

ARTICLE INFO

Graphical abstract
Mentalizing
P
MRI
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ABSTRACT

People often struggle to understand others' mental states. This is particularly true for individuals with autism spectrum conditions (ASC). However, recent research suggests that some individuals with ASC may have enhanced mentalizing abilities. In this study, we used functional MRI (fMRI) to investigate the neural basis of mentalizing in a group of individuals with ASC (N = 90). We compared the brain activation patterns of individuals with ASC to those of a control group during a mentalizing task. The results showed that individuals with ASC had enhanced activation in the fusiform gyrus (MMPA) during mentalizing. This finding suggests that individuals with ASC may have enhanced mentalizing abilities, which could be related to their enhanced social skills.

1. Introduction

Graphical abstract: "The mentalizing brain" (Ihász, 1991). The mentalizing brain is a concept that refers to the brain's ability to understand others' mental states. This ability is essential for social interaction and is often referred to as "theory of mind" (ToM). Research has shown that individuals with autism spectrum conditions (ASC) often have difficulties with ToM. However, recent research suggests that some individuals with ASC may have enhanced mentalizing abilities. In this study, we used functional MRI (fMRI) to investigate the neural basis of mentalizing in a group of individuals with ASC (N = 90). We compared the brain activation patterns of individuals with ASC to those of a control group during a mentalizing task. The results showed that individuals with ASC had enhanced activation in the fusiform gyrus (MMPA) during mentalizing. This finding suggests that individuals with ASC may have enhanced mentalizing abilities, which could be related to their enhanced social skills.

Autism spectrum conditions (ASC) are a group of neurodevelopmental disorders characterized by difficulties in social interaction and communication. One of the core features of ASC is a difficulty in understanding others' mental states, often referred to as "theory of mind" (ToM). However, recent research suggests that some individuals with ASC may have enhanced mentalizing abilities. In this study, we used functional MRI (fMRI) to investigate the neural basis of mentalizing in a group of individuals with ASC (N = 90). We compared the brain activation patterns of individuals with ASC to those of a control group during a mentalizing task. The results showed that individuals with ASC had enhanced activation in the fusiform gyrus (MMPA) during mentalizing. This finding suggests that individuals with ASC may have enhanced mentalizing abilities, which could be related to their enhanced social skills.

* Corresponding author. P. M. C. (E-mail: p.m.c@...).
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1998; McGee et al., 2005). ... (G... G..., 2006; C... C..., 2011), ... (A..., 2014; D..., 2004; H..., 2019; L..., 2011; ..., 2019), ... (A..., 2007; P..., 2005).
 A... (B..., 2008; D..., 1998; M G t t., 2005), ... (1) D... ? (2) H...
 A... (IE ; M..., 2008; t., M..., 2015), ... (R..., 2008).
 I... D... R... H... (D..., 2003; M t t., 1993), ...
 E... / ... (K..., 2013; t., 2014). I...
 L... (C t., 2015; K..., 2013; R..., 2011; t., 2014). M... (2014)
 (MCC), ... (AI), ... (ACC), ... (LPFC) (B..., 2015; C... t t., 2017; G..., 2008; M R t., 2010).
 (... MCC, AI). I... (... ACC, LPFC).
 (... (K..., 2013; t., 2014). ... (D..., 2018; Ott..., 2016). I...
 / t... / t... (E... t1) 20 (3 D) ... (E... t2).

... (K t., A., 2003; G t., 2018; t., 2014).
 (MPVA) t... (E... t2). I... tMPVA

2. Materials and methods

2.1.

F E t1 (... t), ... t 24 ... (12 ... 19.3 ± 0.8). F E t2 (MRI ... (>3 ... 31 ... t (19 ... 21.3 ± 1.1 ...) ... E t2 ... N ... Et C ... P ... C ... P ... C ...

2.2. E...

2.2.1. E... I (...)
 2.2.1.1. I... t... t... t... t... (...) ... A ... (...) ... B (...). I... A... / t... / t... R A ... (F .1). ...
 2.2.1.2. I... t... t... t... A ... G ... B G ... E ... J... J..., 1991) t...

... ; 2) ...
20 (3 D) t / 3 B
... B
... (K t ...
A , 2003; ... , 2014).
B ...
A t ...
t 9- tL t (1= t, t, 9= t)
t ... At E t2, t t -
...
(100 , t 15 D) t t t -
t t t t t

(1 × 1 × 1 mm³, TR = 64 × 64, TE = 3.5 ms, TI = 3.5 ms, FA = 90°, NEX = 3, Matrix = 224 × 224, FOV = 224 × 224 mm, Slice thickness = 3 mm, MPRAGE).

2. ... MRI ... PM8 (...) ... 3 × 3 × 3 mm³ ... MNI ... 8- ... 1/128 H ...

2. ... At ... 18 ... GLM ... MRI ...

- R1: C ... (... = 4.3) ...
- R2-R5: C ... (... = 2) ...
- R6-R9: F ... (2) ...
- R10-R13: ... (2) ...
- R14: ... (1.5) ...
- R15: A ... (5) ...
- R16: M ... (4.3) ...
- R17-R22: ... GLM ...

A ... Att ...

- ... > ...
- ... > ...
- ... A ... > ...
- ... > ...

t ... > ...

t ... > ...

t ... > ...

(L ... C ... , 2009). A ...

C ... (2009), ... < 0.005. ...

t ... > ...

2. ... (P ... F ... , 1997) ...

(F ... t ... , 2005; N ... t ... , 2005) ...

“ ... ” I ...

2. ... (MPPA) ...

... (D., 1999; ..., 1987; ..., 1987). ... (WM) (F., 2001; ..., 2013) ... (C., 2015; ..., 2013; ..., 2014). ... GLM ... (C., 2013; ..., 2011).

3. Results

1. ... A ... (1): ..., (23) = 10.0, < 0.001, = 2.08; ..., (23) = 9.8, < 0.001, = 1.99. ... E ... (1): ..., (30) = 7.8, < 0.001, = 1.41; ..., (30) = 6.4, < 0.001, = 0.77. ... D ... M ... (E ... 1), ... (E ... 2) ... , $\beta = 0.68$, $E = 0.08$, $\lambda = 8.50$, $\lambda = 0.001$. M ... , $\beta = 0.29$, $E = 0.06$, $\lambda = 4.90$, $\lambda = 0.001$, $\beta = 0.08$, $E = 0.04$, $\lambda = 2.26$, $\lambda = 0.03$ (2; F .3A). M ... E ... 2 ... (F .3B). I ... , $\beta = 0.73$, $E = 0.09$, $\lambda = 7.44$, $\lambda = 0.001$. M ... , $\beta = 0.38$, $E = 0.11$, $\lambda = 3.53$, $\lambda = 0.001$, $\beta = 0.16$, $E = 0.08$, $\lambda = 2.14$, $\lambda = 0.04$ (2; F .3B). Ot ...

E ... I 2. ... ANOVA ... (E .1), ... (E .2&3), ... 3 ... :F(1, 22) = 1.04, $\lambda = 0.32$; ... :F(1, 29) = 0.15, $\lambda = 0.70$; E ... 3: F(1, 33) = 0.29, $\lambda = 0.58$. P2. ...

Table 2

Item	In-Group	Out-Group	In-Group	Out-Group	Interaction
Experiment 1					
Overall					$F(1, 23) = 2.26^*$
Guilt Rating	4.0 (.1)	3.6 (.1)	2.8 (.1)	2.1 (.1)	$F(1, 23) = 7.55^*$
Responsibility	6.8 (.3)	6.6 (.4)	4.5 (.5)	3.3 (.4)	2.47
Compensation	3.5 (.5)	3.2 (.6)	3.1 (.5)	2.2 (.3)	0.10
Experiment 2					
Overall					$F(1, 30) = 2.14^*$
Money Allocation	13.5 (.2)	13 (.2)	12.3 (.2)	11.2 (.2)	$F(1, 30) = 5.41^*$
Responsibility	6.9 (.3)	6.7 (.3)	4.4 (.4)	3.3 (.4)	1.05
Guilt Rating	6.5 (.3)	5.9 (.4)	4.1 (.4)	3.2 (.4)	0.16
Compensation	3.6 (.3)	2.7 (.4)	3.3 (.3)	2.6 (.3)	0.11
AI	3.1 (.4)	2.7 (.4)	3.0 (.3)	2.6 (.3)	

Standard deviations are in parentheses. Error bars represent standard errors. * $p < .05$.

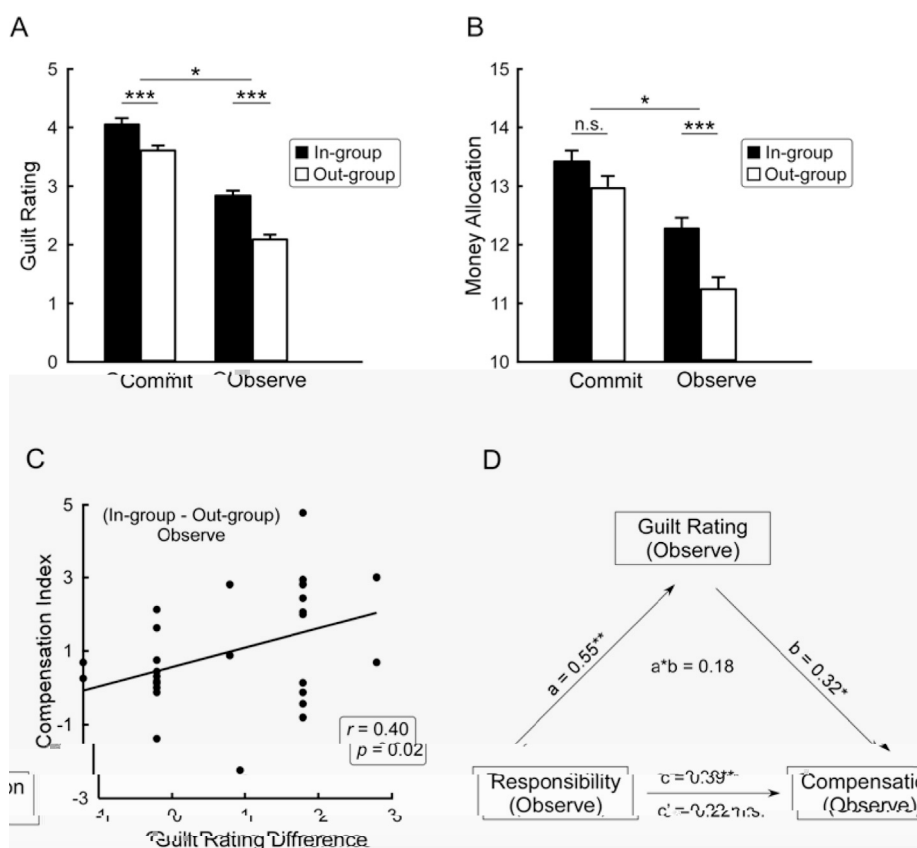


Fig. 3. Behavioral results of Experiment 1 (A) and Experiment 2 (B). F (1, 23) = 2.26* ($p < .05$), F (1, 23) = 7.55* ($p < .01$), F (1, 23) = 2.47 ($p > .05$), F (1, 30) = 2.14* ($p < .05$), F (1, 30) = 5.41* ($p < .01$), F (1, 30) = 1.05 ($p > .05$), F (1, 30) = 0.16 ($p > .05$), F (1, 30) = 0.11 ($p > .05$). * $p < .05$, ** $p < .01$.

... MCC, ... AI ...

H ...

A ... G ...

(MCC; MNI ... = 6, 26, 28; = 85 ...)

(AI; MNI ... = 27, 20, -11; = 78 ...)

MCC, ... AI ...

(C, ... 2011; ... 2014)

(I ... 2009;

K ... 2008; K ... 2013; ... 2003; ... 2007).

... 27 ...

MCC, ... AI ... MCC

(F .4B), ... AI (F .4C) ...

M, MCC ...

(...) ...

(= 0.45, =

0.011), ... MCC ...

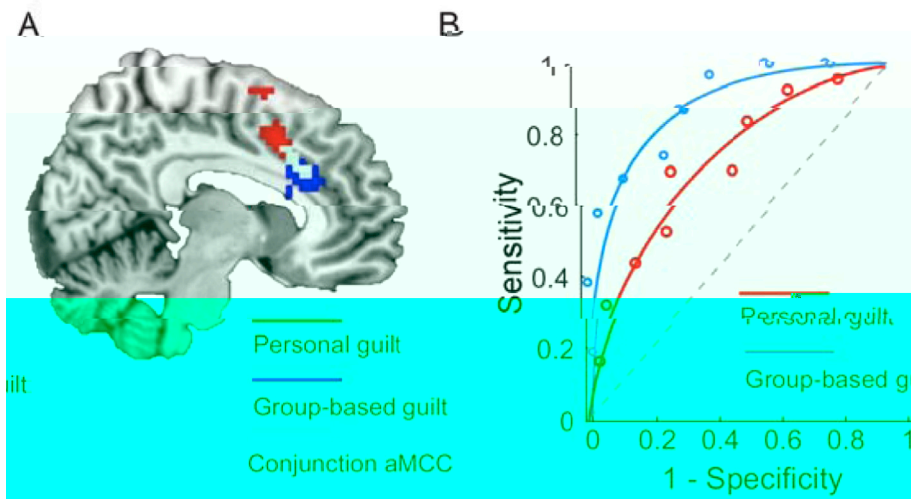


Fig. 6. Results of multi-variate pattern analysis (MVPA). (A) Coronal brain slice showing activation clusters: Personal guilt (red), Group-based guilt (blue), and Conjunction aMCC (green). (B) ROC curve showing Sensitivity vs 1 - Specificity for Personal guilt (red) and Group-based guilt (blue). $p < .005$ (FDR corrected). $R = .86$ (Personal guilt), $R = .81$ (Group-based guilt).

(Guthrie, 2004; Liberman, 2012; Liberman & Liberman, 2016; Liberman, 2015), ... (Eaton, 1988; Fernald, 1993). A ... (Berman, 1994; ... (Berman, 2003). ... (Berman, 2016; Cramer, 2015; Fernald, 2019; Kuhl, 2008; Kuhl, 2013; Liberman, 2017; ... (Berman, 1995). ... (Berman, 1988; ... (Fernald, 2007; ... (Fernald, 2007; Zuhl, 2019): ... (Fernald, 2016; ... (Fernald, 2014; ... (Fernald, 2019). It ... M ... H ... "I" ... "I" ...)

... MRI ... (PJ), ... ACC), ... (PFC), ACC ... (Zhang et al., 2019). I ... A ... (...) ... (...) ... MPFC/ACC ... (... , 2012). ... E ... (... , 1995) ... E ... (... , 1989). ... M ... E ... E ... (M ... K ... , 1991). F ... (...) ... F ... N ... F ... (... B ... , 1994; C ... , 2011; I ... , 2004). It ... C ...) ... E.I.R.D (... , E ... , I ... , R ...) ... (N ... , 2010). I ... E ...) ... O ... E ... H ... A ... (A ... , 2009). I ... (A ... , 2014; B ... C ... , 2019; C ... , 2017). I ... A ... (...) ... (G ... , 2018; ... , 2019).

... MRI ...) ... M ... O ...

5. Conclusion

B MRI ... M ... O ...

Data and materials availability

... F ... 3A-D, 4D, ... 1, 2, ... F ... 1, 2, ... D ... C ... N ... (... // ... / ... / ... =), ... G TH (... // ... / ... 0602/ ...). MRI ...

Declaration of competing interest

... t, tt ... t t t.

CRediT authorship contribution statement

Zhiyi Li: F ... Hongbo Yu: F ... Yongdi Zhou: ... Tobias Kalenscher: ... Xiaolin Zhou: ... & t ...

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... N ... N ... F ... C ... (31630034), N ... B ... R ... P ... C ... (973 P ... : 2015CB856400).

Appendix A. Supplementary data

... t ... tt ... // ... /10.1016/.2019.116488.

References

- A ... A ... , E.N., ... D., 1992. I ... J. P ... P ... 63, 596–612. [tt // ... /10.1037/0022-3514.63.4.596.](#)
- A ... D.M., D ... , P.G., H ... -J ... , E., 2007. A ... 18, 524–530. [tt // ... /10.1111%2F.1467-9280.2007.01933.](#)
- A ... H., 2009. R ... J ... N ...
- A ... D.I.K., G ... , J.E., H ... , J. ... , 2014. E ... P ... N ... A ... A. 111, 8788–8790. [tt // ... /10.1073/1320040111.](#)
- A ... , J.A., B ... , R., G ... , R., D ... , J.A., ... , F., 2014. ... J. P ... P ... 40, 1270–1284. [tt // ... /10.1177/0146167214540724.](#)
- A ... K., A ... -H ... , J.R., D ... , D., 2017. E ... N ... 94, 1263–1273. [tt // ... /10.1016/.2017.05.014.](#)

B... C, H... B.J., D... C.G., M... J., ... 2016. F...
B... R 71, 455-471. tt // /10.1016/... .2016.09.019.
B... R.H., D... D.J., B... D.M., 2008. M...
10.1016/... .2007.12.005.
B... M., 1988. R... M... P... 13, 259-281. tt //
/10.1111/.1475-4975.1988.t00126.
B... D.J., L... R., ... C., ... H.J., 2013. R...
10.1016/... .2012.11.001.
B... D., M... M., B... B., ... 2014. Ftt
4. J... 67, 1-48. tt // /10.18637/... 067. 01.
B... R.F., ... A.M., H... F., 1994. G...
P... R.F. 115, 243-267. tt // /10.1037/0033-2909.115.2.243.
B... R.F., ... A.M., H... F., 1995. P...
173-198. tt // /10.1207/ 15324834 . 1701.
B... N.R., ... B., K... D.M., 2004. C t G t t t i , ... t
t I N t G t P , G
B... R., G... R., Z... H., M... J., C... 2008. N...
J.P... P... 94, 75-90. tt // /10.1037/0022-3514.94.1.75.
B... J., 2015.
C RR OPIN BEHAW CI 3, 122-129. tt // /10.1016/... .2015.03.004.
B... J., C... M.J., 2019. H... ? C... 23,
79-80. tt // /10.1016/... .2018.11.004.
C... E., D... C., B... M., 2015.
A t N ... 11, 357-366. tt // /10.1093/... / 120.
C... E., G... R., 2006. N...
tt // /10.1037/0022-3514.90.5.804.
C... F., A... A.R., K... C., G... W., 2015. R...
371-378. tt // /10.1016/... .2015.03.034.
C... C., E... D.A., H... E., L... W., R... L.D., 2011. A...
10.1037/ 0023936.
C... L.J., G... P.J., M... B., K... A., ... D., 2015. A...
/10.1371/... .1002180.
C... L.J., ... A., D... M., ... A.G., 2011.
/10.1016/... .2011.02.056.
C... M.J., 2017. M... N... H... B... 1, 769-771.
tt // /10.1038/ 41562-017-0213-3.
C... M.J., ... J.J., K... Z., D... P., D... R.J., 2017. M...
tt // /10.1038/ .4557.
C... -D... A... C., ... A., W... P., ... 2016. C...
7, 10904. tt // /10.1038/ 10904.
C... M.N., 2013. D... ? COGN AFFEC BEHAW NE 13, 667-673. tt //
/10.3758/ 13415-013-0186-2.
D... J.M., R... E.M., 2003. A...
10.1037/0021-9010.88.2.284.
D... B., B... N.R., ... R., M... A., 1998. G...
tt // /10.1037/0022-3514.75.4.872.
D... B., B... N.R., ... R., M... A., 2004. C...
B... N.B., B... N.R., D... B.(E.), C t G t I t t
P... P... 95-111.
D... 2018. M... 22, 780-793. tt // /
10.1016/... .2018.06.004.
D... J., 1999. A K G t L... P... 18, 313-325. tt //
/10.1023/A:1006380226393.
E... H., C... L.J., ... D., 2016. M...
tt // /10.1523/JNE RO CI.3672-15.2016.
E... P.C., ... C.A., 1988. F...
tt // /1669.
F... C.F., H... J., ... K., 2014. C...
J.C... P... 45, 265-281. tt // /10.1177/0022022113492892.
tt // /... ? =C t + i t + + t + + + +
F... J., B... D., ... J., E... H.L., 2007. ...
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F... M.A., B... N.R., 2014. ... t... I :
... M., ... C.W.(E.), C t E t : P t P ...
P... O... P... 251-265.
F... N.H., 1993. ... C t E t 7, 357-387.
F... J., H... R., 2001. ... L...
tt t N.
F... K.J., P... D., G... D.E., 2005. C... N... 25,
661-667. tt // /10.1016/... .2005.01.013.
F... N... K.I., ... R., M... 2019. G...
tt // /
10.1007/ 12144-019-0144-4.
G... P.E., 2004. E... P... 71, 901-911.
tt // /10.1086/425944.
G... C., 2007. F : A P... E t . G...
P... G
G... H., ... L., B... P.R., Z... L., H... M., Z... 2018. D...
P... N t A... 115, E7680-E7689. tt // /10.1073/
.1802523115.
G... P.R., M... R., K., R... G... J.J., 2008. ...
577-586. tt // /10.1016/... .2007.05.031.
H... E., G... J., R... R.L., 1993. E... C... D... P...
2, 96-100. tt // /10.1111%2F1467-8721. 10770953.
H... E., ... E... N., 2019. M... E t P t D M... O
t P , O
H... M.L., 2001. E... M... D... I... t... G...
J t C t P , G
I... M.H., M... C... A., D... H., D... A., 2009. N...
10.1073/... .0810363106.
I... A., L... C... P... A., 2004. R... t... t... t...
O... t : R... P... P... R... R... L...
345-361.
I... C.E., 1991. P... E t P , N...
I... K., ... D., Q... H... M., K... R., 2002. P...
N... 113, 298-304. tt // /10.1016/ 1388-2457(01)00734-9.
J... D... J... F.P., 1991. J... G...
P... H... E... C... N.J.
K... G., B... M., H... M. H... 33316 t... 63, P... 23/10.1023.36.10480 D)-340.7 4 E

