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School of Psychology and Cognitive Science, East China Normal University, Shanghai, 200062, China
School of Psychological and Cognitive Sciences, Peking University, Beijing, 100871, China
Department of Psychology, Yale University, New Haven, CT, 06520, USA
Comparative Psychology, Heinrich Heine University, Düsseldorf, Germany
Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, 100871, China
Institute of Psychological and Brain Sciences, Zhejiang Normal University, Zhejiang, 321004, China
PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, 100871, China

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Keywords:
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1. Introduction

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t t - t t t - t t t t - t t t t - t t - (t ., 200 , j t ., 2017 , t t ., 2005), t t tt . (1) t - t t fl t t fl t t t t t fi t t ? T t , t t t- t t t t, t t t t t t ? (2) t - t? fi , - t t t t t? t t t t T (T, t ., 200 , t , 2015), - t t - t t t t t t , t t (t ., 200). t t, t t t (, 2003, t t , 2017 3), t t t t t fi t t . t t t , t t t t / . T t t t , - t t t . t t t ’ t- t t t (t ., 2013, t ., 2014). t t , t t t t t t t t t t t, , t t “ t” t t . T , t t t t t t t t t t. t , t - t t fi t t t t t t t t t t t- t t t (t ., 2015, t ., 2013, t ., 2011, t ., 2014). , t - t t . (2014) t t t t t t ( ) t ( ) t t t- t t t t t t t t t t t t t , - t t , t t t ( ) t t t ( ) (t , 2015, tt t ., 201 , t ., 200 , t ., 2010). T fi t t t t t t t t , , t - t t t , t t t t tt

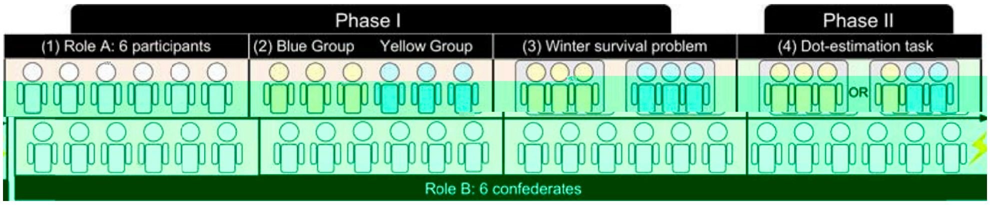

Fig. 1. Overview of the intergroup game. . (1) *Role assignment.* . (2) *Group assignment.* 3- . (3) *Group membership formation and reinforcement.* *Dot-estimation task.*

10 . 3 ., 2014) 3-

5%, /t

2.2.1.3. Pain calibration.

(. ., ., 2002). 0.2 5 10). 1 ('

2 × 2 . 1) *In-group_ Observe,* 2) *Out-group_ Observe,* 3) *In-group_ Commit,* 4) *Out-group_ Commit,* 4 0–6 1)

2.2.1.4. Dot-estimation task.

. 2) . 2) 20, 21, 22), 2

4 (16 5 (1 = ' 50

2.2.2. Procedures of Experiment 2 (fMRI)

t 2 t 1, t 1) (2 , 3 , 23.6 ± 1.3)

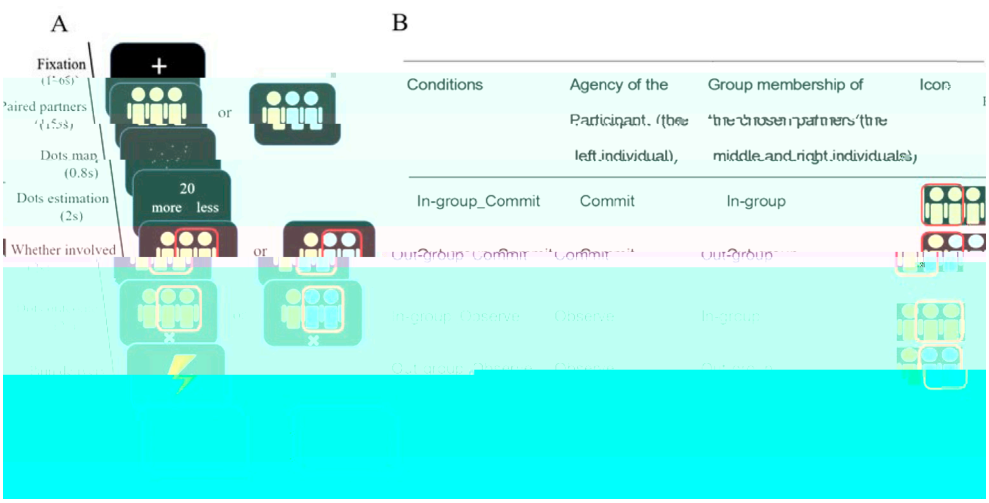

Fig. 2. Experimental design and procedure. (A) … (*Paired partners*). … (*Dots map*). … (e.g., 20) … (*Dots estimation*). … (*Whether involved*). … (e.g., …) (*Dots outcome*). … '×' … (*Pain delivery*). … (… 2). … *Dots outcome* … 1) … 20 *yuan* … (**B**) … *In-group_ Observe*, … *Out-group_ Observe*, … *In-group_ Commit*, … *Out-group_ Commit*, …

… 2) … 20 *yuan* (3) … / … 3 … (… , 2003, … et al., 2014). … (1 = … 9 = …) … 2, … (100 *yuan*, … 15) …

… (e.g., " … ") … (e.g., " … ?"). …

2.2.3. Direct replication of the behavioral findings of experiment 2

… 3) … 36 … 6 … 1. … 35 (23 … 21. ± 0.9 …)

2.2.4. Debriefing the participants

… 5% … (0.), … 5%, …

2.3. Statistical analysis

2.3.1. Behavioral data analysis

… 4 … (… et al., 200 , … et al., 2014). … (… vs. …) … (… vs. …) … 1) … 2 … 3), … × …) … (… et al., 2013). … 20,000 … (http:// …) (200) … 5% …

2.3.2. Imaging data acquisition

… 3.0 T … T2*- … 33 …

(t ó4 × ó4, t).
t t t - (T = 2000 , T = 30 ,

t t t fi t t t t k t t t t t fi t t - t t t t t t t t (. ., t, - t, t) (, , , t .,). T t t t k t “ t”, t t , t t t - t fi t. t t , t t - t t t t, t t k t t t fi t t t fi t. t t ( ) (t ., 2001, t ., 2013) t t t t tt fi t t t fi t t - t. t - - t - t t , t t t fi t - t t (t ., 2015, t ., 2013, t ., 2014). t t *In-group_ Observe vs. Out-group_ Observe*. T t t t, t t t t t t , t t t t t t (t , 2013, t t ., 2011).

3. Results

3.1. Group-based guilt elicited by an interaction-based minimal group paradigm

t k fi t t t t t t t - t t t t- . t 1, *t*-t t t t t t t t t t t t t t - t t t t- t (T 1). , $t(23) = 10.0$, $p < 0.001$, $d = 2.0$, t t , $t(23) = 9$. , $p < 0.001$, $d = 1$. T t t 2. T t t t t t fi t t - t t t t- t (T 1). , $t(30) =$. , $p < 0.001$, $d = 1.41$, t t , $t(30) = 6.4$, $p < 0.001$, $d = 0$. . T t t t t t - / t- t . t t t t t t t t t t t ’ ? t t , t t t t ’ t t ’ t t t t t t t t ? T t - t , t tt - t t(t 1) t t (t 2) t . t - , t t t 1 t t t t t tt t t t , $\beta = 0.6$, $SE = 0.0$, $t = .50$, $p < 0.001$. t t t t t t , t t t t t - t t t t t t- t t , $\beta = 0.2$, $SE = 0.06$, $t = 4$ 0, $p < 0.001$. t t *Commit* t , t fi t × t t , $\beta = 0.0$, $SE = 0.04$, $t = 2.26$, $p = 0.03$ (T 2, . 3). t t t 2 tt t - t t t t 1 (. 3). , t t t t t t tt t t t t , $\beta = 0$. 3, $SE = 0.0$, $t = .44$, $p < 0.001$. fi , t t t t t t - t t t t t t- t t , $\beta = 0.3$, $SE = 0.11$, $t = 3.53$, $p < 0.001$. t t tt - t t, t t *Commit* t , t fi t × t t , $\beta = 0.16$, $SE = 0.0$, $t = 2.14$, $p = 0.04$ (T 2, . 3). t t t t t t t t t *Supplementary Results of Experiments 1 and 2*.

T t t t t ’ - t, t (- t-) (t) ( ) t t t (. 1) t t (. 2&3), t k t t t t t t t t t ’ . T t - t t t fi t 3 t (t t . . 1. $(1, 22) = 1.04$, $= 0.32$, t . $(1, 2) = 0.15$, . 2. $= 0.$ 0, . 3. $(1, 33) = 0.2$, $=$ 0.5). t t ’ t fi t t t .

3.2. Shared responsibility explains group-based guilt and compensation

T t t t t t - t, t t t - t. t , t t t t *Commit* t t t *Observe* t ($F(1, 23) = 151.1$, $p < 0.001$, $\eta^2_p = 0.$ t 1, $F(1, 30) = 9$ .30, $p < 0.001$, $\eta^2_p = 0.$ 3 t 2). t t , t t t t ’ . t t t t t (- *vs.* t-) (t *vs.*) fi t t t ($F(1, 23) =$ .55, $p = 0.011$, $\eta^2_p = 0.25$ t 1, $F(1, 30) = 5.45$, $p = 0.03$, $\eta^2_p = 0.15$, t 2, T 2 - t). fi , t t t t t t t *In-group_ Observe* t t t *Out-group_ Observe* t ($F(1, 23) = 11.3$, $p = .003$, $\eta^2_p = 0.33$ t 1 $F(1, 30) = 13.$, $p < 0.001$, $\eta^2_p = 0.32$ t 2). T t t t t j t t t - t t t t t ‘ t ’ t t - tt - . , t t t t - t- t t t t t t t - t t t (t 1, $r = 0.45$, $p = 0.03$, t 2, $r = 0.52$, $p = 0.003$) t t t t . T t t t t t t t t t t t - t. fi t t t . T t t t t - t t t t 3 (*Supplementary Results of Experiments 3*).

t t t t t t t t t t t k t t - t (. ., t ., 2014). t t j t t (, 200). fi t t t t *via* - t t t t t (t t t t = 0.1 , = 0.0 , 5% fi t 0.00 , 0.35 , *Supplementary Results of Experiments 1 and 2* t). t t , - t, t t t *via* t (t t t t t = 0.1 , = 0.0 , 5% fi t 0.003, 0.331 (. 3), *Supplementary Results of Experiments 1 and 2* t). T fi t t t t - t T , t - t t t t t t t t t t t t t t .

Table 1
t t k

t	-	t-	t-
t 1			$t(23)$
	4. (.2)	2. (.2)	10.0 ***
t t	5.4(.2)	3.5(.2)	9 . ***
t 2			$t(30)$
	4.4(.3)	2. (.2)	. ***
t t	4.3(.2)	3.4(.2)	6.4 ***

Note. t (*SEs*) t . fi t t- t t t * $p < .05$, ** $p < .01$, *** $p < .001$.

Table 2

t t 1 2.

t	-	t t-	t	-	t-	t t	T/F
t 1							
						t t	T
t t	4.0 (.1)	3.6 (.1)		2. (.1)	2.1 (.1)	2.26*	
t- t						t t	F(1, 23)
t	6. (.3)	6.6 (.4)		4.5 (.5)	3.3 (.4)	.55*	
	3.5 (.5)	3.2 (.6)		3.1 (.5)	2.2 (.3)	2.4	
	3.5 (.4)	2 (.5)		2. (.4)	2.4 (.4)	0.10	
t 2							
						t t	T
t t	13.5(.2)	13(.2)		12.3(.2)	11.2(.2)	2.14*	
t- t						t t	F(1, 30)
t	6 (.3)	6. (.3)		4.4 (.4)	3.3 (.4)	5.41*	
t	6.5(.3)	5 (.4)		4.1 (.4)	3.2 (.4)	1.05	
	3.6 (.3)	2. (.4)		3.3 (.3)	2.6 (.3)	0.16	
	3.1 (.4)	2. (.4)		3.0 (.3)	2.6 (.3)	0.11	

Note. t (SEs) t . SEs t 1 t 2 t t t t t . SEs t- t t . fi t t - t t t * $p < .05$.

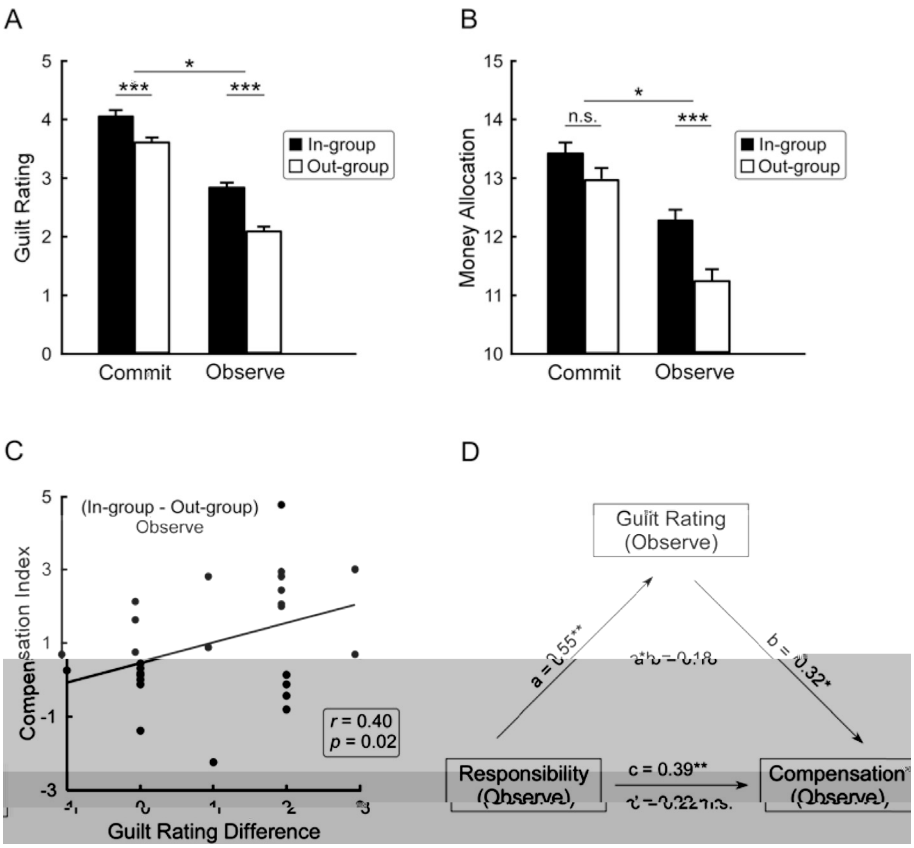

Fig. 3. Behavioral results of Experiment 1 (A) and Experiment 2 (B). . 2 , t t t t fi t (- *vs.* t-) (t *vs.*) t t . t t fi t t t. **(C)** t 2, t t- t t t - (. *In-group_ Observe* > *Out-group_ Observe*) t t t t - t . **(D)** T t t t t , t t , t t t 2. t t - t t t . ***$p < .001$, **$p < .01$, *$p < .05$.

3.3. Brain activations associated with personal and group-based guilt

t t t t tt t t t t fl t - t, t . T t t tt t t t *Supplementary Neuroimaging Results.* T t t t - t, t t t t t . fi t t t t "*In-group_ Observe* > *Out-group_ Observe*", t t - t. T t t t t t t t t (, t = 6, 26, 2 , *k* = 5) t t (, t = 2 , 20, −11 , *k* =) (. 4).

t t t t t (t ., 2011, t ., 2014) t - t t t (- t ., 200 , t ., 200 , t ., 2013, t ., 2003, t ., 200). T t t t t t tt , t t t t t t 2 t t t t . T t t t t t (. 4) t (. 4) t tt t t tt t t . , t t (*In-group_ Observe* > *Out-group_ Observe*) t t t t t- t t t t t t (*r* = 0.45, *p* = 0.011), t t t t t - t.

t t - t - t t t. t t t , ‘ t’ fi t t t ‘*Out-group_ Commit* > *Out-group_ Observe*’. T t t, t t t t , t t t t t ’ t - t t t t , t fl t - t. t fi t t (t ., 2013, t ., 2014), t t t (*Out-group_ Commit* > *Out-group_ Observe*) t t t (t = 12, 1 , 40 , $k = 153$) t t ( ) (t = 15, 5, ó , $k = ó2$) (. 5). t t t t t 2 t t (. 5) t t t t t t t t (*Out-group_ Commit* > *Out-group_ Observe*) t t t t - t t - t t t t ($r = 0.43$, $p = 0.02$). T t t t t(´ t ., 200 , t ., 2013, t ., 2014). t t t t t t 2 t t t fi t t t(3ó, 30, – , t t t ., 2014). T t t t t (. 5) tt t t t t . t t t t fi t t t , t t t t *Out-group_ Commit* t t t t *Out-group_ Observe* t , $t = 2.\ 5$, $p = 0.01$.

3.4. Group-based guilt shares brain representation with personal guilt

T t t - t t t t - t t t (*In-group_ Observe* > *Out-group_ Observe*) t t t t (*Out-group_ Commit* > *Out-group_ Observe*). T t t t t t t. T t , fi t j t t t - t t t . T t fi t j t fi t t t ((t = ó, 2ó, 2 , $k = 31$), . ó) t t t t - t. , t t tt ( ) t t t t t t t t t t t t - t t t t (= ó % ± ó%, $p < 0.001$, . ó). t t , t fi t t t - t t (*Out-group_ Commit vs. Out-group_ Observe*) t 1% ± %, $p = 0.01$ (. ó), t t t t t t t t t t - t.

4. Discussion

t t , t fi - t t t t t. fi , - t - t t t t - t j t t (t t ., 2004, , 2001, - , 2010). , t t t t. fi t t t T - t (t ., 200 , t , 2015), t t t t t - t - t t t t. t t t t t t t t t t t t (, 2001, - , 2010). , t t t t t - t (ˇ j ´- t ., 2011, t ., 2004). t t t t t t , t t t t t t t t t t *Observe* t , t t t t t tt - t t t- t , t t t t t t t t t t (*In-group_ Observe* > *Out-group_ Observe*). T t t t t t - t t - t (, 201 , T , 2006). t t t t t t t

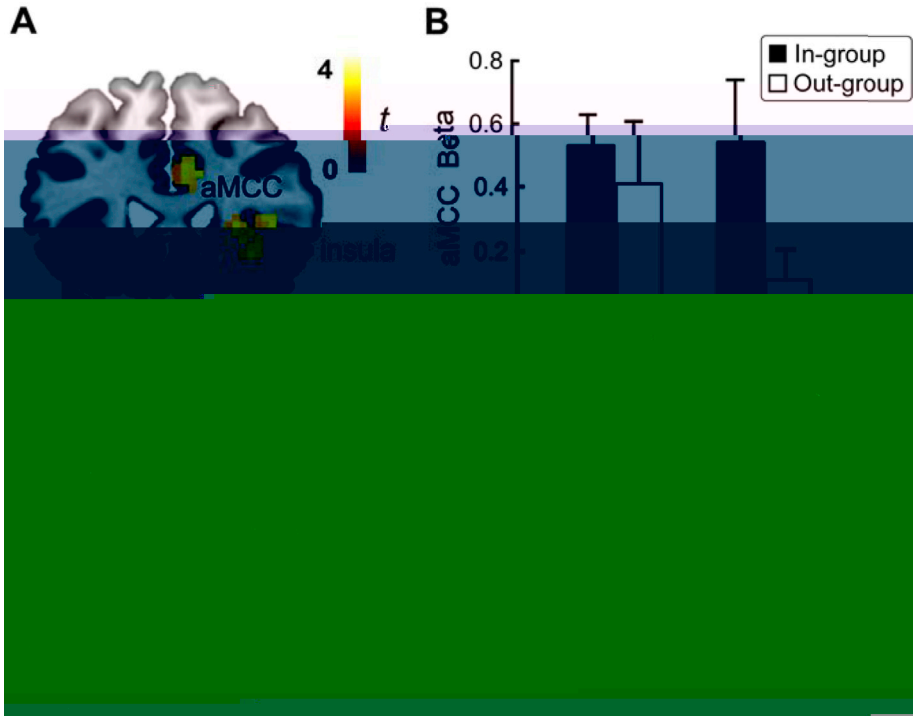

Fig. 4. Brain activations related to group-based guilt. t t t t ‘*In-group_ Observe* > *Out-group_ Observe*’ -t - t ( ). t t t t t $P <$ 0.005 t t t ≥46 . t t tt (. ., t t - t) t t ( ) ( ) - - t t (2 t - t (t = ó, 26, 2) (t = 2 , 20, −11)). ( ) t t t t t (. *In-group_ Observe* > *Out-group_ Observe*) t - t t t t- t t t (. *In-group_ Observe* > *Out-group_ Observe*). t t t . . 4 t.

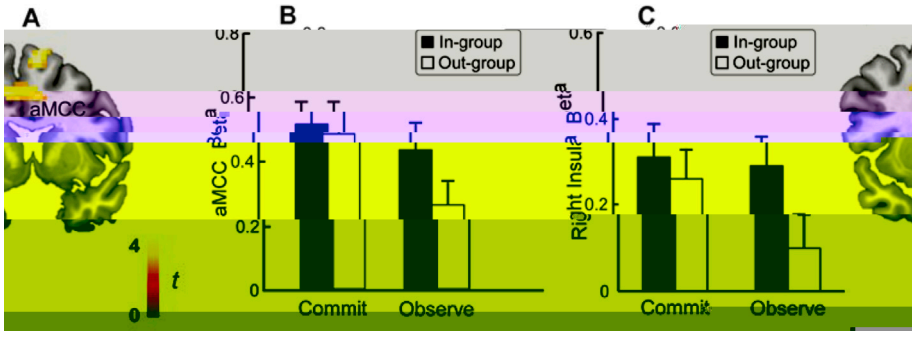

Fig. 5. Brain activations related to personal guilt (‘*Out-group_ Commit > Out-group_ Observe*’). ( ). t t t t ‘*Out-group_ Commit > Out-group_ Observe*’ -t - t . T $P < 0.005$ t t ≥46 ( ). t t tt (. ., t t t). t t 2 t t (t = 12, 1 , 40). ( ). t t tt t t t fi t t (2 t t t t ., 2014, t = 36, 30, –). t t t . . 5 t.

5. Conclusion

Data and materials availability

Declaration of competing interest

CRediT authorship contribution statement

Zhiai Li: **Hongbo Yu:** **Yongdi Zhou:** **Tobias Kalenscher:** **Xiaolin Zhou:**

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Appendix A. Supplementary data

References

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. 63, 5 6–612.
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, ., , ., , ., , . . ., , . ., , . ., 2010. T
t t . . . . 22, 24 –262. tt .//
. /10.1162/j .200 .21243.
, ., . t. . , . (.), t , t ,
t t . . t .,
. 220–240.
- , ., , ., , . ., , . ., 2016. T
t t . T 30, 241–256. tt .// . /
10.100 / 54 2016 43 .
t , ., , ., , ., 2016. T t t t t .
, 31–36. tt .// . /10.1016/j. .2015.0 .015.