

# Social status modulates the neural response to unfairness

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## Abstract

Unfairness is a social phenomenon that is closely related to social status. The neural response to unfairness is modulated by social status. In this study, we used functional magnetic resonance imaging (fMRI) to investigate the neural response to unfairness in high and low social status individuals. The results showed that high social status individuals showed a stronger neural response to unfairness in the dorsal striatum (DS) and the dorsal anterior cingulate cortex (ACC) compared to low social status individuals. This modulation was mediated by the activity of the DS and ACC. These findings suggest that social status modulates the neural response to unfairness, and this modulation is mediated by the activity of the DS and ACC.

**Key words:** unfairness; social status; dorsal striatum; dorsal anterior cingulate cortex; functional magnetic resonance imaging

## Introduction

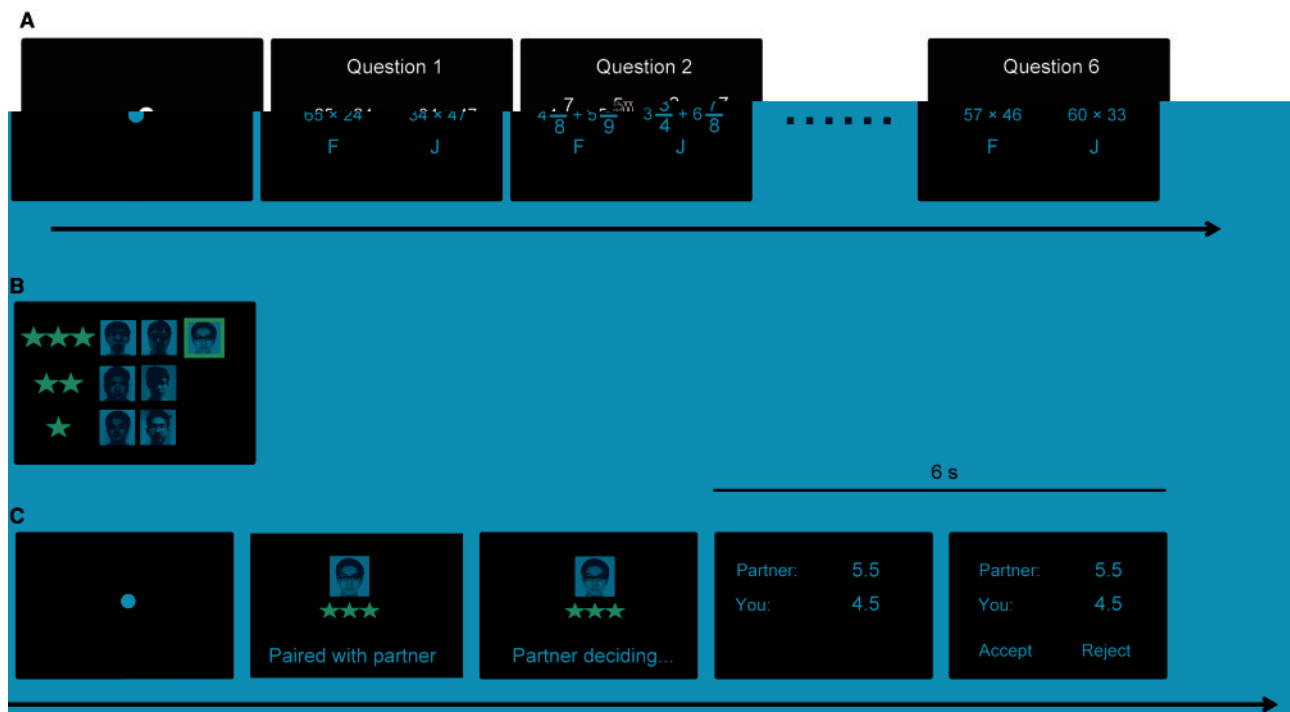
Unfairness is a social phenomenon that is closely related to social status. The neural response to unfairness is modulated by social status. In this study, we used functional magnetic resonance imaging (fMRI) to investigate the neural response to unfairness in high and low social status individuals. The results showed that high social status individuals showed a stronger neural response to unfairness in the dorsal striatum (DS) and the dorsal anterior cingulate cortex (ACC) compared to low social status individuals. This modulation was mediated by the activity of the DS and ACC. These findings suggest that social status modulates the neural response to unfairness, and this modulation is mediated by the activity of the DS and ACC.

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**Fig. 1.** **A**,  $69 \times 24$ ,  $34 \times 47$ ,  $42 \frac{7}{8} + 5 \frac{5}{9}$ ,  $3 \frac{3}{4} + 6 \frac{1}{8}$ ,  $57 \times 46$ ,  $60 \times 33$ . **B**,  $6\text{ s}$ . **C**, Partner: 5.5, You: 4.5, Accept, Reject.

(A) 10  
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 4/6, 4.2/5.8, 4.5/5.5, 4.8/5.2, 5/5)  
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**MRI data acquisition**  
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 AC C 3.1 ,  
 2000 , 30 ,

$90^\circ$   $200 \times 200$   
 $3.1 \times 3.1 \times 3.1$

### fMRI preprocessing

$8$  (  $\dots$  ),  
 $A$   $AB$  (  $\dots$   $k$  ).  $F$   
 $3 \times 3 \times 3$   
 $F$   $H$   $G$   $D$   $y$   
 $1/128H$   $y$

### General linear model analyses

$y$   
 $k$   $(G)$   
 $(B D)$   
 $B D$   $G$   
 $G$  (  $\dots$  )  
 $F$   $y$   
 $A$   
 $(H F)$   $F$   
 $y$  (  $\dots$  )  
 $( > F ; ' F >$

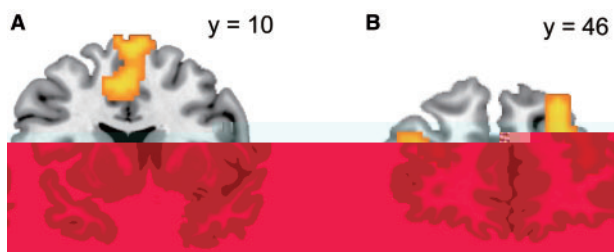


Fig. 3. ACC (A) and DFC (B). A: ACC,  $F(1, 22) = 97.59, P < 0.001, \eta^2 = 0.81$ . B: DFC,  $F(1, 22) = 12.58, P = 0.002, \eta^2 = 0.36$ .  $P < 0.05$  (red),  $P < 0.001$  (orange).  $k = 23$ .

ACC:  $F(1, 22) = 97.59, P < 0.001, \eta^2 = 0.81$ ,  $(5.26 \pm 0.15)$ . A:  $F(1, 22) = 12.58, P = 0.002, \eta^2 = 0.36$ ,  $(3.4 \pm 0.06)$ . DFC:  $F(1, 22) = 10.07, P = 0.004, \eta^2 = 0.31$ ,  $(5.73 \pm 0.12)$ . Correlation analyses: ACC vs. DFC ( $r = 0.46, P = 0.028, d.f. = 21$ ), ACC vs. G ( $r = 0.82, P < 0.001, d.f. = 21$ ), DFC vs. G ( $r = 0.35, P = 0.035$ ), ACC vs. G ( $r = 0.74, P = 0.001, d.f. = 21$ ).

**fMRI results**

**Main effects of social status and fairness.**

ACC,  $F(1, 22) = 97.59, P < 0.001, \eta^2 = 0.81$ . DFC,  $F(1, 22) = 12.58, P = 0.002, \eta^2 = 0.36$ . G,  $F(1, 22) = 10.07, P = 0.004, \eta^2 = 0.31$ . Correlation analyses: ACC vs. DFC ( $r = 0.46, P = 0.028, d.f. = 21$ ), ACC vs. G ( $r = 0.82, P < 0.001, d.f. = 21$ ), DFC vs. G ( $r = 0.35, P = 0.035$ ), ACC vs. G ( $r = 0.74, P = 0.001, d.f. = 21$ ).

**Interaction between social status and fairness.**

ACC:  $F(1, 22) = 97.59, P < 0.001, \eta^2 = 0.81$ . DFC:  $F(1, 22) = 12.58, P = 0.002, \eta^2 = 0.36$ . G:  $F(1, 22) = 10.07, P = 0.004, \eta^2 = 0.31$ .

Table 1. BOLD signal changes in ACC and DFC.  $P < 0.05$  (red),  $P < 0.001$  (orange).  $k = 23$ .

Region	Coordinates (x, y, z)			T-value	k
	x	y	z		
ACC/A	6	23	37	5.20	479
DFC	36	50	16	4.75	182
	-36	50	22	4.12	45
A	-21	-4	-11	4.76	41
	-15	-19	4	4.16	47
Gy	-36	-22	64	3.66	54

Note. ACC = Anterior Cingulate Cortex; DFC = Dorsal Frontal Cortex; Gy = Gyri. Coordinates are in MNI space. ACC/A:  $(x = -21, y = -4, z = -11; F_{(1,22)} = 4A)$ ,  $(x = -15, y = -19, z = 4; F_{(1,22)} = 4C)$ . DFC:  $(x = -36, y = -22, z = 64; F_{(1,22)} = 4B)$ . Gy:  $(x = -36, y = -22, z = 64; F_{(1,22)} = 4D)$ .  $P < 0.05$  (red),  $P < 0.001$  (orange).  $k = 23$ .

Correlation analyses. ACC vs. DFC ( $r = 0.46, P = 0.028, d.f. = 21$ ), ACC vs. G ( $r = 0.82, P < 0.001, d.f. = 21$ ), DFC vs. G ( $r = 0.35, P = 0.035$ ), ACC vs. G ( $r = 0.74, P = 0.001, d.f. = 21$ ).

Functional connectivity analysis. ACC vs. DFC ( $r = 0.46, P = 0.028, d.f. = 21$ ), ACC vs. G ( $r = 0.82, P < 0.001, d.f. = 21$ ), DFC vs. G ( $r = 0.35, P = 0.035$ ), ACC vs. G ( $r = 0.74, P = 0.001, d.f. = 21$ ).

**Discussion**

ACC and DFC are key regions in the social brain. ACC is involved in emotion and decision-making, while DFC is involved in cognitive control and social behavior. G is involved in social cognition and theory of mind. The results show that ACC, DFC, and G are all involved in the processing of social status and fairness information.

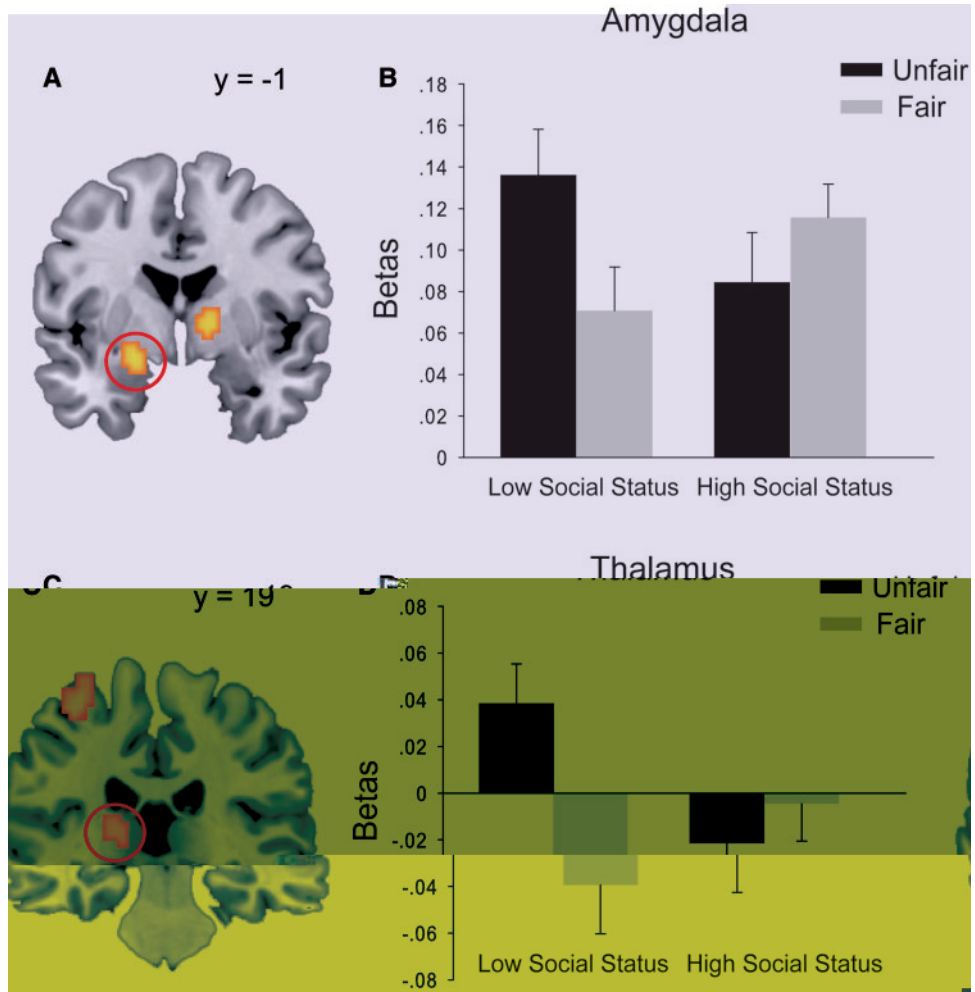


Fig. 4. (A) Axial slice of the brain at  $y = -1$  showing the location of the amygdala. (B) Bar chart showing the beta weights for the amygdala in the low and high social status groups for unfair and fair trials. (C) Axial slice of the brain at  $y = 19$  showing the location of the thalamus. (D) Bar chart showing the beta weights for the thalamus in the low and high social status groups for unfair and fair trials. Error bars represent standard error.  $P < 0.05$  (corrected for multiple comparisons) for the amygdala and  $P < 0.001$  for the thalamus.

He et al., 2014; G. et al., 2015; Ko et al., 2015; et al., 2001; A. et al., 2013; H. et al., 2014). (B) et al., 2010), G. et al., 2015), et al., 2012). (F. et al., 2006), G. et al., 2015). ACC/CC A. ACC/CC A. ACC/CC A.

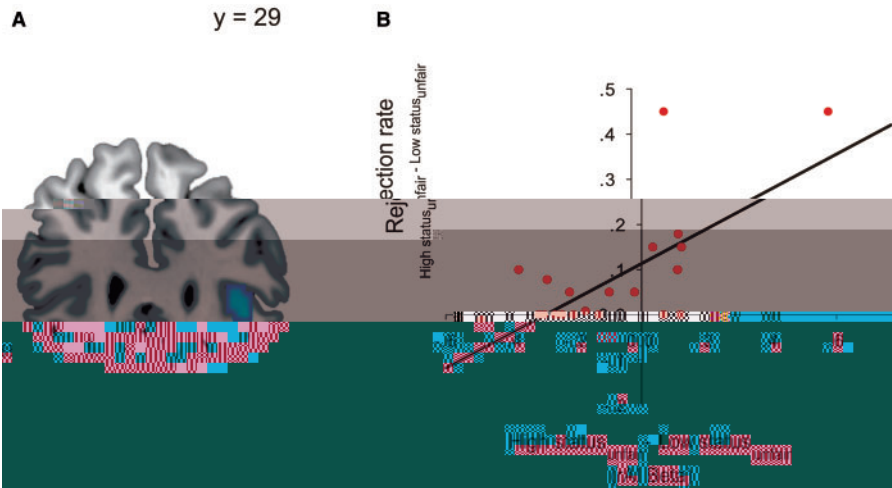


Fig. 5. G... (H... ) (A)... (B)... (A)...  $P < 0.05$  ( $\circ$ )  $P < 0.001$  ( $\bullet$ )... 23... (A)...

(C... -D... 'A... et al., 2013) ... ( ... et al., 2009; ... et al., 2010). ... y... k... y... y... ( ... y... k... et al., 2008). ... k... et al., 2008; ... et al., 2012), ... y... G... y... ( ... et al., 2008; ... et al., 2012) ... y (H... F... , 2009; G... et al., 2011; ... et al., 2014), ... y... ( ... et al., 2008). H... y... G... (F... 4D), ... y... (H... C... , 2009). ... y... y... y... y...

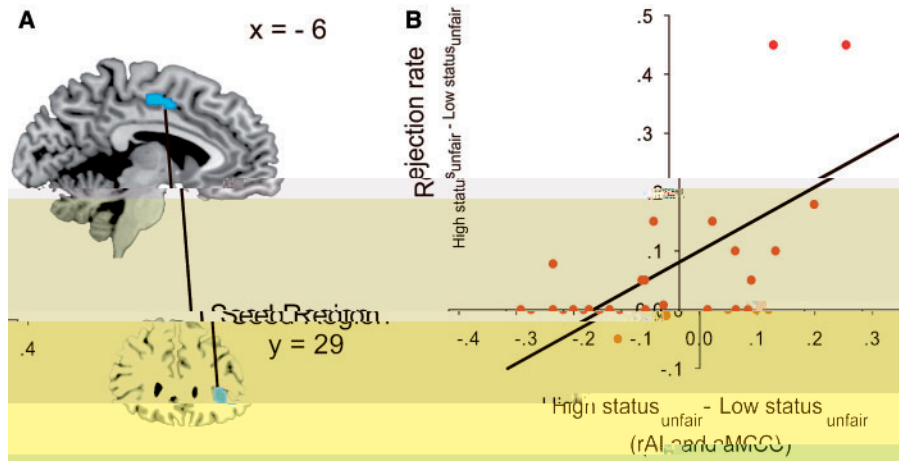


Fig. 6. (A) ACC/CC (A). (B) Rejection rate. High status unfair - Low status unfair. (rAI, ACC/CC).

(C., 2010; G., 2014; et al., 2014). F. ( et al., 2014). ( et al., 2011) et al. (2011) et al. (2009); C. et al., 2012; C. et al., 2013; C. et al., 2009; et al., 2015). A. CC ( et al., 2006; et al., 2008; C. et al., 2009; et al., 2009).

et al., 2009). et al. (2012) et al. (ACC) et al. (ACC) vs CC ( et al., 2003; C. et al., 2012; C. et al., 2013; C. et al., 2009; et al., 2015).

**Conclusion**

By G, k. y. A. CC, F. y.

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k. k. y.

**Funding**

k. B (973 : 2010CB833904, 2015CB856400) y. C.



91232708, 31170972).

Supplementary data

SCAN

Conflict of interest.

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