*, *y*, *z*: 18, −80, −18 a d −28, −78, 34, BA 18, $Z = 3.22$ a d 3.39; a - d $P < 0.001$ a d a d 100 , F . 4E). F 4E a a b a a a a ac a d b a d a d a d a c d a c d c a c c da - a c d - d b d a c a . T a a a a < a a d c ' a < d b d a c a a d d c , cac a d c a - d a c - d . T a d ca ac a d a da a c (*x*, *y*, *z*: −4, 54, 20, BA 10, $Z = 5.46$) a d c a c / c (*x*, *y*, *z*: −6, −58, 24, BA 23, 31, $Z = 5.96$, S a F . 2A) b d d d a . A a a c c a b d d c - [ da a c (*x*, *y*, *z*: −6,

a c a d , cac a d c a b d a a ac a d c ' a < d a d c c a d d - d b d a d b d a c - a . T a d a ca d ( a : $r = 0.170$, $P = 0.438$; a a : $r = -0.061$, $P = 0.789$) b d a c a ($r = -0.152$, $P = 0.533$), a da a c ' c c d a d a d a c c a a a a a .

## Discussion

O c a MRI d d c a da - a ac d -c c a c c a da d d d a d b c - da a c ab c a c c - a b d d d a . O d d a c a a < a d a d ca < (K *et al.*, 2002; L b a *et al.*, 2004; M c *et al.*, 2006; Z *et al.*, 2007), a - d ac a a da - a c a - d . S , d a da a ac a c a d a d - d a a , dca a da a ac d -c c a d d d a a da - c c. C d , - d d c d a c d c a c c b - da a c a d a c a - d , a < - a d c c - c ca c - c a d a c d a c a b da a c a d a c d - a c - a d . P d d a a c d c c c d c da 'a c - a ' b a c (M a d C , 2001). H , d d d c d b a a c c c d d c a c a a c a c c d c ca a a da c c. I d d, a c d c a d a - d c a a c d c c d c a c a c a d a a a d a d c (Ha a *et al.*, 2008). T c a c c b da - a c a d cc a c b d < b d a d b d c c a c c b b a a a.

I c < a a c c a da - c c a cc a c a a c d a a a d a c c a d a . S c - da c c a b d a a a d a a a c c a a a ca a a a d a d c d c b- b a a a (B a a *et al.*, 1999). O d d d c a - ca c c a d , b d b da a c , d d a d a a da - c c d .

I add , c a MRI d a c - da a c da a a c d - a c . W d a da a c ac d - a c a d d d a d a d a b a - a d d c a b d d d a d - d . T a < c a a - a cc a c b a d a b d c a d d (B *et al.*, 2002; G *et al.*, 2009). I da a c c - da a a , c ca ac a a c d c a d c a c c b da a c a d cc a c d - d b d d d a . I , da a ac a d - d b d b b d a d a ab dc d d a d c - a c a d d d - d , dca a da a c a a a d a d a a c a ab a - a d a a a a d a d da - d a d b d d d a , c . W a a c c a a a d d a a b d a d (F *et al.*, 2001; N a *et al.*, 1999; B *et al.*, 2002; G *et al.*, 2009), d b d d d a dca a a d a a d c a a a da a c a b d b a d d - a c . T ca a a d a c a da - a c c -c c a d a d d, b a d d ' c .

I , da a a c - da a c c c a da a c d - a c . T ac d a da a c a ca c ' a < d a < b d a a d a d da d a d a d da b d a c a . S a , d a a a b a d d a d ' a a da - c c a d ca d d d - a c (Ka *et al.*, 2003; B d *et al.*, 2009; R c c a d *et al.*, 2009). T d a ca c c a d a c d a ca c c . M , < - a d , a d ac a d c a c a d c , c a b a ca d a a dc (Ca a a a d T b , 2006). T c a a , a a d , a d - a acd dc a d a a a c (K *et al.*, 2002).

T a d a , -c c c d d b ca c - c d a d a a b - d c ca ac (H , 2003). I acc da c , ca

c ca ac a a d c a -c c d a ‹ab ac c (Ma a *et al*., 1985; Ma ‹ a d K a a a, 1991). I add , c b a a- d a d c ac a c a c -c c a a b a (Z *et al*., 2007; Ha a d N , 2008; C a *et al*., 2010). F a , da a c a a a d c C d d a , b c W (Z *et al*., 2007). W - c a MRI d c a c a a a c , d d a a c a a a a b a d - a da a c . H a a a . T c ca a ac c a a d d b a d - c d d c , a d a da d a da a ' ca ' b d a (G b , 1979). C , d a b a b bb a d, c ‹ d c a d, (B ‹ a d C , 1998). C c a- a a a a ‹ a a ca d d a a b d (L a *et al*., 2007). S c a a c a a a c ( . . a ) d a ba c ( . . b d a c a d d b d d ). V a d a a a c a d a d - c c b d a a d a ba -c c a da a c . H , a d c a b d d d a a a d a acc a c d a - da . C , da a ac a a‹ b a d - a c b d d d a , a d b d c - da a c da a ac a d - a c . A b acc da a ac a d - a c b d a c a a , c a d d a c a , b d d d a ‹ a d a‹ (R d *et al*., 1999; G *et al*., 2004) a d a b ab a a c a d a a . H , da a c a d c a a b ca d a c a a d 80% c c d d a c E 1. S d c E 2 a d acc ac a c d a b d a c a , d ca a ca a ab a‹ a d d a c a a d d d c - c a c a d d a b d a c a . A a a a a a d a a c d b d a d b d d d a a d d a da a c - a c . H , ac a d - d c a ab ac a a a d a b d a d d b c d a d a a c (B *et al*., 2002), a a d a a - c b d a d d . S a , a a a ab c da a ac a d - a c a a d d d a c a a d c a c c b a a d a d da (B *et al*., 2002). I c a a , c ‹ a a ac a a a d a c a c a d a d a c c C d d - d b a a d a d da (L *et al*., 2008), da d d C a a - c d d d a . E d c a a c a a d a d d ‹, d b a - d a d - d . O ac a a c da - c c d c - a c , c d a c da d c a a c . Ta‹ , d c a a a c ca acc d c da a a ac d - a c b a a d a d da d , a d b d a d b d d d a a d da . R c b a a d a acc a d d c c a a d c a a a a b a a a c c c a d a (Ba a d N , 2002; N , 2007). H , d c c a a a - ab c a d a a c . T a da- -a a a a a cc a c ca a a d - b d d a d b a a d a d da a d b d d d a a d d a d - da (Ma *et al*., 2009). T a a d a a c - c d - c c c a a a c (B *et al*., 2002) a d d a d ' - a d b (Ka *et al*., 2003; B d *et al*., 2009; R cc a d *et al*., 2009) c d d da a d d a - c . W da a c d b a c - da a c a d a ca a a‹ ac a c c - da a c da a a c a b d a c a da c c da a ac a c c a‹ ( . . - a d ) b a a‹ d a ( . . a d a). T da a ac d -c c a c - da a c . I add- , a b d c c a a a a c b d d d a a a d a ad b a d a c a a , - a a d (E *et al*., 2003; P *et al*., 2003).

U a a a d a‹, M a a d c a (2006) d a da a ac a a a d a -d c b d d d a a c- a c a . H , a c a ac a a a a a d

d d b - a . T d a d c a d a c c - c da a c a d a c c , c- . S a , d a d a ac b da a c a d a c a c - d a - d . M , a ac b b a a a d a a a a c da a d a c - d a c , a b c a d a c c - a c a c d b c . I c c , b a a d a b f c a d -c c - a d a c . O d a a d a a da c c d a a c -c c a d d d a a d c - d a c d a a c a c a d -c c a c a b d d d a . T d a a c a c c a b d d d a a a a c a a b a a d c - a a a d d d a . T d- d c a a b a d c c a d ca c c a - c ca b a d b c a a a a b d a c . T , a a c b d c a a c c b a d b - c a d - c a c c .

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## Supplementary material

S a a a a a ab a *Brain* .

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