Evolution of Hemispheric Asymmetry During Healthy Aging Revealed by Multivariate Analysis

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Introduction

Accumulated morphological evidences have shown that hemispheric asymmetry alters in healthy aging and neurological disorders [1]. Previous study reported a distinct laterality shift in the limbic system in healthy elderly [2] which may serve as a compensatory and protective mechanism counteracting the age-related cerebral tissue atrophy. However, issues such as when this shift occurs and how the regional laterality evolves over aging process remain unknown. In this study, we measured the hemispheric asymmetry of different age groups using a multivariate model based on morphological variables and track the decennial evolution of cerebral laterality during healthy aging.

Materials and methods

Imaging and demographic data from a total of 223 right-handed healthy subjects aged from 20 to 89 years were retrieved from the Open Access Series of Imaging Studies (OASIS) (www.oasis-brains.org/) and the International Consortium for Brain Mapping (ICBM) databases (http://www.loni.ucla.edu/ICBM/), and categorized into 7 groups with an age step of 10 years with the demographic information of the subjects summarized in the Table.

T1 weighted images of the entire brain were used to calculate morphological variates for each subject. Cerebral cortex and the corresponding white matter (WM) were parcellated into 34 gyral-based regions of interest (ROIs) for each hemisphere using FreeSurfer (http://surfer.nmr.mgh.harvard.edu/). Surface area, mean curvature index, cortical thickness, and subjacent WM volume were calculated from the constructed surface on each ROI as detailed in previous work [3]. Multivariate analysis of covariance (MANCOVA) was performed on the combination of the four variates using SPSS 17.0 (SPSS Inc., Chicago, IL, USA) to compare the shape characteristics between left and right hemispheres on each ROI for each age group. Subject gender was introduced as a covariate. Regions of significant asymmetry were identified as $P<0.05$. The lateralization index of each significant region was defined as $LI=\Sigma_i (L_i-R_i)/(L_i+R_i)$, where L_i and R_i were the mean value of the the ith variate for the left and right hemisphere, respectively. $LI>0$ indicates a leftward asymmetry, and $LI<0$ a rightward asymmetry.

Table. Summary of the demographic information of subjects in each age group.

Groups	# of subjects (male/female)	Mean age ± std
Age 20-29	36 (12/24)	24.14 ± 2.62
Age 30-39	32 (11/21)	32.66 ± 2.79
Age 40-49	31 (10/21)	45.58 ± 2.74
Age 50-59	33 (11/22)	54.36 ± 3.03
Age 60-69	27 (9/18)	64.56 ± 3.15
Age 70-79	35 (10/25)	73.37 ± 2.35
Age 80-89	29 (8/21)	84.07 ± 3.31

Results

As aging progresses, the overall number of ROIs with significant hemispheric asymmetry reduced in regions including precentral, caudal middle frontal, medial orbitofrontal, supramarginal, lingual, caudal anterior and isthmus cingulated gyri and superior parietal lobule (Figure). Laterality shift occurred as early in 30s in cuneus and entorhinal cortex (reversed from right to the left), and as late in 80s in the paracentral lobule and middle temporal gyrus. Hemispheric asymmetry was preserved in the major areas of prefrontal cortex and parahippocampal gyrus that are involved in the functions of cognition and memory during aging, while postcentral gyrus and precuneus were not lateralized throughout the entire age range.

Conclusion

Preservation and reverse were identified in the major context of reduction of hemispheric asymmetries during healthy aging. Laterality significantly reduced in brain regions involving movement execution, decision making, spatial orientation, language processing, and emotional behavior as age advances. Selective asymmetry shift was identified as early as in 30s and as late in 80s, which may partially reflect the neuroplasticity that brain is capable of reprogramming itself adapting to the age-related functional and anatomical changes.

Compositive analysis of hemispheric asymmetry with MANCOVA can provide useful information toward better understanding the procedure of normal aging and earlier identifying the potential substrate of brain disorders.

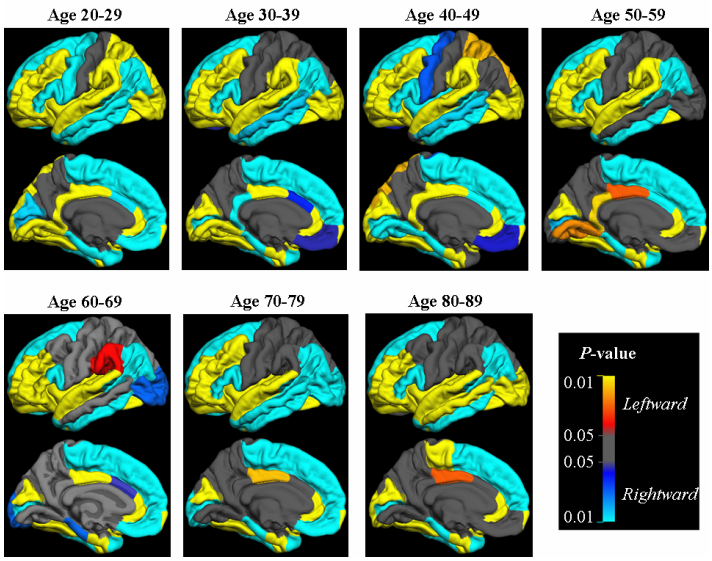

Figure. The evolution of cerebral hemispheric asymmetry during healthy aging across an age span of 20 to 89 years. Preservation and reverse were identified in the major context of reduction of hemispheric asymmetries during healthy aging. Selective asymmetry shift was identified as early in 30s in entorhinal cortex and cuneus, and as late in 80s in paracentral lobule and middle temporal gyrus.

References

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