Hemispheric Asymmetries of Cortical Thickness in Civil Aviation Pilots

Yuan Cao; Chuanya Qiu; Chongsi Zhao; Yong Zhang; Yanmin Qi; Songlin Li

BACKGROUND: Although several studies have shown that an individual's career influences the brain structure, no study has examined cortical asymmetry in civil aviation pilots. This study focused on hemispheric cortical asymmetries in Chinese civil aviation pilots.

METHODS: The MRI structural images of 1065 healthy captains of the Civil Aviation Administration of China were analyzed using a surface-based automated parcellation approach, and hemispheric asymmetries in the global and regional cortical thickness of their brains were examined.

RESULTS: The hemispheric asymmetries were relatively significant. In total, 58 regions out of 74 were clearly asymmetrical. Generally, rightward asymmetries (reduction left) were found in slightly more regions than leftward asymmetries. The study also revealed leftward asymmetries mainly throughout the lateral, dorsal, and mesial surfaces of the frontal lobe, extending into the primary sensory, superior parietal, and anterior temporal cortices. In addition, the rightward asymmetries were mainly located in the temporal and occipital cortices.

DISCUSSION: Compared with previous studies, in this study, the structural lateralization of the cortical thickness was more significant. Most of the results were in agreement with those of previous studies, although there were different results in some regions. Functional structural lateralization was demonstrated among the regions. Hemispheric differences in the thickness of the cortex might be related to hemisphere-specific functional specializations that may be associated with behavioral asymmetries.

KEYWORDS: hemispheric asymmetry, cortical thickness, civil aviation pilot.

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Based on advances in neuroimaging techniques, an increasing number of structural hemispheric asymmetries have been documented.[21] In recent years, advances in imaging methods and analytical tools have provided new insights into measurements of brain structure, such as gray matter volume, surface area, cortical thickness, and local gyrification. It is widely acknowledged that cortical surface area, thickness, and gyrification can vary independently of each other.[22] Moreover, the measurement of cortical thickness is related to cellular characteristics such as cell packing density, myelination, cell size, and the number of cortical neurons. In addition, the surface-based morphometry (SBM) method[19] was developed, which provides more specific morphological measurements and estimates of multiple aspects of cortical structure; consequently, increasing numbers of studies have focused on cortical thickness asymmetries between the hemispheres. The study of cortical thickness has yielded some results that are similar to those of previous studies, although differences between the various measurement parameters have also been found. Among the most prominent observations are the right frontal and left occipital petalia,[10] which can be described as related structural asymmetries. Furthermore, the region of interest (ROI) analyses by Douglas N. Greve[4] and Keller[8] indicated that the planum temporale, pars opercularis, Heschl's gyrus, and insula were all highly significantly left-lateralized.

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ZuoZhi-wei replicated a previous study in Chinese speakers and found that the cortical architecture of language-related areas mainly showed leftward asymmetry.[27] In addition, the center sulcus of the right hemisphere, which houses the primary motor cortex, was found to be deeper and larger than the left sulcus.[21]

Moreover, research has shown that cortical gray matter, which is associated with language, motor, and cognitive functions, might be impacted by development and pathology, including fetal orientation,[9] heredity,[16] gender,[20] hormones,[5] age,[17] hand preference, and hand performance.[24] In addition, career is another factor that is related to asymmetry. There has been overwhelming evidence that extensive use or practice leads to substantial changes in the associated cortical structure, which has been referred to as "training- and learning-induced cortical plasticity." For instance, the 'hand knob' for musicians in the precentral gyrus, which is associated with functional hand and finger movement representation, shows a leftward asymmetry in keyboard players and a rightward asymmetry in string players.[1] Violin players showed a significant rightward asymmetry of the motor and somatosensory cortex.[18] Keenan[7] studied musicians with perfect pitch and found that planar asymmetry was twice as great in those with perfect pitch as it was in nonmusicians. Several longitudinal studies on musical training have provided promising evidence supporting experience-induced brain plasticity. Research on taxi drivers[25] and athletes[14] has led to the conclusion that specific enduring structural brain changes can be induced by biologically relevant behaviors. Although careers have been shown to influence brain structure, with several studies having demonstrated asymmetrical brain structure in different occupational groups, no study has examined cortical asymmetry in civil aviation pilots.

This study focused on hemispheric asymmetries in cortical thickness in Chinese civil aviation pilots. A large sample size was used to improve the reliability and comparability of the results. First, the MRI structural images from 1065 healthy captains of the Civil Aviation Administration of China (CAAC) were analyzed using a surface-based automated parcellation approach. Second, the study examined hemispheric asymmetries in the global and regional cortical thickness in the brains of the pilots. Because cortical thickness may reflect microstructural factors, asymmetric effects were expected to correlate with known functional asymmetries. The paper discusses the potential ramifications and attempts to determine the impact of the occupational characteristics of being a pilot on the structure of the cerebral cortex.

METHODS

Subjects

The study protocol was approved in advance by the CAAC. Each subject provided written informed consent before participating. In total, 1065 pilots in the CAAC with ages ranging from 35 to 64 yr (mean age = 47.64 ± 3.95 yr) were included in this study. Since female pilots are rare in China, the subjects were all men. All the pilots were qualified captains with valid CCAR-121 medical certifications. Magnetic resonance imaging examination confirmed that the pilots had no brain lesions, no bleeding or infarction, and no major neurological diseases. Among the pilots, those who were older than 60 yr passed the Chinese Civil Aviation Pilots Cognitive Abilities Test, which tests a range of cognitive abilities such as executive functioning, working memory, processing speed, and episodic and semantic memory. All the subjects self-reported a right-hand preference.

Imaging and Preprocessing

MRI acquisition. Three-dimensional structural MRI scans were acquired on a 1.5T GE scanner using a T1-weighted 3D-T1 BRAVO sequence (TR = 16.00, TE = 7.02, TI = 450.00, Flip angle = 20°).

MRI processing. Images were processed by Freesurfer software (version 5.1.0, Ubuntu12.04). After manual visual inspection, 797 scans were validated and 74 anatomical typical cortical parcels were automatically calculated as defined by the Freesurfer atlas.[2]

Statistical Analysis

First, Freesurfer software was used to collect the parameters for each participant's brain, including the mean cortical thickness. Second, the study explored the regional distribution of the hemispheric asymmetries in the average thickness of brain regions. For the whole-sample analysis, the laterality index (LI), which was defined by Nagata et al.[13] and adopted by later studies, was used to indicate the degree of asymmetry. Regional LI values were calculated for each subject using the following equation:

$$\mathrm{LI} = \frac{\mathrm{Left} - \mathrm{Right}}{\mathrm{Left} + \mathrm{Right}}$$

Positive LI values indicate leftward asymmetry, while negative LI values indicate rightward asymmetry; zero indicates no asymmetry. To maintain an experimental error rate of 0.05, the false discovery rate was calculated to address the problem of multiple comparisons. The laterality was calculated for the whole brain and then separately for 74 brain regions parcellated by the Freesurfer software. The data were analyzed in R (version 3.2.4; the R Foundation, Vienna, Austria).

RESULTS

Since the current study was interested not only in the asymmetries of the whole brain but also in the relationships between functionally distinctive cortical regions, the thickness in various ROIs was analyzed. The multiple regional hemispheric asymmetries are summarized in **Table I**.

Fig. 1 shows the asymmetries in the cortical thickness of the whole sample. The paired *t*-tests revealed a significant

Table I. Comparison of Hemispheric Cortical Thickness (mm) for Each ROI.

ROI	MEAN (SD)			Sig.
	LEFT	RIGHT	LI	
Frontomarginal gyrus (of Wernicke) and sulcus	2.67 (0.21)	2.71 (0.23)	−0.0066 (0.049)	***
Inferior occipital gyrus (O3) and sulcus	2.42 (0.16)	2.55 (0.18)	−0.0268 (0.040)	***
Paracentral lobule and sulcus	2.35 (0.14)	2.33 (0.14)	0.0052 (0.030)	***
Subcentral gyrus (central operculum) and sulci	2.46 (0.13)	2.43 (0.13)	0.0055 (0.027)	***
Transverse frontopolar gyri and sulci	2.95 (0.24)	2.84 (0.23)	0.0182 (0.043)	***
Anterior part of the cingulate gyrus and sulcus (ACC)	2.81 (0.18)	2.83 (0.16)	−0.0039 (0.033)	***
Middle anterior part of the cingulate gyrus and sulcus (aMCC)	2.76 (0.22)	2.84 (0.19)	−0.0155 (0.041)	***
Middle posterior part of the cingulate gyrus and sulcus (pMCC)	2.54 (0.15)	2.60 (0.16)	−0.0118 (0.034)	***
Posterior-dorsal part of the cingulate gyrus (dPCC)	3.07 (0.22)	3.03 (0.21)	0.0057 (0.040)	***
Posterior-ventral part of the cingulate gyrus (vPCC, isthmus of the cingulate gyrus)	2.40 (0.26)	2.72 (0.23)	−0.0636 (0.064)	***
Cuneus (O6)	2.03 (0.12)	1.97 (0.11)	0.0141 (0.029)	***
Opercular part of the inferior frontal gyrus	2.65 (0.12)	2.65 (0.13)	0.0005 (0.026)	n.s.
Orbital part of the inferior frontal gyrus	2.90 (0.28)	2.87 (0.25)	0.0052 (0.057)	*
Triangular part of the inferior frontal gyrus	2.67 (0.17)	2.65 (0.15)	0.0036 (0.032)	***
Middle frontal gyrus (F2)	2.70 (0.12)	2.70 (0.12)	0.0006 (0.019)	n.s.
Superior frontal gyrus (F1)	2.98 (0.12)	2.97 (0.13)	0.0016 (0.015)	***
Long insular gyrus and central sulcus of the insula	3.50 (0.28)	3.62 (0.35)	−0.0166 (0.057)	***
Short insular gyri	3.75 (0.26)	3.70 (0.26)	0.0064 (0.042)	***
Middle occipital gyrus (O2, lateral occipital gyrus)	2.61 (0.14)	2.71 (0.16)	−0.0182 (0.030)	***
Superior occipital gyrus (O1)	2.22 (0.14)	2.27 (0.13)	−0.0107 (0.033)	***
Lateral occipitotemporal gyrus (fusiform gyrus, O4-T4)	2.57 (0.15)	2.56 (0.16)	0.0021 (0.030)	n.s.
Lingual gyrus, lingual part of the medial occipitotemporal gyrus, (O5)	2.12 (0.13)	2.15 (0.12)	−0.0072 (0.029)	***
Parahippocampal gyrus, parahippocampal part of the medial occipito-temporal gyrus, (T5)	2.68 (0.24)	2.80 (0.22)	−0.0230 (0.045)	***
Orbital gyri	2.96 (0.15)	2.96 (0.14)	0.0002 (0.022)	n.s.
Angular gyrus	2.59 (0.14)	2.60 (0.14)	−0.0028 (0.027)	**
Supramarginal gyrus	2.55 (0.12)	2.60 (0.12)	−0.0105 (0.023)	***
Superior parietal lobule (lateral part of P1)	2.36 (0.11)	2.35 (0.11)	0.0001 (0.023)	n.s.
Postcentral gyrus	2.16 (0.12)	2.14 (0.12)	0.0031 (0.026)	***
Precentral gyrus	2.71 (0.15)	2.70 (0.16)	0.0025 (0.029)	*
Precuneus (medial part of P1)	2.50 (0.13)	2.46 (0.14)	0.0085 (0.027)	***
Straight gyrus, gyrus rectus	3.06 (0.22)	2.96 (0.26)	0.0165 (0.045)	***
Subcallosal area, subcallosal gyrus	3.13 (0.29)	3.24 (0.29)	−0.0175 (0.061)	***
Anterior transverse temporal gyrus (of Heschl)	2.19 (0.16)	2.29 (0.17)	−0.0215 (0.041)	***
Lateral aspect of the superior temporal gyrus	2.79 (0.17)	2.80 (0.17)	−0.0032 (0.030)	***
Planum polare of the superior temporal gyrus	3.19 (0.25)	3.09 (0.25)	0.0172 (0.046)	***
Planum temporale or temporal plane of the superior temporal gyrus	2.28 (0.18)	2.31 (0.16)	−0.0072 (0.044)	***
Inferior temporal gyrus	2.94 (0.15)	2.95 (0.16)	−0.0018 (0.027)	n.s.
Middle temporal gyrus	2.84 (0.15)	2.89 (0.15)	−0.0073 (0.025)	***
Horizontal ramus of the anterior segment of the lateral sulcus (or fissure)	2.31 (0.35)	2.26 (0.23)	0.0090 (0.085)	***
Vertical ramus of the anterior segment of the lateral sulcus (or fissure)	2.27 (0.21)	2.34 (0.25)	−0.0129 (0.067)	***
Posterior ramus (or segment) of the lateral sulcus (or fissure)	2.22 (0.15)	2.35 (0.14)	−0.0276 (0.036)	***
Occipital pole	2.20 (0.17)	2.18 (0.14)	0.0032 (0.033)	**
Temporal pole	3.22 (0.20)	3.21 (0.22)	0.0024 (0.036)	n.s.
Calcarine sulcus	1.90 (0.13)	1.90 (0.12)	0.0006 (0.035)	n.s.
Central sulcus (Rolando's fissure)	1.97 (0.11)	1.96 (0.11)	0.0008 (0.024)	n.s.
Marginal branch (or part) of the cingulate sulcus	2.10 (0.15)	2.13 (0.14)	−0.0082 (0.038)	***
Anterior segment of the circular sulcus of the insula	2.83 (0.25)	2.88 (0.26)	−0.0099 (0.054)	***
Inferior segment of the circular sulcus of the insula	2.71 (0.17)	2.63 (0.20)	0.0161 (0.037)	***
Superior segment of the circular sulcus of the insula	2.52 (0.12)	2.53 (0.13)	−0.0027 (0.027)	**
Anterior transverse collateral sulcus	2.67 (0.31)	2.45 (0.27)	0.0418 (0.056)	***
Posterior transverse collateral sulcus	2.05 (0.22)	2.07 (0.20)	−0.0056 (0.064)	*
Inferior frontal sulcus	2.24 (0.12)	2.24 (0.12)	−0.0007 (0.027)	n.s.
Middle frontal sulcus	2.32 (0.14)	2.30 (0.13)	0.0041 (0.035)	***
Superior frontal sulcus	2.45 (0.10)	2.45 (0.10)	−0.0001 (0.020)	n.s.
Sulcus intermedius primus (of Jensen)	2.35 (0.36)	2.18 (0.18)	0.0316 (0.090)	***
Intraparietal sulcus (interparietal sulcus) and transverse parietal sulci	2.08 (0.10)	2.06 (0.10)	0.0037 (0.025)	***
Middle occipital sulcus and lunatus sulcus	2.09 (0.18)	2.15 (0.20)	−0.0130 (0.054)	***
Superioroccipital sulcus and transverse occipital sulcus	2.11 (0.14)	2.16 (0.14)	−0.0111 (0.036)	***
Anterioroccipital sulcus and preoccipital notch (temporooccipital incisure)	2.21 (0.19)	2.25 (0.18)	−0.0101 (0.053)	***
Lateral occipitotemporal sulcus	2.45 (0.19)	2.43 (0.19)	0.0052 (0.049)	***
Medial occipitotemporal sulcus (collateral sulcus) and lingual sulcus	2.10 (0.14)	2.05 (0.14)	0.0106 (0.036)	***

Continued

Table I, *Continued*

	MEAN (SD)			
ROI	**LEFT**	**RIGHT**	**LI**	**Sig.**
Lateral orbital sulcus	2.30 (0.27)	2.31 (0.25)	−0.0031 (0.070)	n.s.
Medial orbital sulcus (olfactory sulcus)	2.67 (0.30)	2.37 (0.23)	0.0575 (0.062)	***
Orbital sulci (H-shaped sulci)	2.59 (0.22)	2.66 (0.19)	−0.0124 (0.043)	***
Parieto-occipital sulcus (or fissure)	2.01 (0.12)	2.07 (0.12)	−0.0129 (0.030)	***
Pericallosal sulcus (S of corpus callosum)	2.63 (0.22)	2.54 (0.22)	0.0179 (0.052)	***
Postcentral sulcus	2.06 (0.11)	2.03 (0.11)	0.0063 (0.027)	***
Inferior part of the precentral sulcus	2.39 (0.14)	2.38 (0.12)	0.0012 (0.031)	n.s.
Superior part of the precentral sulcus	2.35 (0.12)	2.35 (0.12)	−0.0004 (0.027)	n.s.
Suborbital sulcus (sulcus rostrales, supraorbital sulcus)	2.91 (0.38)	2.92 (0.55)	0.0029 (0.109)	n.s.
Subparietal sulcus	2.31 (0.18)	2.37 (0.20)	−0.0113 (0.047)	***
Inferior temporal sulcus	2.43 (0.16)	2.38 (0.17)	0.0106 (0.042)	***
Superior temporal sulcus (parallel sulcus)	2.29 (0.10)	2.29 (0.10)	−0.0005 (0.021)	n.s.
Transverse temporal sulcus	2.19 (0.24)	2.21 (0.21)	−0.0061 (0.063)	**

ROI: region of interest; LI: laterality index; Sig.: significance.
***$P < 0.005$; **$0.005 \leq P < 0.01$; *$0.01 \leq P < 0.05$; n.s.: no significant difference.

rightward asymmetry within the whole sample [left hemisphere = 2.52 (0.073), right hemisphere = 2.53 (0.075), LI = −0.001 (0.007), $P < 0.05$]. **Fig. 2** displays P-values for the hemispheric differences in cortical thickness in each ROI. To highlight the most robust and best articulated patterns of asymmetries, only the regions with P-values less than 0.05 after false discovery rate corrections were marked. Generally, rightward asymmetries appeared in more regions than leftward asymmetries (right: 31/74, left: 27/74). The most significant ROIs with leftward asymmetries (left > right) are located near the center sulcus, including the precentral gyrus, postcentral gyrus and sulcus, paracentral gyri, subcentral gyrus and sulcus, and precuneus. Additional larger clusters with leftward asymmetry were detected in the superior frontal regions, middle frontal sulcus, pars triangularis of the inferior frontal gyrus, and rectus gyrus. Another large cluster was in the occipital lobe, covering the cuneus gyrus, occipital pole, middle occipital gyrus, and the inferior occipital gyrus and sulcus. The ROIs with leftward asymmetry on the medial aspect appeared to follow a relatively clear pattern. They surrounded the margo superior cerebri (comprising the anterior rectus gyrus, superior frontal gyrus, paracentral gyri, precuneus and cuneus gyri, and occipital pole).

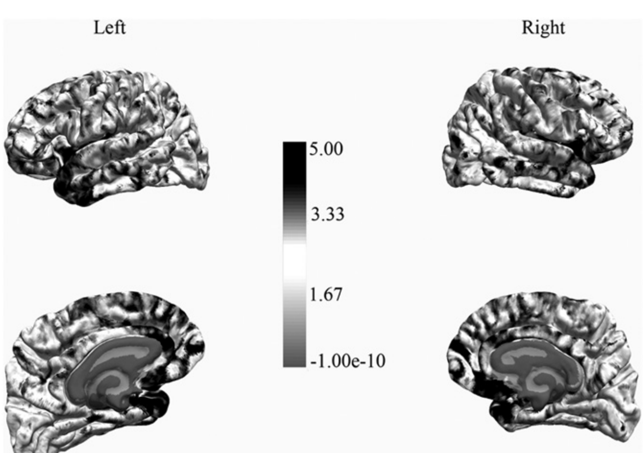

Fig. 1. Maps of the cortical thickness at each cortical surface point.

Conversely, distinct clusters with significant rightward asymmetries (right > left) were observed in the temporal and occipital lobes. The occipital lobe is composed of the superior occipital sulcus and transversus occipital sulcus, middle occipital gyrus and sulcus, anterior occipital sulcus, inferior occipital gyrus and sulcus, and superior occipital gyrus. The temporal lobe includes the superior lateral, temporal lateral, transversus temporal gyrus, and temporal plane. In addition, there were small regions with rightward asymmetry, such as the frontomargingyrus and sulcus, and H-shaped sulcus. Another smaller discontinuous region with pronounced rightward asymmetry was the angular/supramar of the inferior parietal gyrus. Unlike the distribution of the ROIs with leftward asymmetries on the medial surface, the largest distribution of ROIs with rightward asymmetries was in the middle of the medial surface, including the anterior cingulate cortex, anterior midcingulate cortex, posterior midcingulate cortex, marginal branch, and inferior parietal sulcus.

Note that the discrepancy between hemispheres was as high as 13.3%. Among the 58 regions with hemispheric asymmetries, 6 regions displayed hemispheric differences larger than 5%. The posterior-ventral part of the cingulate gyrus and medial orbital sulcus had differences larger than 10%. In addition, 52 regions had differences less than 5%, of which 15 regions had differences less than 1%.

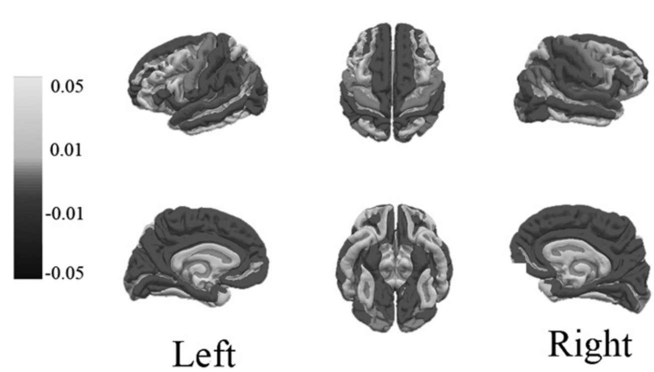

Fig. 2. Maps of significant cortical thickness asymmetries in the two hemispheres with false discovery rate in each region. The direction of the differences and the significance levels are coded according to the color legend.

DISCUSSION

The aim of this study was to determine the differences in cortical thickness in civil aviation pilots in China. The results partially agree with those of some previous studies.[6] The finding of rightward asymmetry for the whole brain was in line with the result of the study by Maingault et al., who identified a trend toward greater rightward asymmetry of cortical gray matter thickness for all brain regions.[12] Moreover, our study found significant leftward cortical asymmetry throughout the lateral, mesial, and dorsal surfaces of the frontal lobe, extending into the primary sensory, superior parietal, and anterior superior temporal cortices. In addition, rightward asymmetry of the posterior temporal, parietal, and occipital cortices was observed. This finding was consistent with the results of the study by Plessen et al.[15] This study showed regions of highly significant leftward cortical thickness asymmetries in the precentral gyrus, which was in line with the results of the study by Luders et al.,[11] who showed leftward asymmetry in the cortical thickness of the precentral gyrus in healthy volunteers. The paracentral lobule and sulcus and the postcentral gyrus were found to have leftward cortical asymmetries, which was consistent with previous results.[6] In a study on gray matter thickness, Zhou et al.[26] found that the thickness of the planum polare of the superior temporal gyrus was larger in the left hemisphere than in the right hemisphere, which agrees with the current results. Furthermore, similar to these findings, significant rightward cortical thickness asymmetry was demonstrated in the anterior transverse temporal gyrus (of Heschl), and the lateral aspect of the superior temporal gyrus and the middle temporal gyrus; in the same study,[6] the authors found a rightward lateralization of the lingual gyrus and the occipital lobe, which was also found in the current study.

Although this study confirmed some of the earlier findings regarding cortical thickness asymmetry, there still existed some differences. In this paper, the differences appeared to exist between civil aviation pilots and the general population. Compared with the results of previous studies, there were differences in the hemispheric asymmetries of pilots. Of the 74 regions, 58 were clear. In addition, some regions showed conflicting results with those of similar studies conducted with different groups. This study revealed rightward asymmetry of the angular gyrus, supramarginal gyrus, and planum temporale, which differed from the asymmetries revealed in the analysis by Zhou et al.[26] and Luders et al.[11] In addition, Toga and Thompson[21] also found leftward asymmetry of the planum temporale. Even compared with the results of studies conducted in Chinese populations, the asymmetry of some regions, such as the planum temporale, pars opercularis, and pars triangularis, were also different in this study, which suggested that race was not the factor influencing the differences in asymmetries. In addition, several longitudinal studies based on musicians, athletes, and taxi drivers have provided promising evidence supporting the concept that experience and training, factors related to nurture rather than nature, can induce brain plasticity. Therefore, the impact of occupational factors is proposed as one possible explanation for the different results of this research.

Though previous studies were based on both postmortem and imaging studies, it has become increasingly apparent that asymmetries in the structural and functional organization of the cerebral hemispheres exist, although substantial variability in the magnitude of these asymmetries has been found among individuals. Given that the pilots in this study were right-handed, the leftward asymmetry of the cortical thickness in the precentral gyrus might be associated with the dominance of the leftward hemisphere with regard to motor functions of the right hand, which is in line with the findings of another study.[11] Similarly, for the sensorimotor system, the structural correlates of handedness have been supported by findings reflecting macrostructural or microstructural asymmetries in regions in or adjacent to the primary motor cortex. This study supported such findings. Furthermore, previous studies proved the left-lateralization of working memory and verbal tasks, which was supported in this work by the leftward asymmetries in the dorsolateral frontal and parietal cortices. Foundas et al.[3] offered evidence that cortical asymmetry in the pars triangularis underlie some aspects of language lateralization; that finding was replicated in this study.

Moreover, it is well known that rightward hemispherical asymmetry is correlated with visuospatial tasks. The right hemisphere, particularly the hippocampus and surrounding regions, is critical for encoding and retrieving certain types of visual-spatial or related information. In this study, the parahippocampal region displayed rightward asymmetry. Rightward asymmetries were also in the lingual gyrus and middle temporal gyrus, which are considered visual function-related cortical regions. Furthermore, this study replicated the previously described asymmetry[23] involved in the processing of emotions, which is found in the anterior part of the cingulate gyrus and sulcus.

However, there exist arguments against the relationship between hemispheric asymmetries and functional dominance, even though that relationship was previously considered well established. One of the most prominent areas of debate is language lateralization. Some studies have shown that the right anterior temporal lobe, right superior temporal gyrus, and right inferior frontal gyrus are activated when making inferences and processing semantics, which challenges the view of leftward asymmetry in the regions that process language and speech. Current knowledge of these functional divisions or distinctions is still very rudimentary. Hence, it is difficult to infer a unidirectional link between the asymmetry of cortical thickness at a particular cortical location and the functional organization and degree of hemispheric specialization of such a region. Consequently, interpreting the possible functional or behavioral correlates of the thickness asymmetries observed in this study would be premature.

Limitations of this study include hand preference and hand performance that may affect regional measures of thickness asymmetry. It has been frequently reported that handedness is correlated with different measures of brain asymmetry. The hand preference of the subjects in this study was self-reported. Additionally, the percentage of left-handedness in the Chinese population is only 0.23%. Consequently, our study concluded that most of the pilots were right-handed without discriminating between different degrees of handedness. Future analyses might profit from classifying subjects based on standardized handedness inventories and/or performance measurements, which might reveal additional insights. Furthermore, our study analyzed the hemispheric asymmetries with surface-based morphometry tools. Compared with the voxel-based morphometry tools, the advantages of the surface-based morphometry tools are obvious. The tool adopted was Freesurfer version 5.0, and the stability and accuracy of the algorithm were lower than those of the current version (6.0).

Future research may focus on studying and proving the differences observed in this study based on more rigorous research with pilots and a control group to determine the relationship between structural differences and career. In addition, investigating the relationship between asymmetries in cortical thickness and functional lateralization will be another important goal for future studies.

First, a search of the literature did not reveal any structural analysis of the brains of civil aviation pilots in China. Among the 74 regions of the brain, 58 showed significant asymmetries, with 6 regions showing differences larger than 5%. Moreover, most of the results agreed with the results of previous studies, although some regions exhibited differences. The structural asymmetries parallel the known function asymmetries in regions predominantly related to hand-specific motor functions, working memory, verbal tasks, and visuospatial tasks. Finally, differences in hemispheric morphology have been suggested to originate from a complex interplay between evolutionary, hereditary, developmental, experimental, and pathological factors. Thus, these findings in our study might not only serve as reference data from a large, well-matched sample of adults against which future findings of cerebral asymmetries in subjects could be compared, but also as a source of new hypotheses.

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