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ORIGINAL RESEARCH

# Only-child and non-only-child exhibit differences in creativity and agreeableness: evidence from behavioral and anatomical structural studies

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**Abstract** Different family composition and size inevitably make only-children different from non-only-children. Previous studies have focused on the differences in behaviors, such as cognitive function and personality traits, between the only-child and the non-only-child. However, there are few studies that have focused on the topic of whether different family environments influence children's brain structural development and whether behavior differentially has its neural basis between only-child and non-only-child status. Thus, in the present study, we investigated the differences in cognition (e.g., intelligence and creativity) and personality and the anatomical structural differences of gray matter volume (GMV) using voxel-based morphometry (VBM) between only-children and non-only-children. The behavioral results revealed that only-children exhibited higher flexibility scores (a dimension of creativity) and lower agreeableness scores (a dimension of personality traits) than non-only-children. Most importantly, the GMV results revealed that there were significant differences in the GMV between only-children and non-only-children that occurred mainly in the brain regions of the supramarginal gyrus, which was positively correlated with flexibility scores; the medial prefrontal cortex (mPFC), which was positively correlated with agreeableness scores; and the parahippocampal gyrus. These findings may suggest that family environment (i.e., only-child vs. non-only-child), may play important roles in the development of the behavior and brain structure of individuals.

**Keywords** Only-child · Supramarginal gyrus · Medial prefrontal cortex (mPFC) · Creativity · Agreeableness

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## Introduction

To ease the enormous pressure of population explosion, the Chinese government started promoting and implementing an only-child family planning program in 1979 (Jiao et al. 1996; S. Li et al. 2013). The implementation of the one-child policy lasted more than 30 years; the controlling effect of the population growth is significant (Festini and de Martino 2004). Today, there are many only children in the younger generation of Chinese due to this policy. An only-child is defined as a child who never had any siblings (Burke 1956; Cai et al. 2012; Fletcher 2014). Different family compositions and sizes may determine the different modes of interaction between family members; therefore, it is generally believed that the family environment inevitably makes only-child groups different from non-only-child groups in terms of the children's cognition, personality and affect characteristics (Feng 1992; Hao and Feng 2002; S. Li et al. 2013). For example, previous studies have revealed that only-children exhibit more positive developmental outcomes (such as achievement, intelligence and creativity) (Falbo et al. 1989; Gaynor and Runco 1992), more positive relationships with their parents (Blake 1981; Falbo and Polit 1986) and fewer behavioral problems in school (Falbo and Polit 1986; Fenton 1928) compared with non-only-children. Otherwise, only-children receive too much attention and excessive praise from their parents and grandparents (Cai et al. 2012; Wang 1984), which may cause undesirable personality traits in the children, such as dependency, selfishness and social ineptitude (Blake 1981; Cai et al. 2012; Fletcher 2014; Polit 1982). Additionally, due to the absence of siblings, only-children usually miss out on important opportunities to rehearse some of the more complicated aspects of relationships within a safe environment and also miss many opportunities to develop psychosocial skills, emotional support and learning opportunities compared with non-only-children (Dunn and Slomkowski 1992; Fletcher 2014). Altogether, the previous studies mainly focus on the difference in the behavior (such as intelligence, creativity and personality) between only-children and non-only-children (Gaynor and Runco 1992; Polit and Falbo 1987). However, to date, whether the different family environments (only-child and non-only-child) influence brain structure development is unclear.

With the development of cognitive neuroscience, increasing numbers of researchers have focused on the neural mechanisms associated with inter-individual differences in human psychological traits, particularly intelligence, creativity and personality (DeYoung et al. 2013; Silvia et al. 2008; Wei et al. 2014a). For example, previous studies have shown that creativity is associated with the structure and function of the frontal lobe (Takeuchi et al. 2012), primarily the ventrolateral prefrontal cortex, dorsolateral prefrontal area, the medial prefrontal cortex and ventromedial prefrontal cortex (Berkowitz and Ansari 2008; Chávez-Eakle et al. 2007; Sawyer 2011), and the temporo-parietal regions, including the angular gyrus and supramarginal gyrus (Arden et al. 2010; Kleibeuker et al. 2013). Regarding intelligence, many studies have suggested that intelligence is associated with brain structures that are mainly localized to the frontal regions, parietal regions and BA37/19 (Duncan et al. 2000; Gray et al. 2003; Haier et al. 2004). Many studies have found that personality traits are associated with brain structures, primarily those in the temporal lobe, parietal cortex, temporoparietal junction, prefrontal cortex, cingulate cortex and hippocampus or parahippocampal gyrus (DeYoung et al. 2010; Sampaio et al. 2014; Saxe and Powell 2006).

Young adulthood is a period of considerable opportunity and challenge. Many young adults move away from the homes of their parents and, for the first time, begin college. Different family environments (i.e., only-child and non-only-child environments) affect the child's cognition in terms of intelligence, creativity, and personality characteristics (Fletcher 2014; Gaynor and Runco 1992). These influences of different family environments may cause young adults to exhibit different adaptabilities to novel college life. It is well known that general intelligence is an important human quantitative trait that accounts for much of the variation in diverse cognitive abilities and is strongly associated with many important life outcomes, including educational and occupational achievements, income, health and lifespan (Davies et al. 2011). Personality traits are stable psychological features and influence a person's behavior, emotion, motivation, and cognition (DeYoung et al. 2010), and creativity is known to serve as a pillar of society that affects all aspects of human life and plays a crucial role in cultural life (Fink et al. 2010). Additionally, structural imaging studies are particularly useful for investigating anatomical correlates of personal characteristics that involve a wide range of behaviors and ideas that occur outside the laboratory, such as cognition and personality (W. Li et al. 2014). Thus, it is very meaningful to investigate different behaviors, primarily related to intelligence, personality and creativity, and the different structural bases between only-children and non-only-children in a young adult sample.

Thus, in the present study, we primarily investigated the anatomical structural differences (i.e., gray matter volume, GMV) using voxel-based morphometry (VBM) between only-children and non-only-children. The general intelligence was measured with the Combined Raven's Test (CRT), personality was measured with the revised Neuroticism-Extraversion-Openness Personality Inventory (NEO-PI-R), and the creativity of the individuals was tested with the well-established Torrance Test of Creative Thinking (TTCT) verbal creativity test. Based on previous studies, we hypothesized that there would be differences in intelligence, personality traits and creativity between the only-children and the non-only-children. Additionally, structural brain differences between the only-children and the non-only-children may be present in some brain regions associated with general intelligence, personality characteristics and creativity.

## Method

### Participants

The participants were college students from our ongoing project examining the associations between brain imaging results, creativity, and mental health. The participants were screened to confirm healthy development with a self-report questionnaire before scanning, and thus the participants with histories of psychiatric or neurological disorders and those who had received mental health treatment or had taken psychiatric medications were excluded. To control the effect of the different nationalities and family structure on the results, a total of 303 subjects from the Han population and two-parent families completed the MRI scanning and the basic family information. All participants were undergraduate or graduate students from the local community of Southwest University, China.

The participants were all right-handed, healthy individuals and included 126 only-children (65 male) and 177 non-only-children (74 male). In the present study, only 270 (108 only-child) of the 303 subjects finished the creativity and general intelligence tests, and 249 (95 only-child) of the 303 subjects finished the personality trait scale. The greater number of non-only-children in the present study may because more participants in our study sample are non-only-children. All participants provided written informed consent prior to the study. The Brain Imaging Center Institutional Review Board of Southwest China University approved this study and the experimental procedure, which was in accordance with the standards of the Declaration of Helsinki (1991).

## Study measures

### Annual family income

The data were collected using the following discrete variables: 1, annual income < Ren Min Bi (RMB) 5000; 2, annual income RMB 5000–15000; 3, annual income RMB 15001–30000; 4, annual income RMB 30001–50000; 5, annual income RMB 50001–100000; and 6, annual income > RMB 100000. The values of 1–6 were used in subsequent regression analyses (Takeuchi et al. 2014).

### The educational qualifications of both parents

There were five options [1, elementary school graduate or below; 2, junior high school graduate; 3, high school graduate; 4, university graduate; and 5, above university graduate], and each choice was converted into the number of years of education according to the Chinese education system (i.e., 1, 6 years; 2, 9 years; 3, 12 years; 4, 16 years; and 5, 19 years). The averages of the converted values for each parent were used in the analyses (Takeuchi et al. 2014).

### Assessment of general intelligence

To examine intellectual ability, the participants completed the Combined Raven's Test (CRT), which is a recognized intelligence test with high degrees of reliability and validity (Tang et al. 2012). The reliability coefficient was 0.92 (Ming 1989). The CRT, including the Raven's standard progressive matrix (the C, D, and E sets) and the Raven's colored progressive matrix (the A, AB, and B sets), consisted of 72 items as revised by the Psychology Department of East China Normal University in 1989. The score for this test (i.e., the number of correct answers given in 40 min) was used as a psychometric index of individual intelligence (Wei et al. 2014b). In line with standard practice, the current study focused on the total score of the test (Jaeggi et al. 2008; Takeuchi et al. 2011).

### Measurements of personality traits

In the current study, the personality traits were assessed using the revised Neuroticism-Extraversion-Openness Personality Inventory (NEO-PI-R) (Costa and McCrae 1992). The NEO-PI-R consists of 240 items and is based on a 5-factor (i.e., Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness) model of personality. All of these factors are divided into 6 subscales. Each factor consists of 48 items, and the items are answered on a five-point Likert scale that ranges from strongly disagrees to strongly agree. Previous studies have shown that the NEO-PI-R has good reliability and validity (Costa and McCrae 1992; McCrae 2011).

### Measuring the level of creativity

Creativity was assessed using the Torrance Tests of Creative Thinking (TTCT, Torrance 1987). The TTCT was designed as a measure of divergent thinking, which is a central aspect of creativity (Huang et al. 2013). The TTCT contains verbal, figural and auditory tests. In this study, the verbal TTCT was used to assess individual divergent thinking abilities (Kim et al. 2006; Torrance 1987). The verbal TTCT comprises seven tasks and for each task scoring comprised three components: fluency, flexibility and originality. The total score of the TTCT is the sum of the fluency, flexibility and originality score. For a detailed description of the TTCT, please see our previously published paper (Wei et al. 2014a).

### MRI data acquisition

A 3.0-T Siemens Trio MRI scanner (Siemens Medical, Erlangen, Germany) was used to obtain MR images. A magnetization-prepared rapid gradient echo (MPRAGE) sequence was used to acquire high-resolution T1-weighted anatomical images (repetition time = 1900 ms, echo time = 2.52 ms, inversion time = 900 ms, flip angle = 9 deg, resolution matrix = 256 × 256, slices = 176, thickness = 1.0 mm, voxel size = 1 × 1 × 1 $mm^3$).

### Preprocessing of structural data

The MR images were processed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK) implemented in MATLAB 7.8 (MathWorks Inc., Natick, MA, USA). First, each MRI image was displayed in SPM8 to filtrate gross anatomical abnormalities. For more accurate image registration, the reorientation of the images was manually fixed to the anterior commissure. The New Segment Toolbox from SPM8 was applied to every T1-weighted MR image to extract tissue maps corresponding to gray matter, white matter, and cerebral spinal fluid in native space. Subsequently, we performed diffeomorphic anatomical registration through exponentiated Lie (DARTEL) algebra in SPM8 for registration, normalization, and modulation (Ashburner 2007). The DARTEL registration involves, first computing the specific template using the average tissue probability maps from all the participants, and followed by warping each participant's segmented maps into specific template. The segmented images of gray and white matter were aligned and warped to a template space. To improve the alignment and achieve a more accurate inter-subject registration, the procedure was repeated until a best study-specific template was generated. To ensure conservation of regional differences in the absolute amounts of GM, the image intensity of each voxel was modulated by the Jacobian determinants. Subsequently, the normalization function in the DARTEL toolbox was used to normalize the individual images of gray and white matter to MNI space (1.5 mm isotropic voxel). Finally, the normalized modulated images (GM images) were smoothed with a 10-mm full-width-at-half maximum Gaussian kernel to increase the signal-to-noise ratio.

### Statistical analyses

All of the behavioral data were analyzed with SPSS 16.0. The statistical analyses of the brain imaging data were performed using SPM8. In the whole-brain analyses, the two-sample *t*-test analysis was used to explore the differences in GMV between the only-child and the non-only-child. In the analyses of gender, age and total grey matter volume were included as nuisance covariates to remove potential confounds. We also applied explicit masking using the population-specific masking toolbox in SPM8 to restrict the search volume to gray matter and white matter. This approach was used instead of absolute or relative threshold masking to reduce the risk of false negatives caused by overly restrictive masking in which potentially interesting voxels are excluded from the statistical analysis (Ridgway et al. 2009).

Next, in the whole-brain analyses, multiple regression analysis was used to explore the association between GMV and individual differences in the behaviors that were found to be significantly different between the only-children and non-only-children. The behaviors were used as the variables of interest, and the total brain GMV, age and sex were entered as covariates of no interest to control for the possible effects of these variables. We also applied explicit masking using the population-specific masking toolbox in SPM8 to restrict the search volume to gray matter and white matter. To increase the power to detect brain structural difference between only-child and non-only-child, statistical analyses focused on key brain structures associated with creativity, intelligence and personality (DeYoung et al. 2010; Gaynor and Runco 1992; Haier et al. 2004; Sawyer 2011). Thus, a small volume correction (SVC) was applied to correct for multiple comparisons in the present study (Becker et al. 2015; Worsley et al. 1996). Based on previous studies these brain regions: ventrolateral prefrontal cortex, dorsolateral prefrontal area, medial prefrontal cortex, ventromedial prefrontal cortex, angular gyrus, supramarginal gyrus, temporal lobe, parietal cortex, temporoparietal junction, cingulate cortex hippocampus and parahippocampal gyrus associated with the creativity, intelligence and personality were choose as the regions of interest (Arden et al. 2010; Berkowitz and Ansari 2008; DeYoung et al. 2010; Gray et al. 2003; Sampaio et al. 2014). Structural regions of interest were defined using the WFU Pickatlas Toolbox (Maldjian et al. 2003). Between-group differences within the a priori regions of interest were computed using a threshold of $P<0.05$ (family-wise error-corrected, FWE; minimum cluster size > 50 voxels).

## Results

### Behavioral results

Tables 1, 2 and 3 lists the demographics of the only-children and non-only-children. As indicated in Tables, there were no significant differences in age or general intelligence between the only-children and the non-only-children. However, the only-children exhibited significantly higher family incomes ($t=2.69$, $p=0.008$), parental years of education ($t=4.47$, $p<0.001$) and creativity scores (flexibility scores) ($t=3.14$, $p=0.002$) and significantly lower agreeableness scores ($t=-3.27$, $p=0.001$) compared with the non-only-children.

### MRI results

After entering age, sex, family income, parental education years and global gray matter volume as covariates, a two-sample *t*-test analysis revealed that the GMVs in some clusters exhibited significant differences between the only-child and the non-only-child. These clusters primarily included the supramarginal gyrus ($x=66$, $y=-18$, $z=32$, cluster size =275 voxels, $t=3.94$, $P=0.015$ (corrected); see Fig. 1a), the mPFC ($x=2$, $y=52$, $z=0$, cluster size = 103 voxels, $t=-3.90$, $P=0.037$ (corrected); see Fig. 1b) and the parahippocampal gyrus ($x=-28$, $y=1$, $z=-33$, cluster size = 97 voxels, $t=-3.93$, $P=0.024$ (corrected); see Fig. 1c). Together, the whole brain *t*-test revealed that the only-child had greater

**Table 1** The demographic characteristics of the all of the only-children and non- only-children samples ($n=303$)

| Items | Only-child ($n=126$) | Non-only child ($n=177$) |
|---|---|---|
| Age (years) | 19.81 ± 1.13 | 19.97 ± 1.18 |
| Family income | 3.83 ± 1.36 | 3.42 ± 1.25** |
| Parental education years | 10.73 ± 3.26 | 9.29 ± 2.34** |

[a] Pearson bivariate correlations, shown are r-values

* $P<0.05$, ** $P<0.01$

**Table 2** The demographic characteristics of the only-children and non-only-children who finished the creativity and general intelligence tests ($n = 270$)

| Items | Only-child ($n = 108$) | Non-only child ($n = 162$) |
|---|---|---|
| Age (years) | 19.70 + ±1.13 | 19.88 ± 1.13 |
| Family income | 3.85 ± 1.35 | 3.40 ± 1.22** |
| Parental education years | 10.63 ± 3.17 | 9.11 ± 2.21** |
| Fluency | 52.68 ± 24.59 | 51.64 ± 18.46 |
| Flexibility | 33.00 ± 11.03 | 28.93 ± 10.00** |
| Originality | 45.70 ± 18.15 | 44.30 ± 14.79 |
| Total creativity score | 131.38 ± 43.15 | 124.88 ± 34.19 |
| General intelligence | 66.23 ± 3.91 | 65.26 ± 4.30 |

[a] Pearson bivariate correlations, shown are r-values

* $P < 0.05$, **$P < 0.01$

supramarginal gyrus volumes and smaller mPFC and parahippocampal gyrus volumes than the non-only-child.

To test whether these different brain structure regions were associated with the differences in the behaviors between only-children and non-only-children, we saved our results for the clusters in which significant differences were observed (mPFC, parahippocampal gyrus and supramarginal gyrus) between the two samples as ROIs and subsequently extracted the three ROI signals (the volumes of the ROIs) from each participant using the SPM8 toolbox. Next, we tested the relationships between the volume of the three brain regions and the behaviors, primarily including creativity and agreeableness, using SPSS 16.0. After controlling for age, sex and total gray matter volume, the results revealed that the flexibility score was positively correlated with the volume of the supramarginal gyrus (for all subjects, r = 0.231, $p < 0.001$; for the only-child, r = 0.165, $p = 0.088$; and for the non-only-child, r = 0.223, $p = 0.004$; see Fig. 2a), and the agreeableness personality scores were significantly positively correlated with the volume of the mPFC (for all subjects, r = 0.232, $p < 0.001$; for the only-child, r = 0.180, $p = 0.081$; and for the non-only-child, r = 0.203, $p = 0.012$;see Fig. 2b).

**Table 3** The demographic characteristics of the only-children and non-only-children who finished the personality trait scale ($n = 249$)

| Items | Only-child ($n = 95$) | Non-only child ($n = 154$) |
|---|---|---|
| Age (years) | 19.76 ± 1.16 | 19.86 ± 1.17 |
| Family income | 3.92 ± 1.28 | 3.32 ± 1.20** |
| Parental education years | 10.95 ± 3.37 | 9.16 ± 2.19** |
| Neuroticism | 137.58 ± 17.60 | 140.06 ± 19.67 |
| Extraversion | 154.43 ± 17.58 | 154.29 ± 17.87 |
| Openness | 159.61 ± 16.08 | 157.90 ± 14.73 |
| Agreeableness | 163.68 ± 11.63 | 168.84 ± 12.36** |
| Conscientiousness | 161.62 ± 17.35 | 163.36 ± 18.55 |

[a] Pearson bivariate correlations, shown are r-values

* $P < 0.05$, **$P < 0.01$

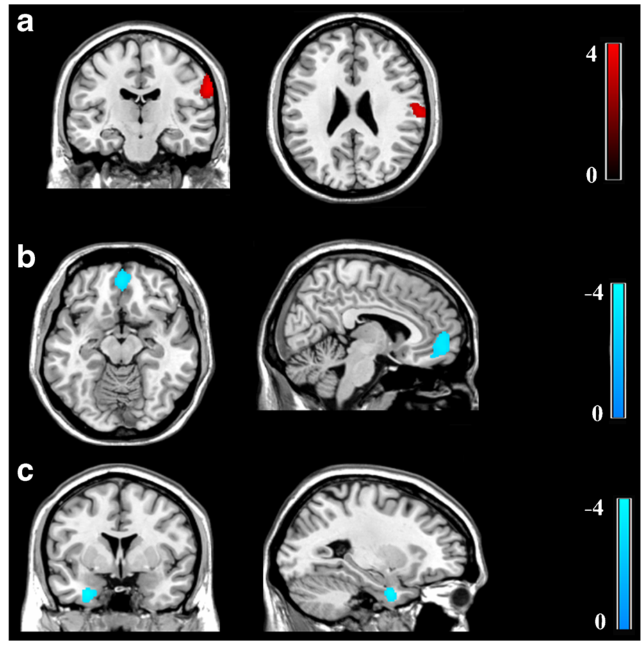


**Fig. 1** The brain regions with differences between the only-children and the non-only-children after controlling age, sex, family income, parental education years and total gray matter volume (the results are shown with a threshold of $P < 0.001$ uncorrected for a display purpose). **a**, the only-children exhibited greater gray matter volume mainly in the supramarginal gyrus compared with the non-only-children. **b**, the only-children had smaller gray matter volumes mainly in the mPFC compared with the non-only-children. **c**, the only-children had smaller gray matter volumes mainly in the parahippocampal gyrus compared with the non-only-children

To test whether the flexibility and agreeableness personality scores were really associated with the supramarginal gyrus and mPFC, multiple regression analysis was applied to the whole-brain analysis. After entering the age, sex, global gray matter volume and general intelligence as covariates and the flexibility score as the covariate of interest into the regression model, multiple regression analysis revealed that the creativity scores were significantly positively correlated with GMV in the right supramarginal gyrus (x = 69, y = −21, z = 27, cluster size =210 voxels, t = 4.34, $P = 0.02$ (corrected); see Fig. 3a). After entering age, sex and global gray matter volume as covariates and agreeableness as the covariate of interest into the regression model, the multiple regression analysis revealed that the agreeableness scores were significantly and positively correlated with the GMV in a cluster that mainly included areas in the mPFC (x = −11, y = 45, z = 15, cluster size =149 voxels, t = 3.92, $P = 0.036$ (corrected); see Fig. 3b). Additionally, the overlap mapping suggested that there were common clusters of the different brain structures and a brain structure associated with behavior (i.e., flexibility and agreeableness) between the only-children and non-only-children (see Fig. 4).

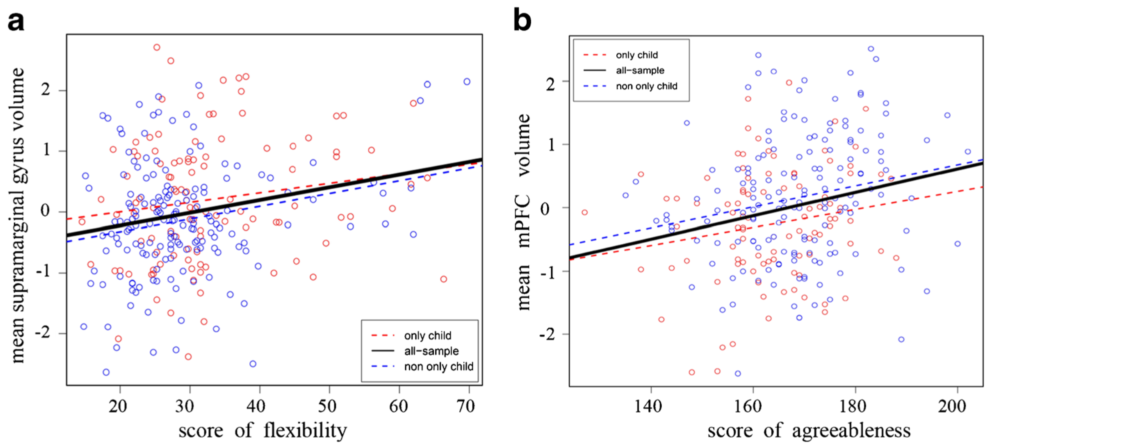


**Fig. 2** Scatterplot (partial correlations controlling for age, sex, and whole-brain gray volume) of the different behaviors and mean GMVs within the significantly different clusters between the only-children and the non-only-children. The *red imaginary line* indicates the only-child sample, the *blue imaginary line* indicates the non-only-child sample, and the *black full line* indicates all subjects in the two samples. **a**, The scatterplot of the flexibility score and mean volume of the supramarginal gyrus. **b**, The scatterplot of the agreeableness score and mean volume of the mPFC

## Discussion

The main aim of present study was to investigate the behavior and anatomical structural differences between only-children and non-only-children. The behavioral results revealed that the only-children had higher creativity scores and lower agreeableness scores than the non-only-children. The GMV differences between the only-children and non-only-children occurred mainly in the supramarginal gyrus, which was positively associated with flexibility scores; the mPFC, which was positively associated with agreeableness; and the parahippocampal gyrus.

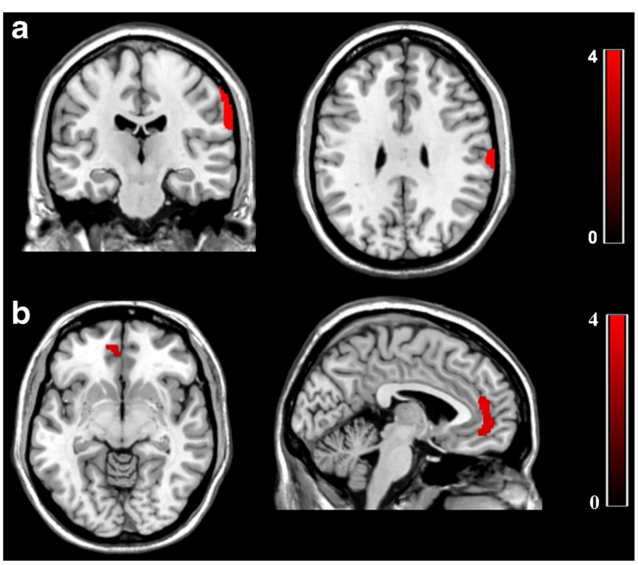


**Fig. 3** **a**. The regions of positive associations between GMV and flexibility after controlling for age, sex, global gray matter volume and general intelligence (the results are shown with a threshold of $P < 0.001$ uncorrected for a display purpose). This brain region cluster mainly included the cluster of the supramarginal gyrus. **b**. The regions of positive associations between GMV and agreeableness after controlling for age, sex and global gray matter volume (the results are shown with a threshold of $P < 0.001$ uncorrected for a display purpose). This brain region cluster mainly included the cluster of mPFC

The behavioral results revealed that the only-children exhibited higher creativity scores and lower agreeableness

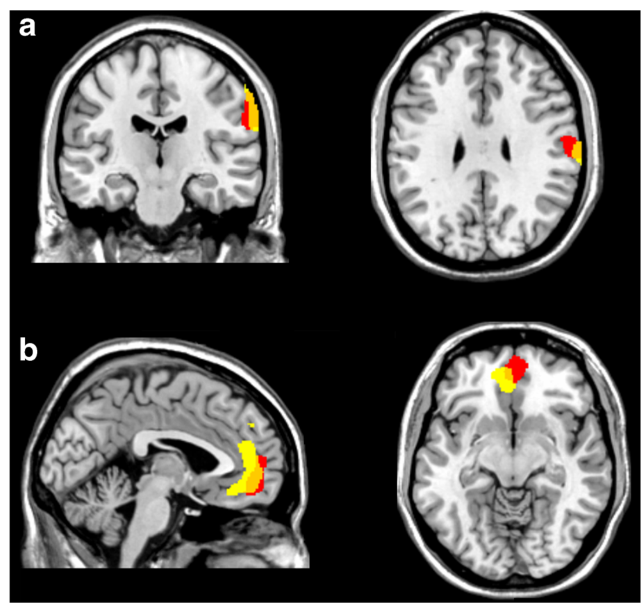


**Fig. 4** **a**. The voxel-based overlap cluster (right supramarginal gyrus) of the different brain structures and the brain structure associated with flexibility between the only-children and non-only-children (*red* indicates the different brain structures between the two samples, and *yellow* indicates the clusters correlated with flexibility; the results are shown with a threshold of $P < 0.001$ uncorrected for a display purpose). **b**, The voxel-based overlap cluster (mPFC) of the different brain structures and the brain structures associate with agreeableness between the only-children and non-only-children (*red* indicates the different brain structures between the two samples, and *yellow* indicates the cluster correlated with agreeableness; the results are shown with a threshold of $P < 0.001$ uncorrected for a display purpose)

scores than the non-only-children. Creativity refers to the ability to change existing thinking patterns, break with the present, and build something new (Dietrich and Kanso 2010). Family structure and parental views are potentially very important for the development of creative abilities (Gaynor and Runco 1992). The actual influence of family structure can probably be explained in terms of interactions, expectations, and opportunities. On the one hand, compared with the non-only-child families, the parents of only-child families might expend more time and effort on the only-child and therefore undoubtedly increase the direct contact opportunities between the parents and children and the parents' expectations of those children (S. Li et al. 2013; Polit and Falbo 1987). Many studies have proven that expectations have a strong influence on cognitive performance, including instance creativity (Shalley et al. 2009; Tierney and Farmer 2002). Additionally, only-children might have more opportunities for independent activity, and independence is strongly related to creative thinking (Albert and Runco 1988). Agreeableness has been linked to psychological mechanisms that allow for the understanding of others' emotions, intentions, and mental states, including empathy, theory of mind, and other forms of social information processing (Graziano et al. 2007; Nettle and Liddle 2008). As a result of the absence of siblings and receiving excessive attention and too much praise from their parents and grandparents, only-children may develop fewer psychosocial skills than non-only-children (Cai et al. 2012; Dunn and Slomkowski 1992; Fletcher 2014). In contrast, because of their bond with their parents, only-children are expected to exhibit a reduced need to affiliate with others (Polit and Falbo 1987). Additionally, only-children must learn at an early age to entertain themselves through relatively solitary activities, such as reading (Polit and Falbo 1987). Thus, it is expected that only-children are less likely to participate in social groups, such as clubs and churches, than non-only-children. Furthermore, studies have indicated that when sociability is measured by self-report, only-children rate themselves as significantly less sociable than others (Falbo and Polit 1986; Polit and Falbo 1987). Altogether, different family environments, such as family composition, family size, parent–child interactions and parental expectations, may cause only-children to have higher creativity scores and lower agreeableness scores than non-only-children.

Previous studies have suggested that the supramarginal gyrus plays an important role in switching from one task to another (Bechtereva et al. 2004; Booth et al. 2002; Sohn et al. 2000), imagination (Knauff et al. 2000), and planning for task solving (Fincham et al. 2002). Additionally, one study emphasized that the supramarginal gyrus is most likely involved in providing flexibility of thinking and the imagination necessary for the successful performance of creative tasks (Bechtereva et al. 2004). Apart from these findings, other studies have indicated that the supramarginal gyrus is more active in decision making in cases of low error rates (Paulus et al. 2002). Indeed, there cannot be any 'mistakes' in creativity because there is no unique answer to the solution of a creative task. Thus, the supramarginal gyrus, which is related to error detection, may facilitate creativity (Bechtereva et al. 2004; Paulus et al. 2002). Based on these overall previous studies, it is possible that the observed greater supramarginal gyrus volumes in the only-children may account for the greater flexibility scores compared to the non-only-children.

Some MRI studies have shown that the mPFC plays a key role in the processing of emotional information and regulation. For example, imaging studies of self-referential encoding tasks have indicated that the mPFC is activated during the processing of emotional information (Fossati et al. 2014; Gusnard et al. 2001; Phan et al. 2004). Additionally, studies have suggested that the agreeableness personality trait, which was the only personality trait positively associated with the MPFC and ACC, is a default mode network (DMN) component that is associated with social awareness (including the ability to attribute mental states to others) (Gusnard et al. 2001; Sampaio et al. 2014). Moreover, stronger activity in the midline core of the DMN has been related to preferential self-related activity, such as emotional state attribution, personal significance, motivation to positive reinforcement, and social cognition (Andrews-Hanna et al. 2010; Sampaio et al. 2014). Together, the agreeableness-related dimensions reflect a prosocial orientation and the ability to respond to the needs of others in an empathic manner, and all of these factors are social-cognitive tasks that are subserved by the midline core of the DMN (Andrews-Hanna et al. 2010). Thus, smaller volumes of the mPFC, which is associated with emotional information and regulation in only-children, may result in lower agreeableness scores compared to those of non-only-children.

The parahippocampal gyrus in combination with the temporopolar area, cingulate cortex, orbitofrontal cortex and insula forms the paralimbic system (Hui et al. 2010; Leung et al. 2012), and the paralimbic system is an important transition area that supports communication between the limbic system and the neocortex (Kiehl 2006; Leung et al. 2012). Additionally, the paralimbic system plays an important role in a range of higher-order cognitive affective functions, such as emotion/mood regulation and self-control (Kiehl 2006; Leung et al. 2012). Additionally, many studies have suggested that the parahippocampal gyrus also plays an important role in emotional memory. For example, some researchers have found that the parahippocampal gyrus is correlated with long-term memory for emotional material (Hamner et al. 1999; Kilpatrick and Cahill 2003) and emotional autobiographical memory (Piefke et al. 2005). Additionally, studies have revealed that abnormalities, such as decreased gray matter volumes and altered activates in the parahippocampal gyrus, are linked with various conditions of emotional dysfunction, such as depression, bipolar disorder and schizophrenia (Chen et al. 2011; Gradin et al. 2011; Guo et al. 2013). In this study, the smaller parahippocampal gyrus volumes in the only-children may suggest that these children have weaker abilities of emotional regulation or self-control than the non- only-children.

Our study is not without limitations, many of which suggest specific directions for future research. First, the sample of this study mainly consisted of highly educated young adults, which may be the main reason that we observed no significant differences between the only-children and non-only-children. Therefore, future work should focus on the adolescent period, which is also a crucial period of lifespan. Second, the VBM analysis represents a more comprehensive measure that integrates changes in the cortical folding and thickness. Other direct measures of brain structures (e.g., cortical thickness, surface area, the local gyrification index, etc.) should be used in further studies to better understand the neural bias differences between only-children and non-only-children. Finally, in the present study, we primarily focused on the differences in intelligence, personality and creativity between the only-children and non-only-children. Future work should focus on differences in other behaviors between these two samples.

These limitations notwithstanding, on the neural level, our results provide the first evidence that there are differences in anatomical structures mainly in the cluster of the supramarginal gyrus that may be correlated with flexibility, in the mPFC cluster that may play an important role in the agreeableness personality trait, and in the parahippocampal gyrus cluster that may play an important role in emotional regulation and self-control between only-child and non-only-child. Additionally, our results contribute to the understanding of the neuroanatomical basis of the differences in cognitive function and personality between only-children and non-only-children. More broadly, our results may reveal that differences in the family environments between only and non-only-children may contribute to the differences in the behavior and anatomical structures between these two samples.

#### Compliance with ethical standards

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**Conflict of interest** The authors declare no competing interests.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the Brain Imaging Center Institutional Review Board of Southwest China University and with the standards of the Declaration of Helsinki (1991).

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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