d :10.1093/b a /a 299 B a 2011: 134; 235 246 235

BRAIN
A JOURNAL OF NEUROLOGY

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

C d c : S Ha , P D,
D a P c ,
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5 Y a R ad,
B 100871,
P ' R b c C a
E- a : a @ . d .c

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 ; d a a c ; b d
Abbreviation: BA = B d a a a; MRI = a c a c a

Introduction

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; Pa c a-L *et al*., 2005). S d a a a d- d a a c a d c d a c a a a d a d c c b c . T cc a c a c d a b d d d a (Sada *et al*., 1996; B c *et al*., 1998; B *et al*., 2002). M , cc a ac a b d d d a d c 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

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 d ca 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 a d ca ' 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 cc a d et al., 2009). T a a c a d c ' b ad 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 ca c c a d da a d d d d a c . A a - a c , 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 ad (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 d d ca d a d dd - a (B a a et al., 1999). H a ' a ac 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 ac c d d a b c a a d a d a ac 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 ac 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 ac a da - c c, a d , a d a ad a a d a a c c a b d a d da d - a c . T d , b a a d a d a a a d a (J et al., 2002). T d d c a d ac a- c a - d a d d d a a c , c a a ca d c a a d . H , d d 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 ac d -c c a d b a a b 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 ac a d b d a (B d a d C , 1998; L a et al., 2007). I c -c c d a ba - a ' a , a a da a ac a d -c c a d b d d a a a a d da . I add , d a a ac 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 ab ' 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 ac d -c c a a d a - d a c - d d d a ac a ca d c ' a d (F . 1). A E 1 d a da a ac a a ca 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 ac a c ad c a a a d a 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

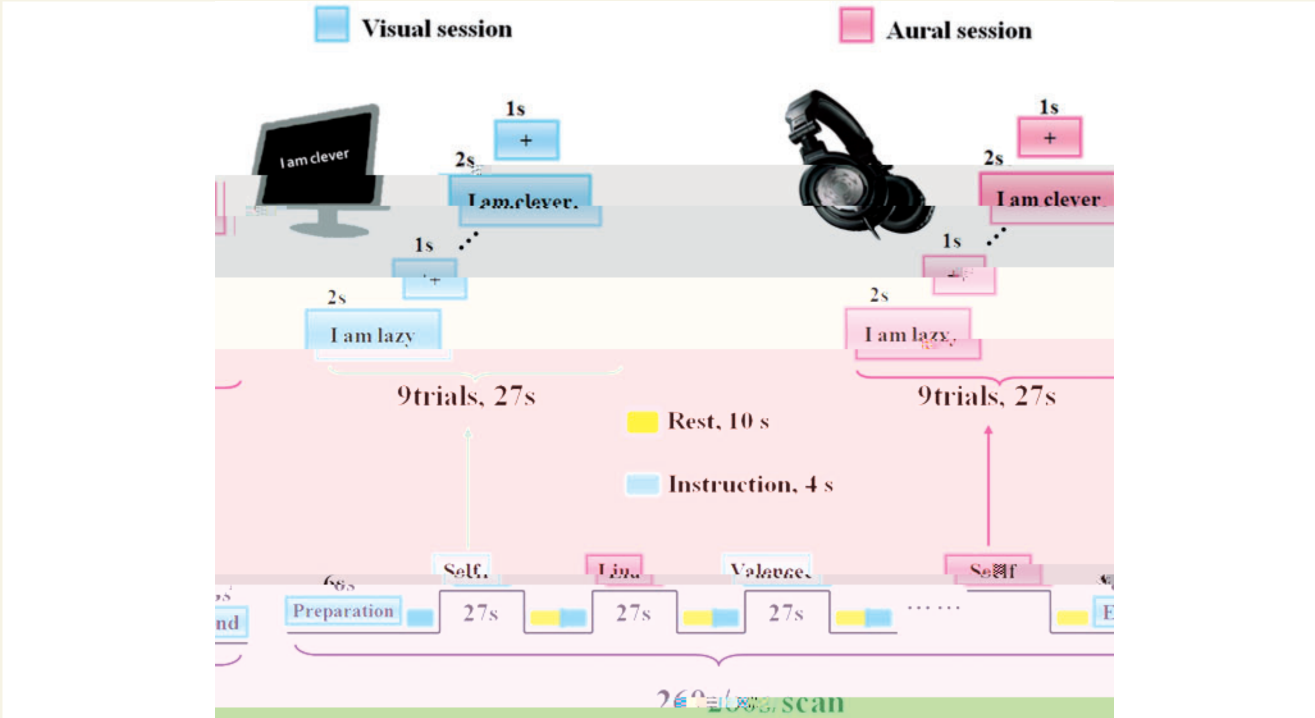

Figure 1 E a d a d d E 1. A b c d a d. B c a c d a c a d c a a c d a ad . T c a a d a d d ca . Eac c d a a d a c d d b a 4 c a d d b a 10 a c . T a a d a a -, - a d a c - d d a a d d . Eac ca a d 260 .

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 da 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 ad 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 ad

(22.05 H , 16 b a a , , G dWa P c). V a - c d c a b ac bac - d a d a d c d - c ad b a a . Eac c d a a ab , a d - a c d C a (X a L a b c a d X a L a b c), a c a d . T a - d d a a d a d da d - ca c . S b c a d a / - d (. ., 'I a b a '), - d (. ., 'L X a a ') a d a c - d (. ., ' a a d') b b d dd . P ca , a c a 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 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 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 ba a c d ac b c . T d a d c b a a d d a 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 ba a c d ac b c . Eac d a d d d a 2 a d a c a d ca 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 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 a d a d a da d T_1 M a N ca I (MNI) a . T a a a a d c a a , c a d 2 c a d a a d a c Ga 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 d d a c a . T d a a c a d d *a priori* c a -d d a a ad 5 c d a MNI c d a 8, 56, 9 [B d a a a (BA) 10] ba d a d d da a 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 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 b a a d a d - a d - d ac d da , -b a 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 b a 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 a c d a *P* < 0.05 (c c d c a).

A c ca ac a a (F *et al.*, 1997) a d d d b a 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- - ad c d a a da a c . T ac ac d, a d c - ca ac 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 b a a a b b c d - a *t*- . T a a d d b a c ac a ca d c a d c - a da a ac d - d c 8 81 d 15d b a a a d - a - c a a a a d d d a c a E 1. T a a a a ‹ d d d a ‹ cac a d a d b c d ANOVA J d (- 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 cac a c a - d - d a d . P c ca ac a a a c d c d a b 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 - [redacted] c (a aa) d a [redacted] 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 [redacted] da (S a Tab 1). T a a a [redacted] ca a c J d [$F(2,44) = 5.273$, $P = 0.009$]. H [redacted] , ac M da × J d a [redacted] ca ($F < 1$). T a - c c a c [redacted] c d c d a 2 (M da : a a a) × 2 (J d [redacted] : - - d) ANOVA, c d a [redacted] 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 [redacted] 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 cac 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 [redacted] a d d - b c a ab [redacted] d a [redacted] ca ac M da × J d [redacted] [$F(1,22) = 12.616$, $P = 0.002$, F [redacted] 2A). *Post hoc t*- c [redacted] d a - d [redacted] 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 [redacted] a c - d) ANOVA d d a [redacted] ca ac M da × J d [$F(1,22) = 0.655$, $P = 0.427$], a c J d [$F(1,22) = 44.646$, P [redacted] < 0.001] a d M da [$F(1,22) = 7.730$, $P = 0.011$] [redacted] ca , d a

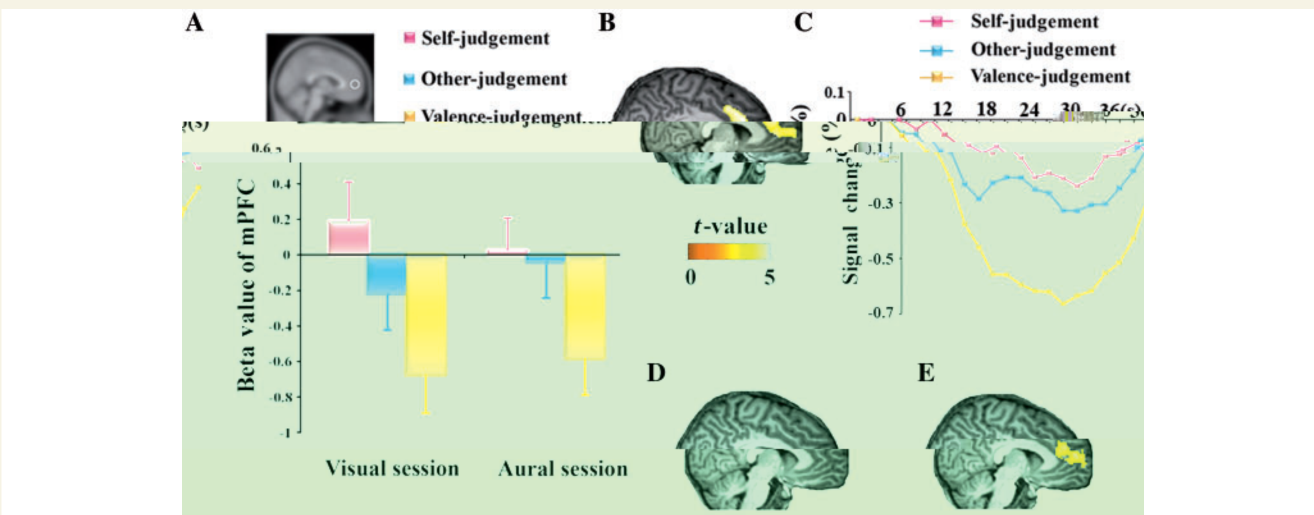

Figure 2 R a d a d c a a E 1. **(A)** T a a . T da a c (PFC) a d a c - a a a a . S a a a a da a c a ca d -, - a d a c - d a ‹ a a d a a a a a . **(B)** T a d c a a . T c a - - d a d d ac a a da a c a d a c a c . **(C)** S a c a da a c a ca d -, -, a d a c - d . **(D)** T a d c a a . T c a - - d a a d a d a ac a . **(E)** T [redacted] ac a a . T c a c a (- - d a a d a a d) d [redacted] ca a c d ac a da a c a d a c a c .

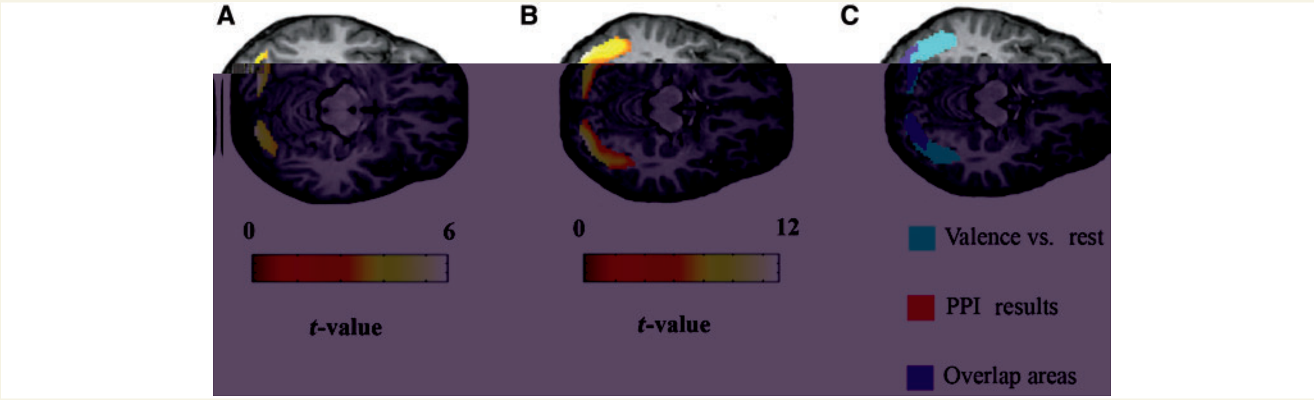

Figure 3 R c ca ac (PPI) a a E 1. **(A)** I c a d c a c c b d a a c a d b a a cc a c a b d d - d c a d - d . **(B)** T a ac a d a c - d a . T c a a c - d d ac a b a a a c . **(C)** T a b a ac a a d cc a ac a d a c d c a c c d a a c d - d . T a a a a d a a .

d a a ac a a - d a a c - d a d a a a a a a . T d ca d a d a a c ac a d - a c a c c a da a d a a ac a ca d c - a d d d d ca b da . A -b a a ca a a c a a a a c - d c d c d a d a a ac a ca d - a c a a d a a d . T c a - d ca - d a d a d ca ac a a d a a c d a c a 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 d a a c - a c d a . T d ca ac a d a a c a d a c a 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 d a a ac d - a c a a da - c c, a d a b a c d c a c c b d a 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

d a 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 a b cc a c , c d a c d c a c c - d a 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 d a a c ca d d b a a a a a a a ac a d b a (a d a d c d), c a d a a c a d a a a d - a c .

T a a d a a ac - 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 d a 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 ac a- d a d a 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 a d , c d c d a ac
a a a c a d c a (-
a c - d a [redacted] a a d). T ,
, d d a a ca ac a a
d a a ac a d [redacted] a
' a d d d 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 [redacted]) ANOVA
c c d c c d a ca a c
J d [$F(2,72) = 13.39$, $P < 0.001$[redacted]. H , ac
G × J d a ca ($F < 1$, S a
Tab 1). P c a a d a a d a ca d
- a d - d b d b a
a ca 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 ca d - d a
a ca d - d a d [redacted] a d .
S c d c , , d d ac [redacted] 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 . [redacted]
A -b a a ca a a c a a a a
c d c d a a c a a a
c c b d a c a b ca c [redacted] [redacted] c a
a c - d . T d [redacted] 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: [redacted]62, −24, 10, BA 41, 42, $Z = 5.25$, F . 4A), c
[redacted] d d (B *et al*., 2002; G *et al*., 2009).

W a d d a a c d
- a c d d d a d
c - da a c [redacted] ab c a . A
a a a [redacted] c d c d ca c a a
a a a b d a c a a d d c
d a a c a a d
- a c a a a a d d

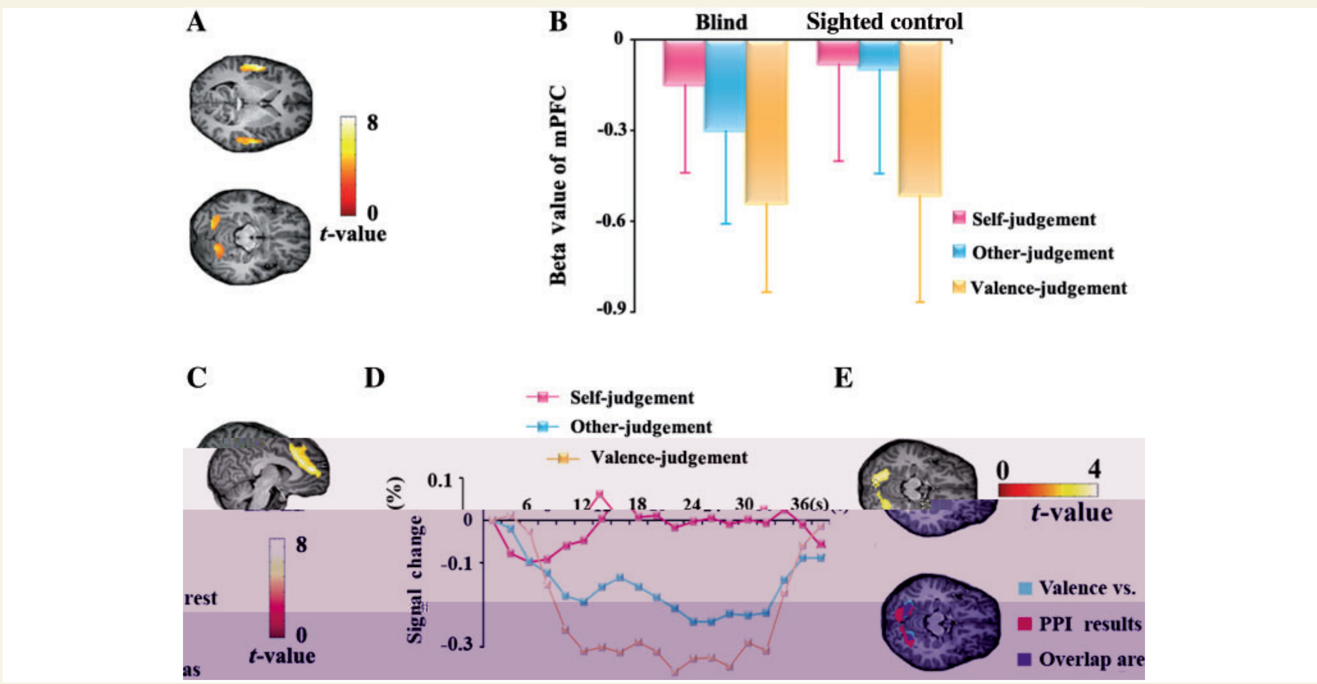

Figure 4 R E 2. (**A**) T ac a c d b a d b d d d a . T c a a c - d d ac a b a a cc a a d a c c . (**B**) T a a . S a a a a a ca d -, - a d a c - d a d a a c (PFC) a a a b d a d d c . (**C**) T a d c a a b d a c a . T c a - - d a a d d ac a a d a a c a d a c a c . (**D**) S a c a d a a c a ca d [redacted] -, -, a d a c - d b d a c a . (**E**) T [redacted] c ca ac a a (PPI). T [redacted] c a d c a c c b d a [redacted] a c a d b a a cc a c d - d c a d - d b d a c a . T b a b ac a c d b a d a d cc a ac a d a c d c a c c d a a c 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 d ca a d a 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 d b b c . A
-b a ca a a c a a a a a c -
d c d c d a 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 d 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 c a c a c c b d a -
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
d a 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 c a c c d a -
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 , ca c a d c a - d
a c - d . T a d ca ac a
d a d a 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 -
[d a a c (x, y, z: −6,100= 24670 6.3 (6 a .9 ([

a c a d , ca c 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 d a a c ' c c d a d a d a c c a a a a .

Discussion

O c a MRI d d c a d a - a ac d -c c a c c a da d d d a 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 d a a ac a ca d - a c a a d d - d a a , d ca a d a 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 - d a 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 d a 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 c d ca ca c a d a c a c - d a a a d a d c (Ha a et al., 2008). T c a c c b d a - 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 d a a c , d d a d a a da - c c d .

I add , c a MRI d a c - da a c d a a ac d - a c . W d a d a 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 d a a c c - da a a , c ca ac a a c d c a d c a c c b d a a c a d cc a c d - d b d d d a . I , d a a ac a d - d b d b b d a d d a ab d c d d a d c - a c a d d d - d , d ca a d a a c a d a a c a ab a - a d 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 d ca a a d a ad c a a a d a a c a b d b a d d - a c . T ca a a d a c a d a - 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 d a a c d - a c . T ac d a d a 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 cc a d et al., 2009). T d a ca c c a d a c c 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 d c (Ca a a a d T b , 2006). T c a a , a a d , a d - a a c d d c a d a a a c (K et al., 2002).

T ad 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 a c 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 a c 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 , d a 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 a a b a d - a da a c . H a 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 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 ad c a a b ca d a c a ad 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 dd d c c - c a c a d d a b d a c a . 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 , a c 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 d a 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 a d a c a ca 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 c ca acc d c da 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 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 d a- -a a a a a cc a c ca a a d - b d d ad 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 ac a b 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 dd 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 a 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 a c da a d a c - da 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 c a d -c c - a d a c . O da a d a a da c c da a ac -c c a d d d a a d c - da a c da a ac a ca d -c c a c a b d d d a . T da a c ac c a b d d d a a a a c a ab a a d c - a a a d d d a . T d- d ca a a b a d c ca 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 - ca c c .

Acknowledgements

T a a Z a S , Y a L a d Ga Wa da a c c . T a a B. Wa , W. Y d a d S. L c a a da a c , a d J a a G a a a d .

Funding

Na a Na a Sc c F da C a (P c 30630025, 30828012, 30910103901), Na a Ba c R a c P a C a (973 P a 2010CB833903) a d F da a R a c F d C a U .

Supplementary material

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

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