

Differential Lifespan Trajectories of Cerebral Asymmetry in Chinese and Western Populations

Chunshui Yu

chunshuiyu@tmu.edu.cn

Tianjin Medical University General Hospital <https://orcid.org/0000-0001-5648-5199>

Liyuan Lin

Department of Radiology and Tianjin Key Laboratory of Functional Imaging, Tianjin Medical University General Hospital, Tianjin, China

Lianglong Sun

Beijing Normal University <https://orcid.org/0009-0007-0164-0893>

Caihong Wang

The First Affiliated Hospital of Zhengzhou University

Jintao Zhang

Beijing Normal University <https://orcid.org/0000-0002-4807-1196>

Qi Huang

Institute of High Energy Physics

Jing Zhang

Lanzhou University Second Hospital

Chao Liu

Beijing Normal University <https://orcid.org/0000-0003-1149-2314>

Qiujin Qian

Peking University Sixth Hospital

Bing Zhang

Nanjing Drum Tower Hospital, Affiliated Hospital of Medical School, Nanjing University

<https://orcid.org/0000-0002-3953-0290>

Ming Meng

The University of Alabama at Birmingham

Xinyuan Liang

Beijing Normal University <https://orcid.org/0009-0007-2141-405X>

Mingrui Xia

Beijing Normal University <https://orcid.org/0000-0003-4615-9132>

Feng Liu

Tianjin Medical University General Hospital <https://orcid.org/0000-0002-3570-4222>

Huagui Liu

Tianjin Medical University General Hospital

Nan Chen

Department of Radiology and Nuclear medicine, Xuanwu Hospital, Capital Medical University

Jinzhu Yang

Department of Radiology and Nuclear medicine, Xuanwu Hospital, Capital Medical University

Bo Hou

Department of Radiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College

Zeyu Liu

Department of Radiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College

Chu-Chung Huang

School of Psychology and Cognitive Science, East China Normal University, Shanghai, China

<https://orcid.org/0000-0002-9096-9610>

Yongqiang Yu

The First Affiliated Hospital of Anhui Medical University <https://orcid.org/0000-0001-8977-2215>

huanhuan Cai

Department of Radiology, The First Affiliated Hospital of Anhui Medical University

Jiang Qiu

Southwest University <https://orcid.org/0000-0003-0269-5910>

Qunlin Chen

Faculty of Psychology, Southwest University

Ying Wei

Department of MRI, The First Affiliated Hospital of Zhengzhou University

Peifang Miao

Department of MRI, The First Affiliated Hospital of Zhengzhou University

Hongwen Song

University of Science and Technology of China

Weiwei Men

Peking University

Yunxia Li

Department of Neurology, Shanghai Pudong Hospital, Fudan University Pudong Medical Center

Yaou Liu

Department of Radiology, Beijing Tiantan Hospital, Capital Medical University <https://orcid.org/0000-0002-2965-0766>

Yunyun Duan

Beijing Tiantan Hospital, Capital Medical University

Peng Zhang

Tianjin Medical University Cancer Institute and Hospital

Ning Yang

State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University

Xue-Ru Fan

Beijing Normal University <https://orcid.org/0009-0007-3883-216X>

Qing Cai

School of Psychology and Cognitive Science, East China Normal University, Shanghai, 200062, China

<https://orcid.org/0000-0002-8341-3833>

Xiaoxue Gao

Shanghai Key Laboratory of Mental Health and Psychological Crisis Intervention, School of Psychology and Cognitive Science, East China Normal University

Shijun Qiu

The First Affiliated Hospital of Guangzhou University of Traditional Chinese Medicine

<https://orcid.org/0000-0002-6739-4265>

Yujie Liu

Department of Radiology, The First Affiliated Hospital of Guangzhou University of Chinese Medicine

Sha Tao

Beijing Normal University <https://orcid.org/0000-0002-0928-0681>

Meiyun Wang

Henan Provincial People's Hospital & Zhengzhou University People's Hospital <https://orcid.org/0000-0003-4454-5005>

Yu Shen

Zhengzhou University People's Hospital & Henan Provincial People's Hospital

Qiyong Gong

West China Hospital of Sichuan University <https://orcid.org/0000-0002-5912-4871>

Xiaoqi Huang

Huaxi MR Research Center (HMRRRC), Institute of Radiology and Medical Imaging, West China Hospital of Sichuan University <https://orcid.org/0000-0001-8686-5010>

Yanghua Tian

Department of Neurology, The First Affiliated Hospital of Anhui Medical University

Gong-Jun Ji

Anhui Medical University <https://orcid.org/0000-0002-7073-5534>

Wenzhen Zhu

Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology

<https://orcid.org/0000-0001-6252-9450>

Fang Xie

Department of Nuclear Medicine & PET Center, Huashan Hospital, Fudan University

<https://orcid.org/0000-0003-2667-281X>

Jianfeng Feng

Fudan University <https://orcid.org/0000-0001-5987-2258>

Hu Li

State Key Laboratory of Cognitive Science and Mental Health, Institute of Psychology, Chinese Academy of Sciences and Department of Psychology, University of Chinese Academy of Sciences
<https://orcid.org/0000-0001-7003-2903>

Jia-Hong Gao

McGovern Institute for Brain Research, Peking University <https://orcid.org/0000-0002-9311-0297>

Tianzi Jiang

Beijing Key Laboratory of Brainnetome and Brain-Computer Interface, Institute of Automation, Chinese Academy of Sciences

Xiongzhao Zhu

Medical Psychological Center, The Second Xiangya Hospital, Central South University

Yuhan Zhang

State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University

Liping Liu

The First Psychiatric Hospital of Harbin

Hanjun Liu

Sun Yat-sen University First Affiliated Hospital <https://orcid.org/0000-0003-1466-4193>

Weihua Liao

Xiangya Hospital, Central South University

Peipeng Liang

Capital Normal University

Dawei Wang

Qilu Hospital, Shandong University

Huali Wang

Peking University Institute of Mental Health (Sixth Hospital) <https://orcid.org/0000-0002-3213-6493>

Tengfei Guo

Shenzhen Bay Laboratory <https://orcid.org/0000-0003-2982-0865>

Zhengjia Dai

Beijing Normal University

Su Lui

West China Hospital of Sichuan University <https://orcid.org/0000-0003-3541-1769>

Kai Xu

The Affiliated Hospital of Xuzhou Medical University <https://orcid.org/0000-0001-5407-5671>

Lingjiang Li

Peng Xie

The First Affiliated Hospital of Chongqing Medical University <https://orcid.org/0000-0002-0081-6048>

Chunliang Feng

Key Laboratory of Brain, Cognition and Education Sciences (South China Normal University), Ministry of Education <https://orcid.org/0000-0001-5595-2146>

Guang-Bin Cui

Tangdu Hospital, Fourth Military Medical University (Air Force Medical University)

Jinsong Wu

Huashan Hospital Fudan University <https://orcid.org/0000-0001-7854-9798>

Xuntao Yin

Guangzhou Medical University

Guosheng Ding

Beijing Normal University Faculty of Psychology <https://orcid.org/0000-0002-0065-6398>

Junfang Xian

Beijing Tongren Hospital, Capital Medical University <https://orcid.org/0000-0003-2191-9393>

Lianping Zhao

Gansu Provincial Hospital

Jie Lu

Xuanwu Hospital, Capital Medical University <https://orcid.org/0000-0003-0425-3921>

Zhifen Liu

Psychiatry Department, First Hospital of Shanxi Medical University

Ying Han

Department of Neurology, Xuanwu Hospital of Capital Medical University

Zhen Yuan

University of Macau, Macau SAR, 999078 <https://orcid.org/0000-0003-3061-6263>

XILIN ZHANG

South China Normal University <https://orcid.org/0000-0003-0449-934X>

Tian-Mei Si

Peking University <https://orcid.org/0000-0001-9823-2720>

Fuqing Zhou

The First Affiliated Hospital, Jiangxi Medical College, Nanchang University

Yanchao Bi

School of Psychological and Cognitive Sciences and Beijing Key Laboratory of Behavior and Mental Health, Peking University <https://orcid.org/0000-0002-0522-3372>

Dan Wu

Zhejiang University <https://orcid.org/0000-0002-9303-5821>

Fei Gao

Department of Radiology, Shandong Provincial Hospital Affiliated to Shandong First Medical University

Fei Wang

The Affiliated Brain Hospital of Nanjing Medical University

Shaozheng Qin

State Key Laboratory of Cognitive Neuroscience and Learning & International Data Group/McGovern Institute for Brain Research, Beijing Normal University, Beijing <https://orcid.org/0000-0002-1859-2150>

Gang Wang

<https://orcid.org/0000-0001-9755-3370>

Feng Chen

Department of Radiology, Hainan General Hospital

Zhiqiang Zhang

Lab. of Neuroimaging, Dept. of Radiology, Jinling Hospital, Nanjing University School of Medicine

<https://orcid.org/0000-0002-3993-7330>

Jing Sui

IDG/McGovern Institute for Brain Research, Beijing Normal University <https://orcid.org/0000-0001-6837-5966>

Huafu Chen

University of Electronic Science and Technology of China <https://orcid.org/0000-0002-4062-4753>

Jinhua Cai

Children's Hospital of Chongqing Medical University

Shuwei Liu

Cheeloo College of Medicine, Shandong University <https://orcid.org/0000-0002-6889-4616>

Zuojun Geng

The Second Hospital of Hebei Medical University

Chen Zhang

Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine

Ning Mao

Department of Radiology, Yantai Yuhuangding Hospital

Hong Yin

Medical Imaging Center, People's Hospital Affiliated to Northwest University

Bo Liu

Guangdong Provincial Hospital of Chinese Medicine

Heng Ma

Department of Radiology, Yantai Yuhuangding Hospital, Qingdao University

Bo Gao

The Affiliated Hospital of Guizhou Medical University

Yanwei Miao

The First Affiliated Hospital of Dalian Medical University

Xiang-Zhen Kong

Zhejiang University <https://orcid.org/0000-0002-0805-1350>

Yuan Zhou

Institute of Psychology, Chinese Academy of Sciences <https://orcid.org/0000-0001-6378-1711>

Li Liu

Beijing Normal University

Jianping Hu

First Affiliated Hospital of Fujian Medical University

Liang Wang

Institute of Psychology, Chinese Academy of Sciences <https://orcid.org/0000-0001-9434-7571>

Quan Zhang

Characteristic Medical Center of Chinese People's Armed Police Force

Hua Shu

Beijing Normal University

Peijun Wang

Tongji Hospital, Tongji University

Tatia M.C. Lee

The University of Hong Kong <https://orcid.org/0000-0002-9992-6609>

Qingjiu Cao

Peking University Sixth Hospital

Li Yang

Peking University Sixth Hospital/Institute of Mental Health <https://orcid.org/0000-0003-3771-5969>

Xi Zhang

Chinese PLA General Hospital

Wenbo Luo

Liaoning Normal University

Meng Liang

Tianjin Medical University <https://orcid.org/0000-0003-0916-520X>

Hongxiang Yao

Chinese PLA General Hospital

Meng Li

Department of Medical Imaging, The Affiliated Guangdong Second Provincial General Hospital of Jinan University

Hao Huang

Radiology Research, Children's Hospital of Philadelphia, Philadelphia, United States;The Department of Radiology, Perelman School of Medicine, University of Pennsylvania, Philadelphia, United

<https://orcid.org/0000-0002-9103-4382>

Yun Peng

Beijing Children's Hospital, Capital Medical University, National Center for Children's Health

Zaizhu Han

Beijing Normal University <https://orcid.org/0000-0003-1751-6452>

Chao Zhou

Department of Geriatric Psychiatry, Nanjing Brain Hospital Affiliated to Nanjing Medical University

Haibo Xu

Department of Radiology, Zhongnan Hospital of Wuhan University, Wuhan, China

<https://orcid.org/0000-0002-8451-8979>

Ming Feng

Department of Neurosurgery, Peking Union Medical College Hospital

Wen Shen

Department of Radiology, Tianjin First Central Hospital

Yuzheng Hu

Zhejiang University <https://orcid.org/0000-0003-3427-0650>

Huajun Chen

Department of Radiology, Fujian Medical University Union Hospital

Ying Wang

The First Affiliated Hospital of Jinan University

Gaolang Gong

Beijing Normal University <https://orcid.org/0000-0001-5788-022X>

Zhihan Yan

The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University

Xiaojun Xu

The Second Affiliated Hospital of Zhejiang University, School of Medicine <https://orcid.org/0000-0002-0127-2812>

Jun Liu

Department of Radiology, The Second Xiangya Hospital, Central South University

Guangxiang Chen

Department of Radiology, The Affiliated Hospital of Southwest Medical University

Pan Wang

Tianjin University

Yunjun Yang

Department of Radiology, The First Affiliated Hospital of Wenzhou Medical University

Cheng Luo

The Clinical Hospital of Chengdu Brain Science Institute, MOE Key Lab for Neuroinformation, School of life Science and technology, University of Electronic Science and Technology of China, Chengdu, <https://orcid.org/0000-0003-0524-5886>

Tong Han

Department of Radiology, Tianjin Huanhu Hospital

Huiguang He

Institute of Automation, Chinese Academy of Sciences <https://orcid.org/0000-0002-0684-1711>

Ce Chen

Wenzhou Seventh People's Hospital

Qihong Zou

Peking University <https://orcid.org/0000-0001-8732-6633>

Hesheng Liu

Division of Brain Sciences <https://orcid.org/0000-0002-7233-1509>

Hui Zhang

The First Hospital of Shanxi Medical University <https://orcid.org/0000-0002-0565-0411>

Chao Chai

Department of Radiology, Tianjin First Central Hospital

Chunming Lu

Beijing Normal University <https://orcid.org/0000-0002-0040-0587>

Yiheng Tu

31 State Key Laboratory of Cognitive Science and Mental Health, Institute of Psychology, Chinese Academy of Sciences, Beijing, 100101, China 57 Department of Psychology, University of Chinese Academy of Sciences

Yong Liu

Beijing University of Posts and Telecommunications <https://orcid.org/0000-0002-1862-3121>

Danhua Lin

Institute of Developmental Psychology, Beijing Normal University

Weihua Zhao

University of Electronic Science and Technology of China <https://orcid.org/0000-0003-1780-4606>

Xiufeng Xu

First Affiliated Hospital of Kunming Medical University

Xiaoli Liu

Zhejiang Hospital

Zaixu Cui

Chinese Institute for Brain Research, Beijing <https://orcid.org/0000-0003-4385-8106>

Zheng Wang

Peking University <https://orcid.org/0000-0001-7138-8581>

Ruiwang Huang

South China Normal University <https://orcid.org/0000-0003-3889-169X>

Zhanjiang Li

Center of Clinical Psychology, Beijing Anding Hospital, Capital Medical University

Yunzhe Liu

Beijing Normal University <https://orcid.org/0000-0003-0836-9403>

Xiaojun Li

Qianjiang Hospital, Chongqing University

Xiujie Yang

Beijing Key Laboratory of Applied Experimental Psychology, National Demonstration Center for Experimental Psychology Education, Beijing Normal University

Nan Zhang

Department of Neurosurgery, The First Affiliated Hospital of Guangzhou Medical University

Antao Chen

Shanghai Jiao Tong University <https://orcid.org/0000-0001-9321-681X>

Bin Zhang

Mental Health Center of Tianjin University, Tianjin Anding Hospital <https://orcid.org/0000-0002-9280-8247>

Pengmin Qin

Key Laboratory of Brain, Cognition and Education Sciences (South China Normal University), Ministry of Education

Chen Liu

Southwest Hospital, Army Medical University (Third Military Medical University)

<https://orcid.org/0000-0001-5149-2496>

Zhenwei Yao

Huashan Hospital, Fudan University

Yanjun Wei

School of Cognitive Science and Allied Health/Institute of Life and Health Sciences/Key Laboratory of Cognitive Science of Language (Ministry of Education)/Center for Cognitive Science of Language,

<https://orcid.org/0000-0002-6114-0555>

Huishu Yuan

Department of Radiology, Peking University Third Hospital

Feng Wang

Division of CT and MRI, The First Affiliated Hospital of Heilongjiang University of Chinese Medicine

Yu Zhang

Zhejiang Lab <https://orcid.org/0000-0001-7159-4561>

Quan Zhang

Tianjin Medical University General Hospital <https://orcid.org/0000-0002-9776-2401>

Fang Hu

College of medical imaging laboratory and rehabilitation/Key Laboratory of Medical Imaging and Artificial Intelligence of Hunan Province, Xiangnan University

Huan Xie

Army Medical Center of PLA

Xuehai Wu

Huashan Hospital of Fudan University, Shanghai 200040 <https://orcid.org/0000-0003-4216-6685>

Jiaojian Wang

State Key Laboratory of Primate Biomedical Research, Institute of Primate Translational Medicine, Kunming University of Science and Technology <https://orcid.org/0000-0002-0421-5709>

Guo-Guang Fan

Department of Radiology, The First Affiliated Hospital of China Medical University

Zhiqun Wang

Aerospace Center Hospital

Dongling Zhang

Department of Neurology, China National Clinical Research Center for Neurological Diseases, Beijing Tiantan Hospital, Capital Medical University

Hui Zhong

Child and Adolescent Psychiatry Department, Hefei City Fourth People's Hospital

Yonggang Wang

Beijing Tiantan Hospital

Lijun Bai

The Key Laboratory of Biomedical Information Engineering, Ministry of Education, Department of Biomedical Engineering, School of Life Science and Technology, Xi'an Jiaotong University

Yongmei Li

The First Affiliated Hospital of Chongqing Medical University

Xinhua Wei

Department of Radiology, Guangzhou First People's Hospital, School of Medicine, South China University of Technology

Jinhui Wang

South China Normal University <https://orcid.org/0000-0003-4900-3184>

Yi Zhang

Center for Brain Imaging, School of Life Science and Technology, Xidian University

Hongjian He

Zhejiang University <https://orcid.org/0000-0001-6272-0810>

Shuyu Li

Beijing Normal University <https://orcid.org/0000-0002-3459-6821>

Tijiang Zhang

Department of Radiology, The Affiliated Hospital of Zunyi Medical University

Fan Jiang

Shanghai Jiao Tong University School of Medicine

Jian Yang

Chongqing Key Laboratory of Neurobiology

Feiyan Chen

Zhejiang University, Hangzhou, Zhejiang, 310027, China <https://orcid.org/0000-0003-3730-1651>

Alzheimer's Disease Neuroimaging Initiative -

Alzheimer's Disease Neuroimaging Initiative

CHIMGEN Consortium

Tianjin Medical University General Hospital

DIDA-MDD Working Group -

DIDA-MDD Working Group

MCADI Consortium -

MCADI Consortium

Chinese Lifespan Brain Mapping Consortium -

-

Tian Tian

Department of Radiology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology

Long Jiang Zhang

Jinling Hospital, Jinling Clinical Medical College, Nanjing Medical University <https://orcid.org/0000-0002-6664-7224>

Dongtao Wei

Southwest University <https://orcid.org/0000-0003-2544-8015>

Jiajia Zhu

The First Affiliated Hospital of Anhui Medical University <https://orcid.org/0000-0001-7343-6241>

Ching-Po Lin

National Yang-Ming University, Taipei <https://orcid.org/0000-0001-6848-8776>

Feng Feng

Chinese Academy of Medical Sciences & Peking Union Medical College

Kuncheng Li

Department of Radiology and Nuclear medicine, Xuanwu Hospital, Capital Medical University
<https://orcid.org/0000-0002-1898-3979>

Xiaochu Zhang

School of Life Sciences, University of Science and Technology of China <https://orcid.org/0000-0002-7541-0130>

Zhaoxiang Ye

Tianjin Medical University Cancer Institute and Hospital <https://orcid.org/0000-0003-3157-8393>

Qi Dong

Beijing Normal University

Wen Qin

Tianjin Medical University General Hospital <https://orcid.org/0000-0002-9121-8296>

Yong He

Beijing Normal University <https://orcid.org/0000-0002-7039-2850>

Article

Keywords: brain chart, asymmetry, normative model, lifespan trajectory, Chinese population

Posted Date: August 19th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10588519/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: There is **NO** Competing Interest.

Differential Lifespan Trajectories of Cerebral Asymmetry in Chinese and Western Populations

Author list:

Liyuan Lin^{1,#}, Lianglong Sun^{2,3,4,#}, Caihong Wang^{5,6,#}, Jintao Zhang^{2,4,#}, Qi Huang^{7,#},
Jing Zhang^{8,#}, Chao Liu^{2,4,9,#}, Qiujin Qian^{10,11,12,13,#}, Bing Zhang^{14,15,16,17,#}, Ming
Meng^{18,19,20,21,22,23,#}, Xinyuan Liang^{2,3,4}, Mingrui Xia^{2,3,4}, Feng Liu¹, Huaigui Liu¹, Nan
Chen^{24,25}, Jinzhu Yang^{26,27}, Bo Hou²⁸, Zeyu Liu²⁸, Chu-Chung Huang^{29,30}, Yongqiang
Yu³¹, Huanhuan Cai³¹, Jiang Qiu^{32,33}, Qunlin Chen^{32,33}, Ying Wei⁶, Peifang Miao⁶,
Hongwen Song³⁴, Weiwei Men^{35,36}, Yunxia Li^{37,38}, Yaou Liu³⁹, Yunyun Duan³⁹, Peng
Zhang^{40,41}, Ning Yang², Xue-Ru Fan², Qing Cai²⁹, Xiaoxue Gao⁴², Shijun Qiu^{43,44}, Yujie
Liu⁴³, Sha Tao², Meiyun Wang⁴⁵, Yu Shen⁴⁵, Qiyong Gong^{46,47,48}, Xiaoqi Huang^{46,47,48},
Yanghua Tian^{49,50,51}, Gong-Jun Ji⁵¹, Wenzhen Zhu⁵², Fang Xie⁷, Jianfeng Feng^{53,54,55}, Li
Hu^{56,57}, Jia-Hong Gao³⁵, Tianzi Jiang⁵⁸, Xiongzhao Zhu⁵⁹, Yuhan Zhang², Liping Liu⁶⁰,
Hanjun Liu⁶¹, Weihua Liao^{62,63}, Peipeng Liang⁶⁴, Dawei Wang^{65,66,67,68}, Huali
Wang^{12,13,69,70}, Tengfei Guo⁷¹, Zhengjia Dai⁷², Su Lui^{47,73}, Kai Xu⁷⁴, Lingjiang Li^{75,76},
Peng Xie^{77,78}, Chunliang Feng^{18,19,20,21,22}, Guangbin Cui⁷⁹, Jinsong Wu^{80,81,82}, Xuntao
Yin⁸³, Guosheng Ding^{2,4}, Junfang Xian⁸⁴, Lianping Zhao⁸⁵, Jie Lu^{24,25}, Zhifen Liu⁸⁶,
Ying Han⁸⁷, Zhen Yuan⁸⁸, Xilin Zhang^{18,19,20,21,22}, Tianmei Si^{10,11,12,13}, Fuqing Zhou⁸⁹,
Yanchao Bi^{2,4,90,91,92,93}, Dan Wu⁹⁴, Fei Gao⁹⁵, Fei Wang⁹⁶, Shaozheng Qin^{2,97}, Gang
Wang⁹⁸, Feng Chen⁹⁹, Zhiqiang Zhang^{100,101}, Jing Sui^{2,4}, Huaifu Chen¹⁰², Jinhua Cai¹⁰³,
Shuwei Liu¹⁰⁴, Zuojun Geng¹⁰⁵, Chen Zhang¹⁰⁶, Ning Mao^{107,108,109}, Hong Yin¹¹⁰, Bo
Liu¹¹¹, Heng Ma¹⁰⁷, Bo Gao¹¹², Yanwei Miao¹¹³, Xiang-Zhen Kong^{114,115,116}, Yuan
Zhou^{56,57}, Li Liu^{2,4}, Jianping Hu¹¹⁷, Liang Wang^{56,57}, Quan Zhang¹¹⁸, Hua Shu^{2,119},
Peijun Wang^{120,121}, Tatia M. C. Lee¹²², Qingjiu Cao^{10,11,12,13,123}, Li Yang^{10,11,12,13,123}, Xi
Zhang¹²⁴, Wenbo Luo^{125,126}, Meng Liang¹, Hongxiang Yao¹²⁷, Meng Li¹²⁸, Hao
Huang^{129,130}, Yun Peng¹³¹, Zaizhu Han^{2,119}, Chao Zhou¹³², Haibo Xu¹³³, Ming Feng¹³⁴,
Wen Shen¹³⁵, Yuzheng Hu¹¹⁴, Huajun Chen¹³⁶, Ying Wang¹³⁷, Gaolang Gong^{2,3,4,97},
Zhihan Yan¹³⁸, Xiaojun Xu¹³⁹, Jun Liu¹⁴⁰, Guangxiang Chen¹⁴¹, Pan Wang¹⁴², Yunjun
Yang¹⁴³, Cheng Luo¹⁴⁴, Tong Han¹⁴⁵, Huiguang He¹⁴⁶, Ce Chen¹⁴⁷, Qihong Zou³⁵,
Hesheng Liu¹⁴⁸, Hui Zhang¹⁴⁹, Chao Chai¹³⁵, Chunming Lu^{2,4}, Yiheng Tu^{56,57}, Yong
Liu¹⁵⁰, Danhua Lin¹⁵¹, Weihua Zhao¹⁵², Xiufeng Xu¹⁵³, Xiaoli Liu¹⁵⁴, Zaixu Cui⁹⁷,
Zheng Wang^{155,156}, Ruiwang Huang^{18,19,20,21,22}, Zhanjiang Li¹⁵⁷, Yunzhe Liu^{2,4,97},
Xiaojun Li¹⁵⁸, Xiujie Yang^{119,159}, Nan Zhang¹⁶⁰, Antao Chen¹⁶¹, Bin Zhang¹⁶², Pengmin
Qin^{18,21}, Chen Liu¹⁶³, Zhenwei Yao¹⁶⁴, Yanjun Wei¹⁶⁵, Huishu Yuan¹⁶⁶, Feng Wang¹⁶⁷,
Yu Zhang¹⁶⁸, Quan Zhang¹⁶⁹, Fang Hu¹⁷⁰, Huan Xie¹⁷¹, Xuehai Wu¹⁷², Jiaojian Wang¹⁷³,
Guoguang Fan¹⁷⁴, Zhiqun Wang¹⁷⁵, Dongling Zhang¹⁷⁶, Hui Zhong¹⁷⁷, Yonggang
Wang¹⁷⁸, Lijun Bai¹⁷⁹, Yongmei Li¹⁸⁰, Xinhua Wei¹⁸¹, Jinhui Wang¹⁸², Yi Zhang¹⁸³,
Hongjian He^{115,184}, Shuyu Li², Tijiang Zhang¹⁸⁵, Fan Jiang^{186,187,188}, Jian Yang¹⁸⁹,
Feiyan Chen¹⁸⁴, Alzheimer's Disease Neuroimaging Initiative, CHIMGEN Consortium,
DIDA-MDD Working Group, MCADI, Chinese Lifespan Brain Mapping Consortium,
Tian Tian^{190,*}, Longjiang Zhang^{191,*}, Dongtao Wei^{32,33,*}, Jiajia Zhu^{31,*}, Ching-Po Lin^{192,*},
Feng Feng^{28,*}, Kuncheng Li^{24,25,*}, Xiaochu Zhang^{34,*}, Zhaoxiang Ye^{40,41,*}, Qi Dong^{2,*},

43 Wen Qin^{1,*}, Yong He^{2,3,4,97,*}, Chunshui Yu^{1,*}

44

45 **Affiliations:**

46 ¹ Department of Radiology/Tianjin Key Lab of Functional Imaging/Tianjin Institute of
47 Radiology/State Key Laboratory of Experimental Hematology, Tianjin Medical
48 University General Hospital, Tianjin, China

49 ² State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal
50 University, Beijing, China

51 ³ Beijing Key Laboratory of Brain Imaging and Connectomics, Beijing Normal
52 University, Beijing, China

53 ⁴ IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing,
54 China

55 ⁵ Department of Medical Imaging, The Fifth Affiliated Hospital of Zhengzhou
56 University, Zhengzhou, China

57 ⁶ Department of MRI, The First Affiliated Hospital of Zhengzhou University,
58 Zhengzhou, China

59 ⁷ Department of Nuclear Medicine & PET Center, Huashan Hospital, Fudan
60 University, Shanghai, China

61 ⁸ Department of Magnetic Resonance, Lanzhou University Second Hospital, Lanzhou,
62 China

63 ⁹ Beijing Key Laboratory of Safe AI and Superalignment, Beijing Normal University,
64 Beijing, China

65 ¹⁰ Peking University Sixth Hospital, Beijing, China

66 ¹¹ Peking University Institute of Mental Health, Beijing, China

67 ¹² NHC Key Laboratory of Mental Health (Peking University), Beijing, China

68 ¹³ National Clinical Research Center for Mental Disorders (Peking University Sixth
69 Hospital), Beijing, China

70 ¹⁴ Department of Radiology, Nanjing Drum Tower Hospital, Affiliated Hospital of
71 Medical School, Nanjing University, Nanjing, China

72 ¹⁵ Institute of Medical Imaging and Artificial Intelligence, Nanjing University,
73 Nanjing, China

74 ¹⁶ Institute of Brain Science, Nanjing University, Nanjing, China

75 ¹⁷ Medical Imaging Center, Affiliated Drum Tower Hospital, Medical School of
76 Nanjing University, Nanjing, China

77 ¹⁸ Key Laboratory of Brain, Cognition and Education Sciences (South China Normal
78 University), Ministry of Education, Guangzhou, China

79 ¹⁹ School of Psychology, South China Normal University, Guangzhou, China

80 ²⁰ Center for Studies of Psychological Application, South China Normal University,
81 Guangzhou, China

- ²¹ Guangdong Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou, China
- ²² Philosophy and Social Science Laboratory of Reading and Development in Children and Adolescents (South China Normal University), Ministry of Education, Guangzhou, China
- ²³ Department of Neurobiology, The University of Alabama at Birmingham, Birmingham, AL 35294, United States
- ²⁴ Department of Radiology and Nuclear medicine, Xuanwu Hospital, Capital Medical University, Beijing, China
- ²⁵ Beijing Key Laboratory of Magnetic Resonance Imaging and Brain Informatics, Beijing, China
- ²⁶ Key Laboratory of Intelligent Computing in Medical Image of Ministry of Education, School of Computer Science and Engineering, Northeastern University, Shenyang, China
- ²⁷ National Frontiers Science Center for Industrial Intelligence and Systems Optimization, Shenyang, China
- ²⁸ Department of Radiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China
- ²⁹ School of Psychology and Cognitive Science, East China Normal University, Shanghai, China
- ³⁰ Institute of Aging, East China Normal University, Shanghai, China
- ³¹ Department of Radiology, The First Affiliated Hospital of Anhui Medical University, Hefei, China
- ³² Faculty of Psychology, Southwest University, Chongqing, China
- ³³ Key Laboratory of Cognition and Personality (Ministry of Education), Southwest University, Chongqing, China
- ³⁴ Division of Life Science and Medicine, University of Science & Technology of China, Hefei, China
- ³⁵ Center for MRI Research, Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China
- ³⁶ Beijing City Key Laboratory for Medical Physics and Engineering, Institute of Heavy Ion Physics, School of Physics, Peking University, Beijing, China
- ³⁷ Department of Neurology, Shanghai Pudong Hospital, Fudan University Pudong Medical Center, Shanghai, China
- ³⁸ Department of Neurology, Tongji Hospital, School of Medicine, Tongji University, Shanghai, China
- ³⁹ Department of Radiology, Beijing Tiantan Hospital, Capital Medical University, Beijing, China
- ⁴⁰ Department of Radiology, Tianjin Medical University Cancer Institute & Hospital, National Clinical Research Center for Cancer, Tianjin, China
- ⁴¹ State Key Laboratory of Druggability Evaluation and Systematic Translational Medicine, Tianjin, China

- 124 ⁴² Shanghai Key Laboratory of Mental Health and Psychological Crisis Intervention,
125 School of Psychology and Cognitive Science, East China Normal University,
126 Shanghai, China
- 127 ⁴³ Department of Radiology, The First Affiliated Hospital of Guangzhou University of
128 Chinese Medicine, Guangzhou, China
- 129 ⁴⁴ State Key Laboratory of Traditional Chinese Medicine Syndrome, Guangzhou,
130 China
- 131 ⁴⁵ Medical Imaging Research Institute, Henan Provincial People's Hospital & People's
132 Hospital of Zhengzhou University, Zhengzhou, China
- 133 ⁴⁶ Department of Radiology, Huaxi MR Research Center (HMRRC), Institute of
134 Radiology, Functional and Molecular Imaging Key Laboratory of Sichuan
135 Province, West China Hospital of Sichuan University, Chengdu, China
- 136 ⁴⁷ Research Unit of Psychoradiology, Chinese Academy of Medical Sciences,
137 Chengdu, China
- 138 ⁴⁸ Xiamen Key Laboratory of Psychoradiology and Neuromodulation, Department of
139 Radiology, West China Xiamen Hospital of Sichuan University, Xiamen, China
- 140 ⁴⁹ Department of Neurology, The First Affiliated Hospital of Anhui Medical
141 University, Hefei, China
- 142 ⁵⁰ Anhui Province Key Laboratory of Cognition and Neuropsychiatric Disorders,
143 Hefei, China
- 144 ⁵¹ School of Mental Health and Psychological Sciences, Anhui Medical University,
145 Hefei, China
- 146 ⁵² Tongji Hospital, Tongji Medical College, Huazhong University of Science and
147 Technology, Wuhan, China
- 148 ⁵³ Institute of Science and Technology for Brain-Inspired Intelligence/Key Laboratory
149 of Computational Neuroscience and Brain-Inspired Intelligence (Ministry of
150 Education), Fudan University, Shanghai, China
- 151 ⁵⁴ Department of Computer Science, University of Warwick, Warwick, United
152 Kingdom
- 153 ⁵⁵ Fudan ISTBI—ZJNU Algorithm Centre for Brain-inspired Intelligence, Zhejiang
154 Normal University, Hangzhou, China
- 155 ⁵⁶ State Key Laboratory of Cognitive Science and Mental Health, Institute of
156 Psychology, Chinese Academy of Sciences, Beijing, China
- 157 ⁵⁷ Department of Psychology, University of Chinese Academy of Sciences, Beijing,
158 China
- 159 ⁵⁸ Beijing Key Laboratory of Brainnetome and Brain-Computer Interface, Institute of
160 Automation, Chinese Academy of Sciences, Beijing, China
- 161 ⁵⁹ Medical Psychological Center, The Second Xiangya Hospital, Central South
162 University, Changsha, China
- 163 ⁶⁰ Science and Education Department, The First Psychiatric Hospital of Harbin,
164 Harbin, China
- 165 ⁶¹ Department of Rehabilitation Medicine, The First Affiliated Hospital, Sun Yat-sen

166 University, Guangzhou, China
 167 ⁶² Department of Radiology/National Clinical Research Center for Geriatric
 168 Disorders/National Engineering Research Center of Personalized Diagnostic and
 169 Therapeutic Technology/Hunan Engineering Research Center for Intelligent
 170 Medical Imaging, Xiangya Hospital of Central South University, Changsha, China
 171 ⁶³ FuRong Laboratory, Changsha, China
 172 ⁶⁴ School of Psychology, Capital Normal University, Beijing, China
 173 ⁶⁵ Department of Radiology, Qilu Hospital of Shandong University, Ji'nan, China
 174 ⁶⁶ Qilu Medical Imaging Institute of Shandong University, Ji'nan, China
 175 ⁶⁷ Institute of Magnetic Field-free Medicine and Functional Imaging, Shandong
 176 University, Ji'nan, China
 177 ⁶⁸ Shandong Key Laboratory for Magnetic Field-free Medicine and Functional
 178 Imaging, Ji'nan, China
 179 ⁶⁹ Dementia Care and Research Center, Peking University Institute of Mental Health
 180 (Sixth Hospital), Beijing, China
 181 ⁷⁰ Beijing Municipal Key Laboratory for Translational Research on Diagnosis and
 182 Treatment of Dementia, Beijing, China
 183 ⁷¹ Shenzhen Bay Laboratory, Shenzhen, China
 184 ⁷² Department of Psychology, Sun Yat-sen University, Guangzhou, China
 185 ⁷³ Department of Radiology, and Psychoradiology Key Laboratory of Sichuan
 186 Province, West China Hospital, Sichuan University, Chengdu, China
 187 ⁷⁴ Department of Radiology, The Affiliated Hospital of Xuzhou Medical University,
 188 Xuzhou, China
 189 ⁷⁵ Department of Psychiatry, and National Clinical Research Center for Mental
 190 Disorders, The Second Xiangya Hospital of Central South University, Changsha,
 191 China
 192 ⁷⁶ Mental Health Institute of Central South University, China National Technology
 193 Institute on Mental Disorders, Hunan Technology Institute of Psychiatry, Hunan
 194 Key Laboratory of Psychiatry and Mental Health, Hunan Medical Center for
 195 Mental Health, Changsha, China
 196 ⁷⁷ Chongqing Key Laboratory of Neurobiology, Chongqing, China
 197 ⁷⁸ Department of Neurology, The First Affiliated Hospital of Chongqing Medical
 198 University, Chongqing, China
 199 ⁷⁹ Department of Radiology & Functional and Molecular Imaging Key Lab of Shaanxi
 200 Province, Tangdu Hospital, Fourth Military Medical University (Air Force
 201 Medical University), Xi'an, China
 202 ⁸⁰ Department of Neurosurgery, Huashan Hospital, Shanghai Medical College, Fudan
 203 University, Shanghai, China
 204 ⁸¹ National Center for Neurological Disorders, Shanghai, China
 205 ⁸² Shanghai Key Laboratory of Clinical and Translational Brain-Computer Interface
 206 Research, Shanghai, China

207 ⁸³ Department of Medical Imaging, Guizhou Rehabilitation Hospital, Guiyang, China

208 ⁸⁴ Department of Radiology, Capital Medical University-Beijing Tongren Hospital,

209 Beijing, China

210 ⁸⁵ Gansu Provincial Hospital, Lanzhou, China

211 ⁸⁶ Psychiatry Department, First Hospital of Shanxi Medical University, Taiyuan,

212 China

213 ⁸⁷ Xuanwu Hospital, Capital Medical University, Beijing, China

214 ⁸⁸ Centre for Cognitive and Brain Sciences/Faculty of Health Sciences, University of

215 Macau, Macau, China

216 ⁸⁹ Jiangxi Provincial Key Laboratory for Precision Pathology and Intelligent

217 Diagnosis, Department of Radiology, The First Affiliated Hospital, Jiangxi

218 Medical College, Nanchang University, Nanchang, China

219 ⁹⁰ School of Psychological and Cognitive Sciences and Beijing Key Laboratory of

220 Behavior and Mental Health, Peking University, Beijing, China

221 ⁹¹ IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

222 ⁹² Institute for Artificial Intelligence, Peking University, Beijing, China

223 ⁹³ Key Laboratory of Machine Perception (Ministry of Education), Peking University,

224 Beijing, China

225 ⁹⁴ College of Biomedical Engineering and Instrument Science, Zhejiang University,

226 Hangzhou, China

227 ⁹⁵ Department of Radiology, Shandong Provincial Hospital Affiliated to Shandong

228 First Medical University, Ji'nan, China

229 ⁹⁶ The Affiliated Brain Hospital of Nanjing Medical University, Nanjing, China

230 ⁹⁷ Chinese Institute for Brain Research, Beijing, China

231 ⁹⁸ Addiction Department, Wuhan Mental Health Center, Wuhan, China

232 ⁹⁹ Department of Radiology, Hainan General Hospital, Haikou, China

233 ¹⁰⁰ Department of Diagnostic Radiology, Affiliated Jinling Hospital, Medical School

234 of Nanjing University, Nanjing, China

235 ¹⁰¹ State Key Laboratory of Analytical Chemistry for Life Science, Nanjing

236 University, Nanjing, China

237 ¹⁰² Sichuan Provincial Key Laboratory of Brain-Computer Interface and Brain-

238 inspired intelligence/School of Life Science and Technology, University of

239 Electronic Science and Technology of China, Chengdu, China

240 ¹⁰³ Department of Radiology, Children's Hospital of Chongqing Medical University,

241 Chongqing, China

242 ¹⁰⁴ Department of Anatomy and Neurobiology, Shandong Key Laboratory of Mental

243 Disorders, Institute for Sectional Anatomy and Digital Human, School of Basic

244 Medical Sciences, Institute of Brain and Brain-Inspired Science, Cheeloo College

245 of Medicine, Shandong University, Ji'nan, China

246 ¹⁰⁵ Department of Medical Imaging, The Second Hospital of Hebei Medical

247 University, Shijiazhuang, China

- 248 ¹⁰⁶ Department of Psychiatry, Shanghai Mental Health Center, Shanghai, China
- 249 ¹⁰⁷ Department of Radiology, Yantai Yuhuangding Hospital, Qingdao University,
250 Yantai, China
- 251 ¹⁰⁸ Big Data and Artificial Intelligence Laboratory, Yantai Yuhuangding Hospital,
252 Qingdao University, Yantai, China
- 253 ¹⁰⁹ Shandong Provincial Key Medical and Health Laboratory of Intelligent Diagnosis
254 and Treatment for Women's Diseases, Yantai Yuhuangding Hospital, Qingdao
255 University, Yantai, China
- 256 ¹¹⁰ Medical Imaging Center, People's Hospital Affiliated to Northwest University,
257 Xi'an, China
- 258 ¹¹¹ Provincial Hospital of Traditional Chinese Medicine, Guangzhou, China
- 259 ¹¹² Department of Radiology, Affiliated Hospital of Guizhou Medical University,
260 Guiyang, China
- 261 ¹¹³ Department of Radiology, The First Affiliated Hospital of Dalian Medical
262 University, Dalian, China
- 263 ¹¹⁴ Department of Psychology and Behavioral Sciences, Zhejiang University,
264 Hangzhou, China
- 265 ¹¹⁵ The State Key Lab of Brain-Machine Intelligence, Zhejiang University, Hangzhou,
266 China
- 267 ¹¹⁶ Department of Psychiatry of Sir Run Shaw Hospital, Zhejiang University School
268 of Medicine, Hangzhou, China
- 269 ¹¹⁷ Department of Radiology, The First Affiliated Hospital of Fujian Medical
270 University, Fuzhou, China
- 271 ¹¹⁸ Department of Radiology, Characteristic Medical Center of Chinese People's
272 Armed Police Force, Tianjin, China
- 273 ¹¹⁹ Faculty of Psychology, Beijing Normal University, Beijing, China
- 274 ¹²⁰ Department of Medical Imaging, Tongji Hospital, School of Medicine, Tongji
275 University, Shanghai, China
- 276 ¹²¹ Institute of Medical Imaging Artificial Intelligence, Tongji University School of
277 Medicine, Shanghai, China
- 278 ¹²² Laboratory of Neuropsychology and Human Neuroscience, Department of
279 Psychology, The University of Hong Kong, Hong Kong, China
- 280 ¹²³ Beijing Key Laboratory for Big Data Innovative Application of Child and
281 Adolescent Mental Disorders, Beijing, China
- 282 ¹²⁴ Department of Neurology, The Second Medical Centre, National Clinical Research
283 Centre for Geriatric Diseases, Chinese PLA General Hospital, Beijing, China
- 284 ¹²⁵ Institute of Psychological and Brain Sciences, Liaoning Normal University,
285 Dalian, China
- 286 ¹²⁶ Key Laboratory of Brain and Cognitive Neuroscience, Liaoning Province, Dalian,
287 China
- 288 ¹²⁷ Department of Radiology of the Second Medical Centre, National Clinical

289 Research Centre for Geriatric Diseases, Chinese PLA General Hospital, Beijing,
 290 China

291 ¹²⁸ Department of Medical Imaging, The Affiliated Guangdong Second Provincial
 292 General Hospital of Jinan University, Guangzhou, China

293 ¹²⁹ Department of Radiology, Children's Hospital of Philadelphia, Philadelphia, PA,
 294 United States

295 ¹³⁰ Department of Radiology, Perelman School of Medicine, University of
 296 Pennsylvania, Philadelphia, PA, United States

297 ¹³¹ Department of Radiology, Beijing Children's Hospital, Capital Medical University,
 298 National Center for Children's Health, Beijing, China

299 ¹³² Department of Geriatric Psychiatry, Nanjing Brain Hospital Affiliated to Nanjing
 300 Medical University, Nanjing, China

301 ¹³³ Department of Radiology/Hubei Provincial Engineering Research Center of
 302 Multimodal Medical Imaging Technology and Clinical Application, Zhongnan
 303 Hospital of Wuhan University, Wuhan, China

304 ¹³⁴ Department of Neurosurgery, Peking Union Medical College Hospital, Beijing,
 305 China

306 ¹³⁵ Department of Radiology, Tianjin First Central Hospital, Tianjin, China

307 ¹³⁶ Department of Radiology, Fujian Medical University Union Hospital, Fuzhou,
 308 China

309 ¹³⁷ Medical Imaging Center, First Affiliated Hospital of Jinan University, Guangzhou,
 310 China

311 ¹³⁸ Department of Radiology, The Second Affiliated Hospital of Wenzhou Medical
 312 University, Wenzhou, China

313 ¹³⁹ Department of Radiology, The Second Affiliated Hospital, Zhejiang University
 314 School of Medicine, Hangzhou, China

315 ¹⁴⁰ Department of Radiology, The Second Xiangya Hospital, Central South University,
 316 Changsha, China

317 ¹⁴¹ Department of Radiology, The Affiliated Hospital of Southwest Medical
 318 University, Luzhou, China

319 ¹⁴² Tianjin Huanhu Hospital, Tianjin, China

320 ¹⁴³ Department of Radiology and Nuclear Medicine, The First Affiliated Hospital of
 321 Wenzhou Medical University, Wenzhou, China

322 ¹⁴⁴ The Clinical Hospital of Chengdu Brain Science Institute, School of Life Science
 323 and Technology, University of Electronic Science and Technology of China,
 324 Chengdu, China

325 ¹⁴⁵ Department of Radiology, Tianjin Huanhu Hospital, Tianjin, China

326 ¹⁴⁶ State Key Laboratory of Brain Cognition and Brain-inspired Intelligence
 327 Technology, Institute of Automation, Chinese Academy of Sciences, Beijing,
 328 China

329 ¹⁴⁷ Wenzhou Seventh People's Hospital, Wenzhou, China

330 ¹⁴⁸ Changping Laboratory, Beijing, China
 331 ¹⁴⁹ Department of Radiology, The First Hospital of Shanxi Medical University,
 332 Taiyuan, China
 333 ¹⁵⁰ Center for Artificial Intelligence in Medical Imaging, School of Artificial
 334 Intelligence, Beijing University of Posts and Telecommunications, Beijing, China
 335 ¹⁵¹ Institute of Developmental Psychology, Beijing Normal University, Beijing, China
 336 ¹⁵² School of life Science and Technology, University of Electronic Science and
 337 Technology of China, Chengdu, China
 338 ¹⁵³ The First Affiliated Hospital of Kunming Medical University, Kunming, China
 339 ¹⁵⁴ Zhejiang Hospital, Hangzhou, China
 340 ¹⁵⁵ School of Psychological and Cognitive Sciences, Beijing Key Laboratory of
 341 Behavior and Mental Health, State Key Laboratory of General Artificial
 342 Intelligence, IDG/McGovern Institute for Brain Research, Peking-Tsinghua Center
 343 for Life Sciences, Peking University, Beijing, China
 344 ¹⁵⁶ School of Biomedical Engineering, Hainan University, Haikou, China
 345 ¹⁵⁷ Center of Clinical Psychology, Beijing Anding Hospital, Capital Medical
 346 University, Beijing, China
 347 ¹⁵⁸ Qianjiang Hospital, Chongqing University, Chongqing, China
 348 ¹⁵⁹ Beijing Key Laboratory of Applied Experimental Psychology, National
 349 Demonstration Center for Experimental Psychology Education, Beijing Normal
 350 University, Beijing, China
 351 ¹⁶⁰ Department of Neurosurgery, The First Affiliated Hospital of Guangzhou Medical
 352 University, Guangzhou, China
 353 ¹⁶¹ Brain Health Institute, National Center for Mental Disorders, Shanghai Mental
 354 Health Center, Shanghai Jiao Tong University School of Medicine and School of
 355 Psychology, Shanghai, China
 356 ¹⁶² Tianjin Anding Hospital, Tianjin Medical University, Tianjin, China
 357 ¹⁶³ 7T Magnetic Resonance Translational Medicine Research Center, Department of
 358 Radiology, Southwest Hospital, Army Medical University (Third Military Medical
 359 University), Chongqing, China
 360 ¹⁶⁴ Department of Radiology, Fudan University Huashan Hospital, Shanghai, China
 361 ¹⁶⁵ School of Cognitive Science and Allied Health/Institute of Life and Health
 362 Sciences/Key Laboratory of Cognitive Science of Language (Ministry of
 363 Education)/Center for Cognitive Science of Language, Beijing Language and
 364 Culture University, Beijing, China
 365 ¹⁶⁶ Department of Radiology, Peking University Third Hospital, Beijing, China
 366 ¹⁶⁷ Division of CT and MRI, The First Affiliated Hospital of Heilongjiang University
 367 of Chinese Medicine, Harbin, China
 368 ¹⁶⁸ School of Psychology, Shanghai Jiao Tong University, Shanghai, China
 369 ¹⁶⁹ Department of Radiology, Tianjin Key Lab of Functional Imaging, Tianjin Institute
 370 of Radiology& State Key Laboratory of Experimental Hematology, Tianjin

371 Medical University General Hospital, Tianjin, China
 372 ¹⁷⁰ College of medical imaging laboratory and rehabilitation/Key Laboratory of
 373 Medical Imaging and Artificial Intelligence of Hunan Province, Xiangnan
 374 University, Chenzhou, China
 375 ¹⁷¹ Department of Radiology, Army Medical Center of PLA, Chongqing, China
 376 ¹⁷² Department of Neurosurgery, Huashan Hospital, Shanghai, China
 377 ¹⁷³ State Key Laboratory of Primate Biomedical Research/Institute of Primate
 378 Translational Medicine, Kunming University of Science and Technology,
 379 Kunming, China
 380 ¹⁷⁴ Department of Radiology, First Hospital of China Medical University, Shenyang,
 381 China
 382 ¹⁷⁵ Aerospace Center Hospital, Beijing, China
 383 ¹⁷⁶ Department of Neurology, China National Clinical Research Center for
 384 Neurological Diseases, Beijing Tiantan Hospital, Capital Medical University,
 385 Beijing, China
 386 ¹⁷⁷ Child and Adolescent Psychiatry Department, Hefei City Fourth People's Hospital,
 387 Hefei, China
 388 ¹⁷⁸ Beijing Tiantan Hospital, Beijing, China
 389 ¹⁷⁹ The Key Laboratory of Biomedical Information Engineering, Ministry of
 390 Education, Department of Biomedical Engineering, School of Life Science and
 391 Technology, Xi'an Jiaotong University, Xi'an, China
 392 ¹⁸⁰ Department of Radiology, The First Affiliated Hospital of Chongqing Medical
 393 University, Chongqing, China
 394 ¹⁸¹ Department of Radiology, Guangzhou First People's Hospital, School of Medicine,
 395 South China University of Technology, Guangzhou, China
 396 ¹⁸² Institute for Brain Research and Rehabilitation, South China Normal University,
 397 Guangzhou, China
 398 ¹⁸³ Center for Brain Imaging, School of Life Science and Technology, Xidian
 399 University, Xi'an, China
 400 ¹⁸⁴ School of Physics, Zhejiang University, Hangzhou, China
 401 ¹⁸⁵ Department of Radiology, The Affiliated Hospital of Zunyi Medical University,
 402 Zunyi, China
 403 ¹⁸⁶ Department of Developmental and Behavioral Pediatrics and Pediatric
 404 Translational Medicine Institute and Shanghai Key Laboratory of Child Brain and
 405 Development, National Children's Medical Center, Shanghai Children's Medical
 406 Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China
 407 ¹⁸⁷ Ministry of Education Key Laboratory of Children's Environmental Health,
 408 Xinhua Hospital, School of Medicine, Shanghai Jiao Tong University, Shanghai,
 409 China
 410 ¹⁸⁸ Shanghai Center for Brain Science and Brain-Inspired Technology, Shanghai,
 411 China
 412 ¹⁸⁹ Department of Radiology, The first Affiliated Hospital of Xi'an Jiaotong

413 University, Xi'an, China
414 ¹⁹⁰ Department of Radiology, Tongji Hospital, Tongji Medical College, Huazhong
415 University of Science and Technology, Wuhan, China
416 ¹⁹¹ Department of Radiology, Jinling Hospital, Affiliated Hospital of Medical School,
417 Nanjing University, Nanjing, China
418 ¹⁹² Institute of Neuroscience, National Yang Ming Chiao Tung University, Taipei,
419 China
420

421 # These authors contributed equally

422 * Correspondence to: chunshuiyu@tmu.edu.cn, yong.he@bnu.edu.cn,
423 wayne.wenqin@gmail.com, dongqi@bnu.edu.cn, yezhaoxiang@163.com,
424 zxcustc@ustc.edu.cn, cjr.likuncheng@vip.163.com, ffeng@pumch.cn,
425 chingpolin@gmail.com, zhujiajiagraduate@163.com, dongtao@swu.edu.cn,
426 kevinzhjl@163.com and tongjitiantian@163.com

427

428 **Keywords:** brain chart, asymmetry, normative model, lifespan trajectory, Chinese
429 population

430

431

Abstract

Cerebral asymmetry is a core principle of human brain organization, showing dynamic changes across the lifespan and alterations in brain disorders. However, it remains unclear whether lifespan trajectories of asymmetry differ across populations. We compared lifespan structural asymmetry normative charts of 221 cerebral imaging phenotypes from 43,037 Chinese and 56,339 Western participants aged 0–100 years. The two populations showed distinct lifespan asymmetry patterns in 26.2% of the phenotypes. Chinese-minus-Western asymmetry difference curves displayed distinct patterns across brain phenotypes: rightward (45.7%), leftward (26.2%), rightward-to-leftward (11.8%), leftward-to-rightward (10.0%), and unclassified (6.3%). Population-matched normative models outperformed population-unmatched normative models in capturing normal asymmetry variability among healthy individuals and in detecting abnormal asymmetry deviations in patients with Alzheimer’s disease, mild cognitive impairment, schizophrenia, and major depressive disorder. These findings indicate that population mismatch can bias chart-based individual-level asymmetry assessment and underscore the need for population-representative brain asymmetry normative charts.

Introduction

Cerebral asymmetry is a core principle of human brain organization¹⁻³ and underlies a wide range of perceptual and neurocognitive functions^{4,5}, including language⁶, facial recognition⁷, visuospatial processing⁸, and reasoning⁹. Inter-individual differences in cerebral asymmetry are associated with normal variations in behavioral performance⁵, while abnormal asymmetries are observed in various neuropsychiatric disorders¹⁰, such as major depressive disorder (MDD)¹¹, schizophrenia (SZ)¹², Alzheimer's disease (AD)¹³, and mild cognitive impairment (MCI)¹⁴. Despite these advances, most prior studies have focused on group-level asymmetry changes; the normative landscape of brain asymmetry across the general population remains incompletely characterized, limiting our ability to distinguish abnormal deviations from normal individual variation in cerebral asymmetry.

Brain asymmetry changes dynamically across the lifespan rather than remaining static. Characterizing normative trajectories of brain asymmetry provide a framework for understanding age-related variation across development and aging. For example, using longitudinal structural brain magnetic resonance imaging (MRI) data from 11,270 U.S. children aged 10–14 years with mixed ancestries, a recent study identified age-related, modality-specific development patterns of asymmetry in cortical thickness, surface area, and subcortical volume, and linked these patterns to cognitive and mental health⁵. Using cross-sectional diffusion MRI data from 35,120 participants aged 0-100 years across 50 population-based cohorts with broad geographic representation, another study showed highly heterogeneous and dynamic lifespan trajectories of asymmetry in

white matter tracts¹⁵. The largest lifespan brain asymmetry study included 138,231 individuals aged from 20 post menstrual weeks to 102 years, aggregated from 128 neuroimaging studies, providing normative models of structural brain asymmetry across the lifespan¹⁶. Although these studies have advanced our understanding of regional dynamic changes in brain asymmetry across the lifespan, none has examined differences in these normative trajectories between ancestral populations, which is critical for determining whether the normative models of brain asymmetry constructed using data from one population can be generalized to other ancestral groups.

Growing evidence indicates that ancestral populations differ in neuroanatomical organization^{17,18} and in developmental trajectories¹⁹⁻²². Regarding structural asymmetry, a surface-based morphometry study reported differences in cortical asymmetry between Chinese and Caucasian young adults across cortical thickness, surface area, and cortical volume²³, raising a broader question about the generalizability of population-derived neuroimaging models. Recent advances in brain modeling have exhibited that ancestry-related sampling bias can influence both prediction accuracy and clinical interpretation. For example, resting-state functional connectivity models trained primarily on White participants showed reduced behavioral prediction accuracy in non-White participants²⁴. Furthermore, Western-centric lifespan normative models for structural brain measures cannot accurately estimate deviations in these measures in Chinese patients with brain disorders²², suggesting that their deviations from the norm may arise from demographic mismatch with the reference population, rather than from disease-related abnormalities alone²⁵. However, whether and how lifespan normative trajectories of brain asymmetry

differ across populations remains unclear, and the practicability of applying asymmetry normative models derived from one ancestral population to other groups has not been systematically evaluated.

In the present study, we hypothesized that lifespan trajectories of structural brain asymmetry exhibit population-specific variation while preserving core features across populations. Accordingly, population-matched normative models should better capture normal asymmetry variability among healthy individuals and detect atypical deviations in patients with neuropsychiatric disorders than population-mismatched models. To test this hypothesis, we utilized the Phase I dataset of the Chinese Lifespan Brain Mapping (C-LBM) Consortium—comprising 43,037 healthy Chinese participants aged 0–100 years across 384 sites—to construct population-specific lifespan asymmetry trajectories for 244 structural brain MRI phenotypes. For comparison, corresponding trajectories were generated using a Western dataset of 56,339 participants aged 0–100 years from 174 sites. We quantified Chinese–Western differences in lifespan trajectories of cerebral asymmetry and compared the predictive performance of population-matched versus population-mismatched normative asymmetry models in test datasets of both healthy individuals and patients with brain disorders. Population-matched prediction refers to cases where both the training and testing datasets are drawn from the same population, whereas population-mismatched prediction uses training and testing datasets from two different populations. The contrast was specially designed to test whether population-matched models would more accurately characterize normal individual variability and more reliably capture pathological deviations than population-mismatched models. An

overview of the study is presented in **Fig. 1**.

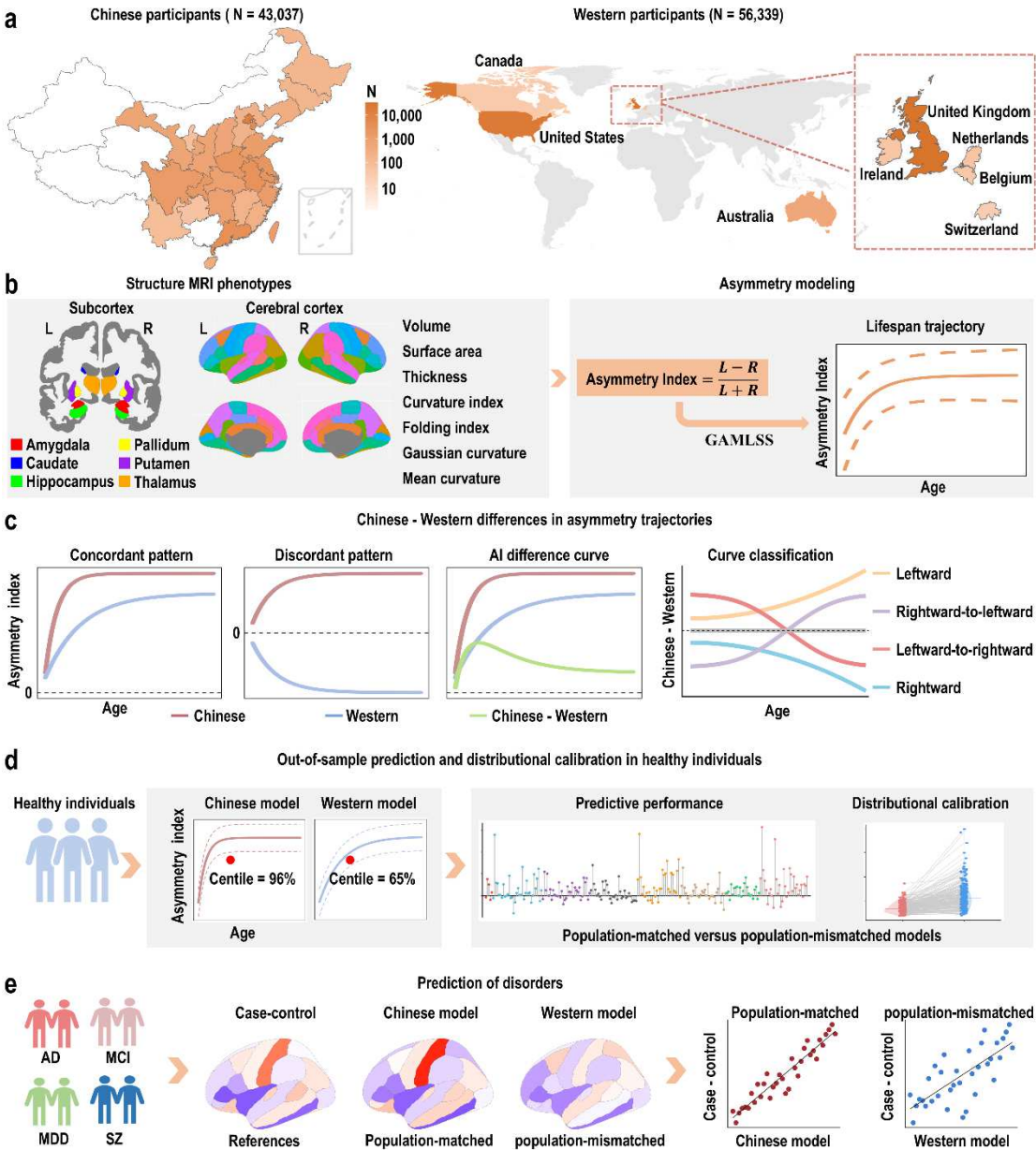


Fig. 1 | The schematic overview of the study design. *a*, Geographic distribution of the participants. The 43,037 Chinese participants are recruited from 29 Chinese provinces, whereas the 56,339 Western participants are recruited from eight Western countries. *b*, MRI phenotypes and asymmetry modeling. We include 244 pairs of structural brain MRI phenotypes shared by both hemispheres: 238 pairs from seven measures of 34

cortical regions and six pairs from the volumes of six subcortical structures. For each
 pair, we calculate an AI phenotype and estimate its lifespan trajectory using GAMLSS.
c, Chinese-Western differences in AI trajectories. In each population, we model lifespan
 trajectories of all AI phenotypes and classify them into distinct patterns, then compare
 pattern concordance between populations (left two panels). For each AI phenotype, we
 compute the inter-population difference curve (Chinese minus Western) of lifespan AI
 trajectories, and categorize these curves into distinct classes (right two panels). **d**, We
 compare out-of-sample prediction and distributional calibration of population-
 matched versus population-mismatched models in healthy participants. **e**, Using
 observed case–control AI differences as references, we compare performance of
 population-matched versus population-mismatched models in predicting case–control
 AI differences in four brain disorders. AD, Alzheimer’s disease; AI, asymmetry index;
 GAMLSS, generalized additive models for location, scale, and shape; L, left; MDD,
 major depressive disorder; MCI, mild cognitive impairment; MRI, magnetic resonance
 imaging; R, right; SZ, schizophrenia.

Results

We established population-specific lifespan normative charts for 244 brain asymmetry phenotypes quantified using the asymmetry index (AI), based on Chinese (C-LBM: $n = 43,037$) and Western ($n = 56,339$) datasets, respectively (**Supplementary Tables 1-3**). These charts captured nonlinear age-related variation in brain asymmetry and provided normative distributions while accounting for site-related effects.

Classification of lifespan asymmetry patterns within populations

To ensure brain asymmetry phenotypes had stable lifespan trajectories, we quantified stability using the trajectory coverage rate (TCR), defined as the proportion of sampled points from the full-sample curve that fell within the 95% confidence intervals (CIs) derived from curves refitted after age-stratified matched subsampling (detailed in Methods). Six phenotypes in the Chinese population and three in the Western population had TCR values below the predefined threshold of 0.95 and were therefore excluded from subsequent analyses (**Supplementary Table 4**). Of the remaining 238 Chinese and 241 Western phenotypes, we classified them—based on their fitted trajectories—into six patterns: right asymmetry (right > left), left asymmetry (left > right), right-to-left (transition from right to left), left-to-right (transition from left to right), no asymmetry (95% CI of AI includes zero at all lifespan points), and unclassified (multiple switches among asymmetry types). The 238 Chinese phenotypes were classified as right (35.71%), left (29.83%), right-to-left (16.81%), left-to-right (14.29%), and unclassified (3.36%), while the 241 Western phenotypes were classified

as right (34.02%), left (38.17%), right-to-left (12.03%), left-to-right (12.45%), no asymmetry (0.41%), and unclassified (2.92%) (**Fig. 2a** and **Supplementary Table 4**).

After excluding unstable and unclassified trajectories, 221 asymmetry phenotypes that were retained in both the Chinese and Western populations were included in the between-population comparison of lifespan asymmetry patterns. Of these phenotypes, 73.76% showed concordant asymmetry pattern assignments between the two populations (**Fig. 2b**). Representative examples included leftward surface area asymmetry of the pars opercularis, a language-related region^{1,26}, and rightward cortical thickness asymmetry of the superior temporal gyrus²⁷, both consistently observed in Chinese and Western populations, in agreement with previous reports (**Fig. 2c**). By contrast, the remaining 26.24% showed discordant assignments, including lateral orbitofrontal surface area, which was rightward asymmetric in Chinese participants but leftward asymmetric in Western participants (**Fig. 2d**).

asymmetry of the superior temporal gyrus. d, An example of a discordant lifespan asymmetry pattern between populations: surface area asymmetry of the lateral orbitofrontal cortex. AI, asymmetry index; CI, confidence interval.

Chinese-Western differences in lifespan asymmetry trajectories

We calculated Chinese-minus-Western asymmetry difference curves for the 221 brain phenotypes retained in both populations and assigned these curves to five categories: rightward (showing Chinese AI < Western AI at age points where the 95% CI of the AI difference excluded zero), leftward (showing only Chinese AI > Western AI at age points where the 95% CI of the AI difference excluded zero), rightward-to-leftward, leftward-to-rightward, and unclassified (**Fig. 3a**). Across the 221 phenotypes, the most common difference pattern was rightward (45.7%), followed by leftward (26.2%), rightward-to-leftward (11.8%), leftward-to-rightward (10.0%), and unclassified (6.3%) (**Fig. 3b**). These widespread point-wise AI differences between Chinese and Western populations indicate that applying normative charts from one population could bias individual asymmetry assessments in the other.

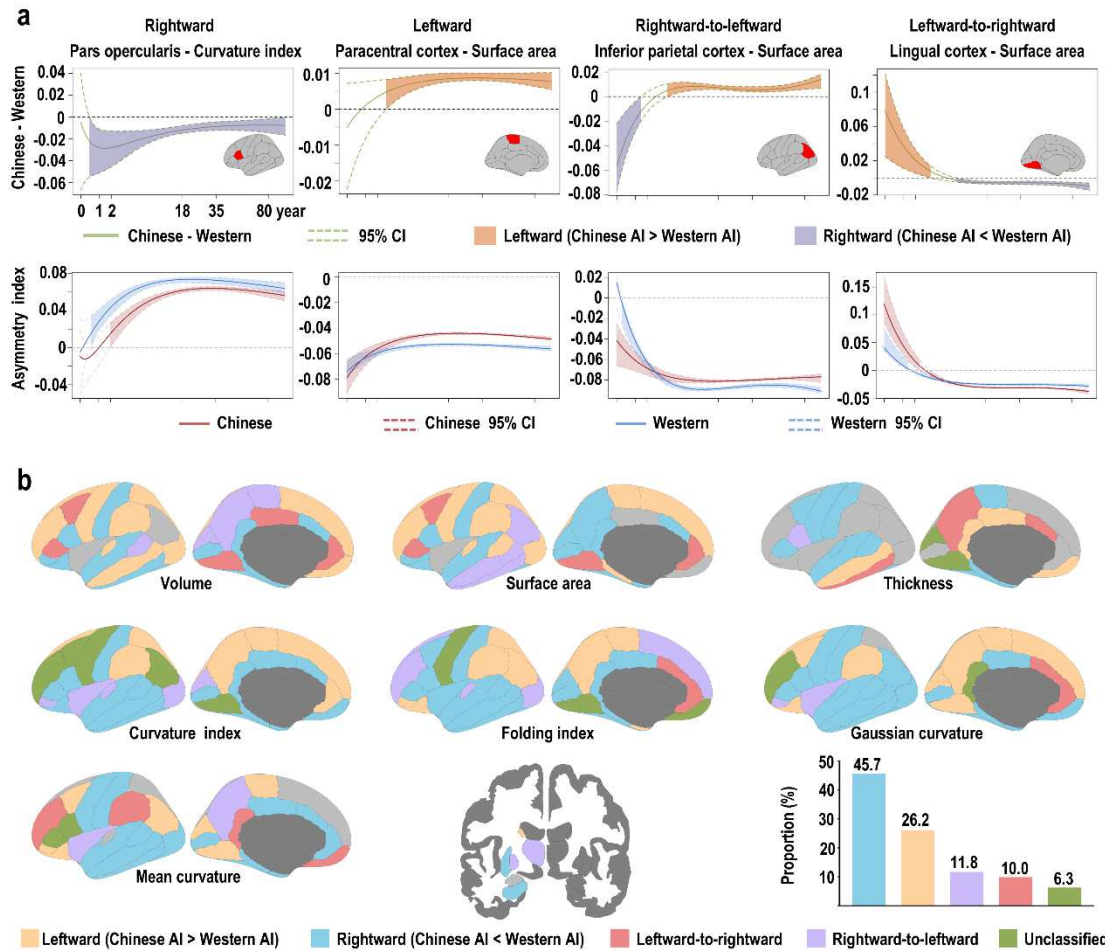


Fig. 3 | Lifespan asymmetry differences between Chinese and Western populations.

a, Representative example for each lifespan asymmetry difference pattern. Asymmetry difference curves are defined as Chinese minus Western fitted asymmetry trajectories. The upper panels show Chinese–Western difference curves with 95% CIs, and the lower panels show the corresponding population-specific asymmetry trajectories. **b**, Brain maps show the asymmetry difference pattern assigned to each phenotype, with colors indicating distinct patterns. Bar chart summarizes the proportion of each pattern across the 221 phenotypes. AI, asymmetry index; CI, confidence interval.

Sex consistency of between-population asymmetry difference patterns

We recalculated the Chinese–Western asymmetry difference curves of these phenotypes separately in females and males and compared the resulting pattern assignments. We found similar assignments between females and males: rightward (44.34% vs. 46.15%), leftward (27.15% vs. 23.98%), rightward-to-leftward (12.22% vs. 11.77%), leftward-to-rightward (9.50% vs. 10.41%), and unclassified (6.79% vs. 7.69%) (**Extended Data Fig. 1a** and **Supplementary Table 5**). Among the 221 phenotypes, 185 (83.71%) were assigned to the same asymmetry difference patterns in both sexes (**Extended Data Fig. 1b**), whereas 36 (16.29%) were assigned to distinct patterns. For instance, the Gaussian curvature of the supramarginal gyrus showed greater rightward asymmetry in Chinese males than in Western males, whereas it showed greater leftward asymmetry in Chinese females than in Western females (**Extended Data Fig. 1c**).

Population-matched models improved prediction and distributional calibration

To determine whether population-matched normative asymmetry models yielded more reliable individual deviation estimates than population-mismatched normative models, we assessed predictive accuracy and distributional calibration of the two models in two independent test datasets. One comprised 4,041 healthy Chinese participants aged 0.1–96 years from 240 sites, and the other comprised 5,477 healthy Western participants aged 0–100 years from 65 sites. For each phenotype, we calculated the normalized root mean squared error (NRMSE) to reflect the accuracy of the estimated center of the normative distribution, and then computed its NRMSE reduction ratio to quantify the

predictive improvement of the population-matched model over the population-mismatched model (**Fig. 4a**). Population-matched models demonstrated more accurate prediction than population-mismatched models, with mean NRMSE reduction ratios significantly greater than zero across phenotypes. Specifically, Chinese models achieved higher predictive accuracy (Cohen's $d = 0.69$, $P = 2.39 \times 10^{-28}$) in the Chinese sample than Western models (**Fig. 4b**), while Western models achieved higher predictive accuracy (Cohen's $d = 0.37$, $P = 3.53 \times 10^{-15}$) in the Western sample than Chinese models (**Extended Data Fig. 2a**).

Adequate calibration of the estimated normative distribution to observed AI values is crucial for reliable individual inference from normative asymmetry models. For each of the 221 phenotypes, we employed the D-statistic from the one-sample Kolmogorov–Smirnov (KS) test to evaluate distributional calibration in the test samples by assessing how closely model-derived deviation z-scores matched the expected standard normal distribution. In the Chinese sample, the Chinese models produced deviation z-score distributions that significantly departed from the expected standard normal distribution for only one phenotype (KS test: $P < 1.13 \times 10^{-4}$, Bonferroni corrected); by contrast, the Western models produced significant departures for 42 phenotypes (**Fig. 4c**). Across phenotypes, Chinese models showed better calibration than Western models, as indicated by lower D-statistics (Cohen's $d = 0.95$, $P = 2.79 \times 10^{-30}$; **Fig. 4c**). In the Western sample, Western models also produced fewer phenotypes (15 vs. 68) with departures and smaller D-statistics (Cohen's $d = 0.72$, $P = 7.33 \times 10^{-30}$) than Chinese models (**Extended Data Fig. 2b**). We further used absolute skewness and absolute

excess kurtosis to determine the patterns of departure from the standard normal distribution. Chinese models yielded lower absolute excess kurtosis (Cohen's $d = 0.50$, $P = 1.73 \times 10^{-14}$) and similar absolute skewness (Cohen's $d = -0.06$, $P = 0.09$) in the Chinese sample compared with Western models (**Fig. 4d**), and Western models also yielded lower excess kurtosis (Cohen's $d = 0.51$, $P = 4.44 \times 10^{-21}$) and similar skewness (Cohen's $d = 0.16$, $P = 0.004$) in the Western sample compared with Chinese models (**Extended Data Fig. 2c**). These findings indicate that population-matched normative models yield more reliable out-of-sample deviation estimates than population-mismatched models, with higher predictive accuracy and better distributional calibration.

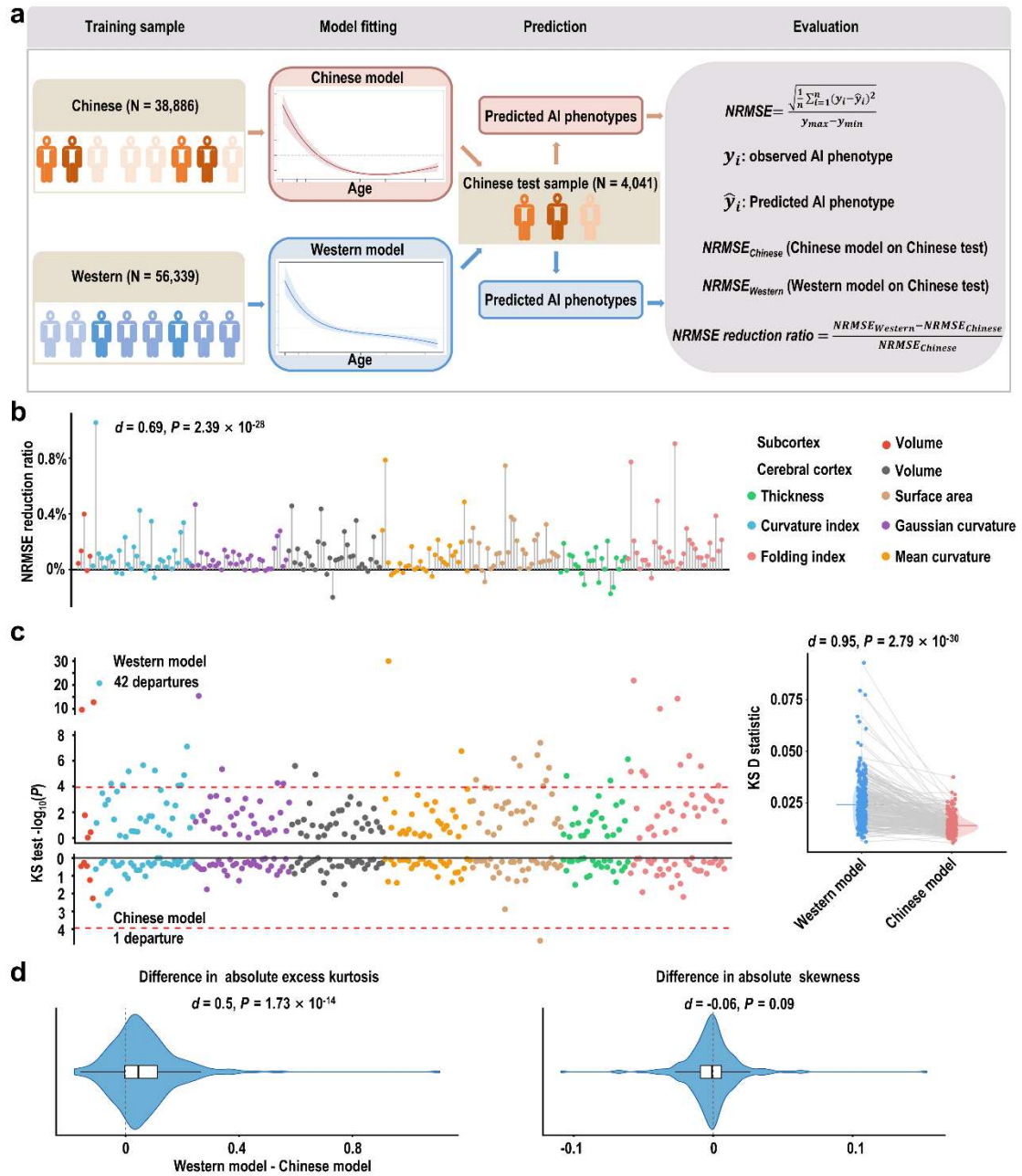


Fig. 4 | Predictive accuracy and distributional calibration of Chinese and Western normative asymmetry models in an independent healthy Chinese sample. a, The pipeline for evaluating predictive accuracy. We utilize Chinese and Western normative models to predict AI values for all phenotypes in each participant of an independent healthy Chinese test sample. We assess predictive accuracy using NRMSE and quantify the improvement of Chinese over Western models using the NRMSE reduction ratio. b,

Lollipop plot shows NRMSE reduction ratios for brain asymmetry phenotypes. Positive values indicate better predictive performance of the Chinese model compared with the Western model. Points are color-coded by phenotype category. **c**, Distributional calibration of Chinese and Western models in the Chinese test sample. The left panel shows $-\log_{10}(P)$ values from phenotype-wise Kolmogorov–Smirnov tests assessing whether deviation z-scores in the test sample conform to the expected normal distribution; the horizontal dashed line indicates the Bonferroni-corrected significance threshold of $P = 1.13 \times 10^{-4}$. Overall, Chinese models yield fewer phenotypes with significant departures than Western models (1 vs. 42). The right panel compares D-statistics of all phenotypes between the two models. **d**, Violin plots show phenotype-wise differences in absolute excess kurtosis (left panel) and skewness (right panel) of deviation z-scores (Western minus Chinese). Positive values indicate better calibration for Chinese models than for Western models. AI, asymmetry index; KS, Kolmogorov–Smirnov; NRMSE, normalized root mean squared error.

Population-matched models better recapitulated case-control differences

We also investigated whether population-matched normative models more accurately recapitulated pathology-associated asymmetry deviations than population-mismatched models. We included 304 Chinese case–control pairs for Alzheimer’s disease (AD), 273 for mild cognitive impairment (MCI), 663 for schizophrenia (SZ), and 1,319 for major depressive disorder (MDD), and 804 Western case–control pairs for AD, 576 for MCI,

and 306 for SZ. For the 221 phenotypes, we calculated their case–control AI differences for disorders as references for disorder-associated AI deviations. For each disorder, we computed patient deviation z-scores for these phenotypes using Chinese and Western normative asymmetry models, respectively. For each phenotype, we used one-sample Cohen’s d to represent normative-derived AI deviation, which quantified the deviation of patient z-scores from the normative expected value of zero. For each disorder, we calculated the intraclass correlation coefficient (ICC) between AI deviations across phenotypes derived from each normative model and the reference to determine which normative model (population-matched or population-mismatched) better predicts the observed disorder-related AI deviations using a permutation test with 1,000 iterations.

In the Chinese case–control pairs, disorder-associated AI deviations estimated by Chinese models showed stronger concordance with case–control references than those from Western models, with higher ICCs across disorders: SZ (0.87 vs. 0.69; **Fig. 5a**), AD (0.87 vs. 0.65; **Fig. 5b**), MCI (0.82 vs. 0.63; **Fig. 5c**), and MDD (0.86 vs. 0.55; **Fig. 5d**). All disorders showed significant ICC differences (permutation test: all $P < 0.001$) between the two models. In the Western case–control pairs, disorder-associated AI deviations estimated by Western models also showed stronger concordance with case–control references than those from Chinese models, with higher ICCs for SZ (0.82 vs. 0.67; **Extended Data Fig. 3a**), AD (0.76 vs. 0.57; **Extended Data Fig. 3b**), and MCI (0.75 vs. 0.46; **Extended Data Fig. 3c**). These between-model ICC differences were also significant for all disorders (permutation test: all $P < 0.001$). These results indicate that population-matched normative models can more accurately recapitulate disorder-

related deviations in brain asymmetry in clinical samples than population-mismatched models.

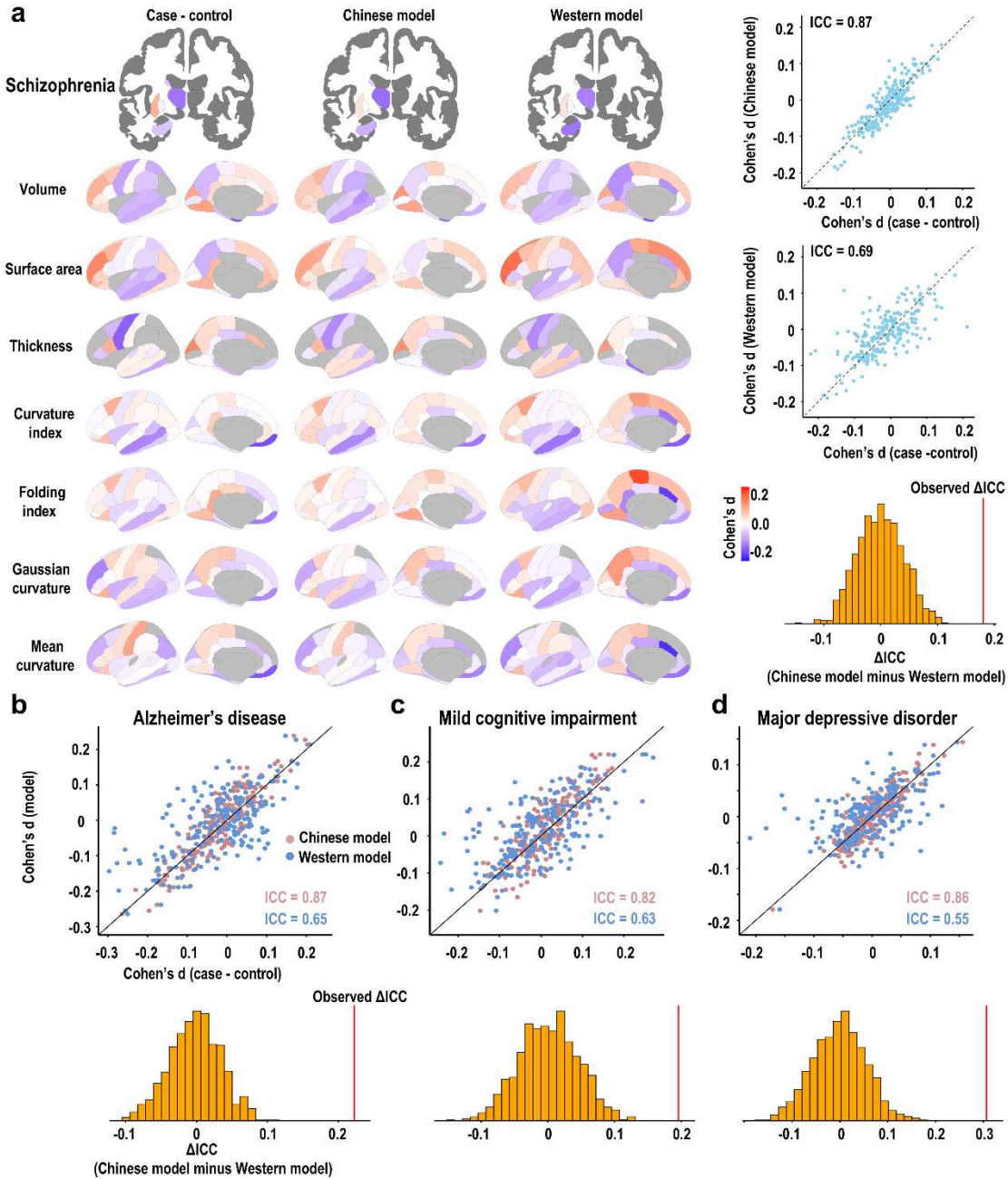


Fig. 5 | Differences in disorder-associated AI deviations estimated by Chinese and Western normative models in Chinese case-control pairs. a, Schizophrenia-associated AI deviations estimated by Chinese and Western normative models in

Chinese case-control pairs. Brain maps (left panel) show the observed case-control Cohen's d values and the Cohen's d values predicted by the Chinese and Western models. Scatter plots (upper right panel) depict the concordance between normative-derived and observed Cohen's d values across phenotypes; each point represents a phenotype and concordance is quantified by the ICC. Histogram (lower right panel) shows the permutation-based null distribution of ICC differences between models, with the observed ICC difference marked by a red line. **b-d**, AI deviations for Alzheimer's disease (**b**), mild cognitive impairment (**c**), and major depressive disorder (**d**) estimated by Chinese and Western normative models in Chinese case-control pairs. The upper panels display scatter plots of the observed and predicted Cohen's d values, and the lower panels show histograms of permutation distributions of ICC differences. AI, asymmetry index; ICC, intraclass correlation coefficient.

Sensitivity analyses

To assess the impact of age-specific sample-size imbalance, we conducted age-stratified matched subsampling to equalize sample sizes between the two populations within each age group, yielding 20,770 participants per population ($N_{\text{Chinese}} = N_{\text{Western}} = 20,770$), and re-estimated the between-population asymmetry difference trajectories for all 221 phenotypes. Robustness was quantified by TCR, defined as the proportion of age points on the original difference trajectory that fell within the 95% CIs of the trajectory derived from age-matched resampling. All 221 phenotypes showed TCR values greater than 0.96 (**Supplementary Table 6**). Among the 221 phenotypes, 180 (81.45%) demonstrated the same assignments of Chinese–Western asymmetry difference patterns before and after age-stratified subsampling (**Extended Data Fig. 4**).

Discussion

We performed the first large-scale study comparing lifespan normative trajectories of structural brain asymmetry across ancestral populations. We found both shared (73.8%) and divergent (26.2%) patterns of lifespan normative asymmetry trajectories between Chinese and Western populations, and further revealed widely occurring and strikingly diverse patterns of between-population differences in asymmetry curves. We illustrated the practical implications of these between-population differences by identifying that population-matched models outperformed population-mismatched models in capturing normal variability among healthy individuals and in detecting abnormal deviations in patients with brain disorders. The biased population-mismatch normative-chart-based

prediction of brain asymmetry indicates that normative models should not be assumed to be directly applicable across populations without prior evaluation of their suitability and calibration in the target population.

A previous study reported differences in structural brain asymmetry between 45 Chinese and 45 Caucasian young adults aged 22-29 years²³. We extended these earlier findings by identifying the dynamic evolution of Chinese–Western differences in brain asymmetry across the lifespan. The two populations exhibited broadly similar lifespan asymmetry trajectories in 74% of structural brain phenotypes, consistent with the 72% proportion of replicated ancestry-shared genetic associations with 3,414 brain imaging phenotypes between the White British and Han Chinese populations²⁸. Previous genetic studies have further suggested that that genetic factors are potential determinants of structural brain asymmetry^{7,29,30}; however, the genetic architecture of the ancestry-shared lifespan asymmetry trajectories requires further investigation. Besides overall pattern differences in 26% of structural brain phenotypes, almost all phenotypes exhibited differences in lifespan asymmetry trajectories between the Chinese and Western populations, with distinct difference-patterns across phenotypes. The between-population differences may reflect differences in genetic structure and effect, environmental exposures, and sociocultural experiences across populations. For example, the between-population asymmetry differences may be associated with differences in allele frequencies and linkage disequilibrium structure across ancestral populations³¹; significant heterogeneity in genetic effects on brain imaging phenotypes observed between White British and Han Chinese populations^{28,32}; and differences in

environmental and sociocultural exposures across populations^{33,34}.

Normative modeling provides a statistical framework for examining individual deviations from covariate-adjusted population reference distributions, thereby enabling single-subject inference^{35,36}. Critically, such deviation scores are inherently tied to the characteristics of the reference population used for normative model training. We found that population-matched normative models predicted normal variability in structural brain asymmetry among healthy individuals and abnormal deviations in structural brain asymmetry among patients with four brain disorders more accurately than population-mismatched normative models. These findings align with previous studies showing that normative models derived from one population cannot accurately estimate abnormal echocardiographic alterations³⁷, delayed fetal growth³⁸, and bone mineral density-based disease diagnoses³⁹ in another population. These results highlight a broader principle: normative standards reflect the distributional characteristics of their source population and should not be assumed to represent a universal baseline of all populations. While developing population-specific normative models of structural brain asymmetry for every population may be infeasible, constructing normative models for major ancestral groups is necessary for identifying abnormal deviations in structural brain asymmetry among patients with brain disorders, and therefore improving diagnosis and assessment of these conditions.

Several limitations should be considered when interpreting our findings. First, we did not include handedness as a covariate in this study because this information was not routinely recorded at many participating centers, particularly those in China. Although

the association between handedness and brain asymmetry remains debated^{40,41}, future studies should include handedness as a covariate to clarify its effects on structural brain asymmetry trajectories. Second, we constructed cortical asymmetry trajectories at the regional level using the Desikan–Killiany atlas; its limited spatial resolution prevented detection of subtle, localized asymmetry patterns. While vertex-wise modeling provides finer spatial granularity, it imposes prohibitive computational demands. How to balance spatial granularity and computational burden therefore remains an important challenge for large-scale normative modeling. Third, the constructed lifespan brain asymmetry normative charts of Chinese and Western populations cannot be applied to populations not included in the normative modelling without careful assessment. Finally, neither the Chinese dataset nor the Western dataset captures within-population ancestral diversity. Among Chinese participants with self-reported ethnicity information, 98.8% were Han Chinese, higher than the 91% proportion of Han Chinese in the national population. Whether the resulting normative charts are applicable to ethnic minority groups in China requires further investigation. Similarly, among Western participants with self-reported ethnicity information, 87.8% were White. The resulting Western normative charts may not be applicable to Western ethnic minority groups.

Methods

Study populations

Ethics. This study was a secondary analysis of existing data pooled from multiple sites. For each acquisition site, recruitment procedures were approved by the respective local

ethics committees, and written informed consent was obtained from all participants or their legal guardians.

Chinese neuroimaging dataset. To construct Chinese lifespan normative trajectories of structural brain asymmetry, we integrated structural MRI data collected from multiple sites across China. The final Chinese sample included 43,037 healthy participants aged 0–100 years (24,425 females) from 29 provinces and 384 sites (**Supplementary Table 1**). Of the 20,486 participants with self-reported race and ethnicity information, 20,232 (98.76%) were Han Chinese (**Supplementary Table 2**).

Western neuroimaging dataset. To construct Western lifespan normative trajectories of structural brain asymmetry, we integrated MRI data collected from 174 scanning sites across eight Western countries: Australia, Belgium, Canada, Ireland, the Netherlands, Switzerland, the United Kingdom, and the United States. After excluding definite Asian participants and applying quality control, the final Western sample comprised 56,339 healthy participants aged 0–100 years (28,356 females) from 174 scanning sites (**Fig. 1a and Supplementary Table 3**). Of the 51,321 participants with self-reported race and ethnicity information, 45,036 (87.75%) were White.

Although neither the Chinese sample nor the Western sample can be interpreted as genetically homogeneous ancestry groups, the two samples represent two nearly non-overlapping ancestral populations.

Structural MRI data processing

To account for age-dependent differences in brain anatomy and MRI tissue contrast, we

used different pipelines to process structural MRI data from participants aged 0–2 years and from participants aged 2–100 years.

Structural MRI data from participants aged 2 years and older were processed using FreeSurfer-based pipelines. We used officially released structural MRI data from the Adolescent Brain Cognitive Development (ABCD) dataset processed with FreeSurfer v6.0.0 and from the UK Biobank (UKB) dataset processed with the UKB FreeSurfer pipeline⁴². For all other datasets, structural MRI data were preprocessed using the PreFreeSurfer⁴³ and FreeSurfer pipelines recommended by the Human Connectome Project (HCP). The PreFreeSurfer pipeline mainly included: distortion correction; rigid alignment of structural images to MNI space; brain extraction; T2-to-T1 registration when T2 weighted scans were available; and bias field correction. The FreeSurfer pipeline primarily included: segmentation of cortical and subcortical structures; cortical surface reconstruction; correction of topological defects in reconstructed cortical surfaces; and projection of the surface onto a sphere for surface registration.

For participants aged less than 2 years, structural MRI data were processed using the iBEAT v2.0 pipeline⁴⁴, except for neonates from the developing HCP (dHCP) study, who were processed using the dHCP pipeline⁴⁵. The iBEAT pipeline mainly included: intensity inhomogeneity correction of T1-images and, when available, T2-images; brain extraction; automatic cerebellar removal, followed by slice-by-slice manual correction when removal was incomplete; tissue segmentation; and cortical surface reconstruction, including topological correction and reconstruction of the inner and outer cortical surfaces.

To extract cortical phenotypes in a common surface space across the full age range, cortical surfaces from participants aged 0–2 years were further aligned to the standard fsaverage surface space. Specifically, for neonates aged 40–44 postmenstrual weeks, surface registration included three steps: individual cortical surfaces were registered to their corresponding postmenstrual-week templates⁴⁶; the pre-registered individual surfaces were registered to the 40-week template; and all individuals' surfaces were aligned to the standard fsaverage surface template. For infants and young children aged 1–24 months, the procedure included: individual cortical surfaces were registered to their corresponding monthly age templates⁴⁷; the monthly pre-registered individual surfaces were registered to the 12-month template; and all individuals' surfaces were aligned to the standard fsaverage surface template.

Neuroimaging data quality control

A unified quality control (QC) pipeline was applied to structural images before and after preprocessing⁴⁸. Prior to data preprocessing, raw structural images were screened using quantitative image-quality metrics, such as contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR), together with site-specific quality scores when available. After data preprocessing, expert visual QC was performed to identify imaging artifacts that could affect brain tissue segmentation, and to evaluate the quality of segmentation and cortical surface reconstruction. Postprocessing QC also included quantitative assessment using the Euler number derived from cortical surface reconstruction. Details are provided in our prior study⁴⁸ and on the website: <https://github.com/sunlianglong/BrainChart-FC-Lifespan/blob/main/QC/README.md>.

Structural brain phenotypes and asymmetry indices

Structural brain phenotypes comprised two major categories: regional cortical measures and subcortical volumes. For each participant, the Desikan–Killiany atlas (68 regions; 34 per hemisphere) was used to extract seven measures (volume, surface area, thickness, mean curvature, Gaussian curvature, folding index, and curvature index) from each cortical region. Subcortical volumes were extracted using age-specific procedures. For participants aged 2–100 years, we extracted volumes of the bilateral caudate, putamen, pallidum, thalamus, amygdala, and hippocampus using FreeSurfer-based automated subcortical segmentation. For participants aged 0–2 years, individual structural images were registered to a 12-month template using age-specific registration strategies⁴⁸, and a standard subcortical atlas was used to extract individual subcortical volumes.

We included 244 pairs of structural MRI phenotypes shared by both hemispheres: 238 pairs from seven measures of 34 cortical regions and six pairs from the volumes of six subcortical structures. For each pair, the asymmetry index (AI) was calculated as $(L - R) / (L + R)$, where L and R represent the left and right values, respectively. Positive and negative values indicate left and right asymmetry, respectively.

Modelling lifespan trajectories of brain asymmetry

We modeled lifespan trajectories of these 244 structural brain asymmetry phenotypes using Generalized Additive Models for Location, Scale and Shape (GAMLSS)^{49,50}, implemented with the *gamlss* package in R (version 5.4-3). GAMLSS is a flexible distributional regression framework that allows the location, scale, and shape of the response distribution to vary as functions of explanatory variables.

Selection of response distribution families. Although WHO guidelines recommend the Box–Cox t -distribution as an appropriate starting point for modeling anthropometric growth charts⁵¹, we did not assume that structural brain asymmetry followed the same distribution. We therefore evaluated candidate distributions using the *gamlss* R package for seven representative global cortical asymmetry measures and six subcortical volume asymmetry phenotypes in the pooled Chinese and Western sample⁵². We evaluated candidate response distribution families with at least three parameters. Among models for which GAMLSS fitting converged, the optimal distribution was selected using the Bayesian information criterion (BIC).

We found the optimal distribution for each asymmetry phenotype (**Extended Data Fig. 5**). The generalized t -distribution (GT) was selected for all cortical phenotypes and for amygdala and hippocampal phenotypes, while the skew- t -distribution (ST) family was selected for other subcortical asymmetry phenotypes, including ST5 for the caudate, ST1 for the pallidum, SST for the putamen, and ST3 for the thalamus.

Model specification and fitting. For each asymmetry phenotype, AI was modeled using GAMLSS with the phenotype-specific distribution (GT or ST). Both distributions were parameterized by four distributional parameters: μ , σ , ν , and τ . In general, μ and σ describe the location and scale of the response distribution, respectively, while ν and τ are shape parameters, with ν mainly related to skewness and τ mainly related to kurtosis.

Fractional polynomials were used to model nonlinear age-related changes in all asymmetry phenotypes. Compared with flexible non-parametric smoothers, fractional polynomials provide a more constrained and stable functional form, helping to reduce

model complexity and convergence difficulties in multi-parameter models with random effects. The general model specification was as follows:

$$AI \sim D(\mu, \sigma, \nu, \tau), \quad D \in \{GT, ST\}$$

$$\mu = \alpha_{\mu} + \beta_{\mu}(sex) + \gamma_{site} + \sum_{j=1}^{m_{\mu}} f_{\mu j} (age)^{p_{\mu j}}$$

$$\log(\sigma) = \alpha_{\sigma} + \beta_{\sigma}(sex) + \sum_{j=1}^{m_{\sigma}} f_{\sigma j} (age)^{p_{\sigma j}}$$

$$\log(\nu) = \alpha_{\nu}$$

$$\log(\tau) = \alpha_{\tau}$$

In this model specification, age and sex were modelled for both the μ and σ parameters, with nonlinear age effects represented by fractional-polynomial functions; scanner site was included only for the μ parameter as a site-specific random intercept. The ν and τ parameters were modelled as intercept-only terms to reduce potential model instability, given the lack of strong rationale for age- or site-dependent variation in distributional shape⁵². The α -term denotes the parameter-specific fixed intercept, the β -term denotes the fixed effect of sex, the f -term denotes the coefficient of the fractional polynomial age-term, and the γ -term denotes the site-level random effect. The m -term denotes the number of polynomial terms, and the p -term denotes the polynomial power.

To ensure comparability between Chinese and Western models, we selected the optimal number of fractional-polynomial terms (1, 2, or 3) for each phenotype by modelling age effects in the pooled Chinese and Western sample. The power of each term was selected automatically during iterative fitting from the standard set $p \in \{-2, -1, -0.5, 0, 0.5, 1, 2, 3\}$, with $p = 0$ denoting a logarithmic transformation.

Candidate GAMLSS models were fitted using the standard iterative maximum

likelihood-based procedure implemented in the gamlss R package. Model convergence was assessed using the default GAMLSS criterion based on changes in global deviance between successive iterations, with a convergence threshold of 0.001 and a maximum of 200 iteration cycles. For each asymmetry phenotype, the convergent candidate model with the lowest BIC was selected as the optimal model specification. The selected specification was then used to fit lifespan normative models separately in the Chinese and Western samples, with fixed-effect coefficients and site-level random effects re-estimated within each sample.

Age-stratified matched subsampling

Age-stratified matched subsampling was performed to assess the stability of lifespan asymmetry trajectories within each sample (Chinese or Western) and to account for age-specific sample-size imbalance between the two samples. Age was stratified into 26 periods: 0–3, 3–6, and 6–12 months; 1–2 years; 2-year intervals from 2 to 10 years; and 5-year intervals from 10 to 100 years. For each age period, the population with the larger sample size was resampled to match the size of the population with the smaller sample size, with replacement. This procedure was repeated 100 times, resulting in a fixed total sample size of 20,700 participants per population in each iteration. For each iteration, normative models were refitted in the resampled Chinese and Western datasets for each asymmetry phenotype. For each population and each phenotype, resampling-derived age-specific 95% CIs were computed from the empirical distribution of the 100 resampled trajectories. We applied the trajectory coverage rate (TCR) to assess within-

sample trajectory stability. For each phenotype, the full-sample trajectory was sampled at 1,000 equally spaced age points between 0 and 100 years. TCR was defined as the proportion of full-sample trajectory values at these sampled points that fell within the corresponding age-specific 95% CIs from age-stratified resampling. Phenotypes with a TCR below 0.95 were considered unstable and excluded from subsequent analyses. Age-stratified matched subsampling was also applied in a sensitivity analysis to assess the robustness of our findings to age-specific sample-size imbalance between samples.

Classification of lifespan asymmetry patterns

For each sample (Chinese or Western), stratified bootstrap resampling (100 iterations, maintaining the original sample size) was performed with replacement while preserving site- and sex-specific proportions. Population-specific normative models were refitted for all asymmetry phenotypes within each bootstrap sample, yielding 100 bootstrap-derived trajectories per phenotype. For each phenotype, bootstrap-derived 95% CIs for the fitted lifespan asymmetry trajectory were computed from the empirical distribution of the 100 bootstrap-derived trajectories.

We sampled the within-sample lifespan asymmetry trajectory of each phenotype at 1,000 equally spaced age points between 0 and 100 years. We then divided age points into left asymmetry (95% CI entirely above zero), right asymmetry (95% CI entirely below zero), and no asymmetry (95% CI including zero). Phenotypes were assigned to six lifespan asymmetry patterns: left asymmetry (including left-asymmetry points and not including right-asymmetry points); right asymmetry (including right-asymmetry

points and not including left-asymmetry points); left-to-right (shifting from left to right asymmetry); right-to-left (shifting from right to left asymmetry); no asymmetry (the absence of asymmetry at any point); and (6) unclassified (two or more shifts between left and right asymmetry across the lifespan).

Chinese-Western differences in asymmetry trajectories

To quantify Chinese–Western differences in lifespan asymmetry trajectories for each phenotype, we created a difference curve by subtracting the Western median trajectory from the Chinese median trajectory. We computed all pairwise differences between the 100 Chinese and 100 Western bootstrap-derived trajectories, yielding 10,000 curves, which were used to estimate 95% CIs at 1,000 age points. We divided age points into leftward (95% CI entirely above zero), rightward (95% CI entirely below zero), and no shift (95% CI including zero). We assigned brain phenotypes to five Chinese–Western difference patterns: leftward (including leftward-shift points and no rightward-shift points); rightward (including rightward-shift points and no leftward-shift points); left-to-right (shifting from leftward to rightward); right-to-left (shifting from rightward to leftward); and unclassified (two or more shifts, or no shift).

To evaluate sex consistency of lifespan asymmetry difference patterns, Chinese–Western difference curves were constructed for each sex and classified using the same criteria. The resulting pattern assignments were then compared between sexes.

Individual deviation scores from normative models

The population-specific normative models enable each participant’s asymmetry values

to be expressed as deviation scores (e.g. z-scores or centiles). For each phenotype, each participant's age, sex, and imaging site were entered into the fitted normative model to derive a participant-specific conditional normative distribution. We then calculated a deviation score according to the position of the observed value within this distribution, quantifying how unusual that asymmetry phenotype is relative to peers of the same age and sex while accounting for imaging-site effects. The covariate-standardized deviation scores enabled comparisons across phenotypes, datasets, and clinical groups.

For datasets acquired from imaging sites that were not included during normative model fitting, the site effects required for site-adjusted deviation-score calculation are not directly available. In such cases, individual deviation scores can be calculated using an out-of-sample normative scoring framework⁵², which could derive deviation scores without refitting the normative model. Using the likelihood implied by the fitted normative model, site-specific random-effect offsets were estimated by maximum likelihood conditional on the fixed-effect components of the model. These random-effect estimates were combined with the fixed-effect components of the fitted model to derive individual deviation scores for the new dataset.

Out-of-sample predictive accuracy and distributional calibration

To evaluate whether population-matched normative models better characterized healthy individual variation than population-mismatched models, we compared out-of-sample predictive accuracy and distributional calibration in healthy Chinese and Western test samples. Population-matched models referred to models trained and tested within the

same population, such as Chinese models applied to Chinese individuals or Western models applied to Western individuals. In contrast, population-mismatched models referred to models trained in one population and applied to individuals from the other population, such as Chinese models applied to Western individuals or Western models applied to Chinese individuals.

A held-out healthy Chinese test sample ($n = 4,041$; age range, 0.1–96 years; from 240 sites) was constructed by randomly selecting 10% of healthy participants from each Chinese site with more than 50 participants. After excluding the held-out individuals, the Chinese normative models were refitted using the remaining Chinese participants to prevent data leakage. Model-predicted asymmetry values and deviation z-scores were then derived for each participant and each asymmetry phenotype in the held-out Chinese test sample using the corresponding refitted Chinese normative models and Western normative models, according to the individual deviation-score calculation. In this calculation, site-specific effects relevant to the Chinese held-out test sample were accounted for using same-site data outside the held-out test set for both models.

A held-out Western test sample ($n = 5,477$; age range, 0–100 years; from 65 sites) was constructed using the same strategy as the held-out Chinese test sample. To prevent data leakage, the Western normative models were refitted after excluding the held-out Western individuals. Model-predicted asymmetry values and deviation z-scores were derived for each participant and each asymmetry phenotype in the held-out Western test sample using the refitted Western models and Chinese models. Site-specific effects relevant to the held-out Western test sample were also accounted for using same-site

data outside the held-out test set for both models.

These model-derived measures from held-out test samples were used to evaluate predictive accuracy and distributional calibration for both population-matched and population-mismatched models, as described below.

Out-of-sample predictive accuracy. For each phenotype, we quantified out-of-sample predictive accuracy by comparing model-predicted and observed asymmetry values using the normalized root mean squared error (NRMSE), with lower values indicating better predictive accuracy. NRMSE was calculated as

$$NRMSE = \frac{\sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2}}{y_{max} - y_{min}}$$

where n is the number of participants, y_i and $\hat{y}_i$ denote the observed and predicted asymmetry values for participant i , respectively, and $y_{max} - y_{min}$ denotes the range of observed values. To quantify predictive improvement of population-matched models over population-mismatched models, we calculated the NRMSE reduction ratio for each phenotype as

$$NRMSE \text{ reduction ratio} = (NRMSE_{mismatched} - NRMSE_{matched}) / NRMSE_{matched}$$

with positive values indicating lower prediction error for the population-matched model. NRMSE reduction ratios across all phenotypes were tested against zero using a one-sample Wilcoxon signed-rank test to determine whether population-matched models showed an overall predictive advantage over population-mismatched models ($P < 0.05$).

Distributional calibration of Chinese and Western normative models. Distributional calibration assesses whether the model-estimated conditional normative distributions adequately approximate the observed data distribution, providing an essential basis for

reliable individual-level inference from normative models⁵³. Distributional calibration can be assessed using model-derived deviation z-scores. In a well-calibrated GAMLSS model, out-of-sample deviation z-scores are expected to approximately follow a normal distribution⁵⁴.

For each phenotype, a one-sample Kolmogorov–Smirnov (KS) test was used to assess how closely the distribution of model-derived deviation z-scores matched the expected standard normal distribution. The KS D-statistic quantified the magnitude of distributional discrepancy, with smaller values indicating better calibration. For each held-out test sample, a Bonferroni correction was applied across KS tests for all model applications across 221 asymmetry phenotypes, yielding a significance threshold of $P < 0.05 / (2 \times 221) = 1.13 \times 10^{-4}$. Significant KS tests were considered evidence of poorer calibration relative to the expected standard normal distribution.

To further characterize the nature of departures from normality, we calculated the absolute skewness and absolute excess kurtosis of model-derived deviation z-scores in each test sample. Absolute skewness captures deviations in distributional symmetry, whereas absolute excess kurtosis captures deviations in tail heaviness; for both metrics, smaller values indicated closer conformity to the expected standard normal distribution and therefore better distributional calibration. Within each test sample, distributional calibration metrics (KS D-statistic, absolute skewness, and absolute excess kurtosis) were compared between population-matched and population-mismatched models using paired Wilcoxon signed-rank tests across phenotypes to determine whether population-matched models showed better overall distributional calibration.

Disorder-associated asymmetry deviations from normative models

To investigate whether population-matched normative models better captured disease-associated asymmetry deviations than population-mismatched normative models, we included case-control datasets of neuropsychiatric disorders from Chinese and Western populations. The Chinese case-control datasets comprised Alzheimer's disease (AD; 399 patients, aged 43–89 years; 308 controls, aged 47–95 years), mild cognitive impairment (MCI; 283 patients, aged 42–88 years; 287 controls, aged 47–95 years), schizophrenia (SZ; 691 patients, aged 11–67 years; 762 controls, aged 9–65 years), and major depressive disorder (MDD; 1,492 patients, aged 11–93 years; 1,715 controls, aged 13–81 years). The Western case-control datasets comprised AD (871 patients, aged 49–96 years; 1,359 controls, aged 19–96 years), MCI (782 patients, aged 55–93 years; 659 controls, aged 47–96 years), and SZ (344 patients, aged 16–59 years; 354 controls, aged 12–59 years). The same preprocessing and quality-control pipeline used for the healthy data was applied to the patient data. To reduce potential age and sex imbalance between patients and controls, propensity score matching (PSM) at a 1:1 ratio was performed separately for each disorder within each population before estimating the AI deviations of patients. After matching, we included 304 Chinese case-control pairs for AD, 273 for MCI, 663 for SZ, and 1,319 for MDD; and 804 Western case-control pairs for AD, 576 for MCI, and 306 for SZ.

For each combination of phenotypes, disorders, and populations, a linear mixed model (LMM)⁵⁵ was used to estimate case-control AI differences, which were used as the reference for evaluating disease-associated AI deviations derived from normative

models. In each LMM, AI was the dependent variable, diagnostic group was the fixed effect of interest, age and sex were included as nuisance covariates, and scanner site was modeled as a random intercept:

$$AI = \beta_0 + \beta_1 Group + \beta_2 Sex + \beta_3 Age + \gamma_{site} + \varepsilon$$

where γ and ε denote the site-specific random intercept and residual error, respectively.

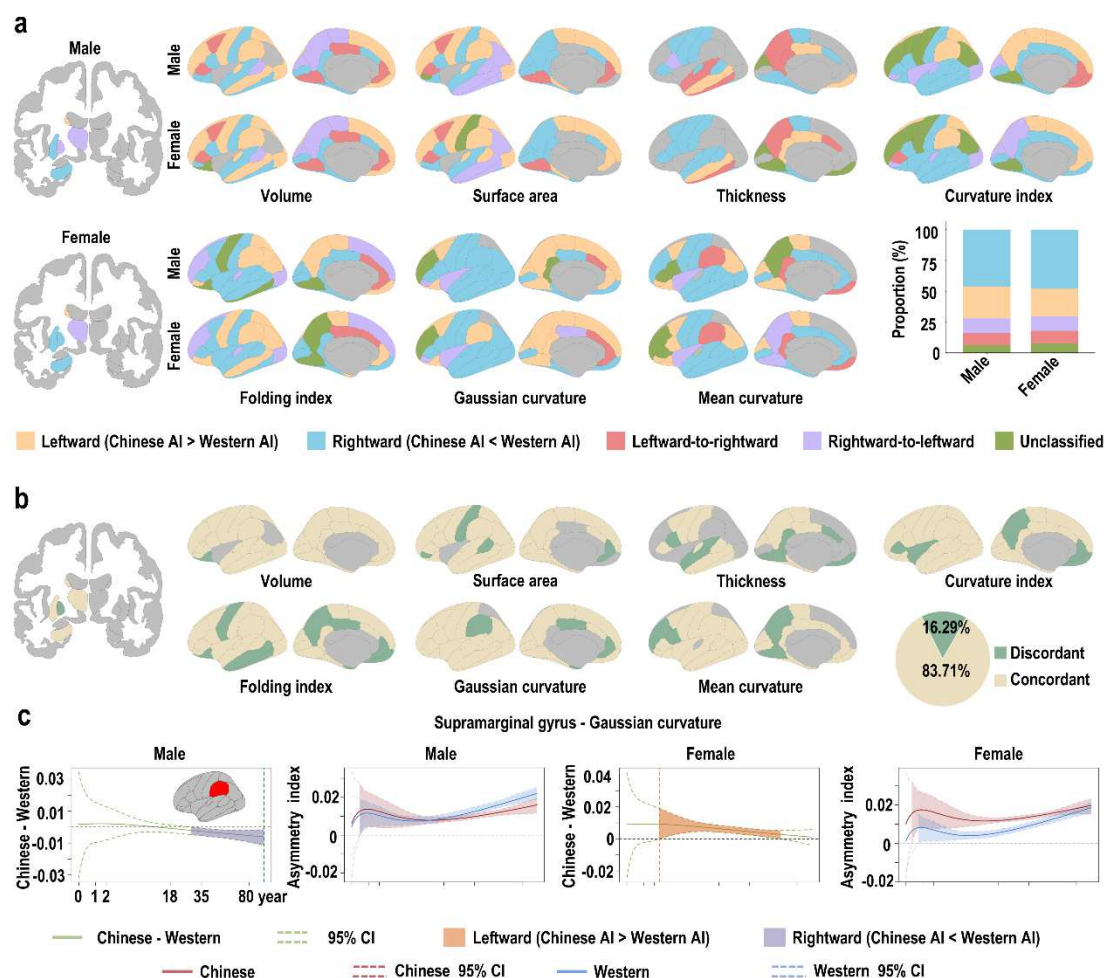
With diagnostic group coded as patient = 1 and control = 0, β_1 represented the covariate-adjusted case-control AI difference. This adjusted group effect was further standardized as Cohen's d for each phenotype.

To estimate disorder-associated AI deviations from normative models, deviation z-scores were calculated for each patient using the population-matched and population-mismatched normative models, where site-specific effects were estimated from site-matched healthy controls. For each disorder and phenotype, Cohen's d was calculated from deviation z-scores derived from each model to quantify model-derived disorder-associated AI deviations relative to the normative expectation of zero.

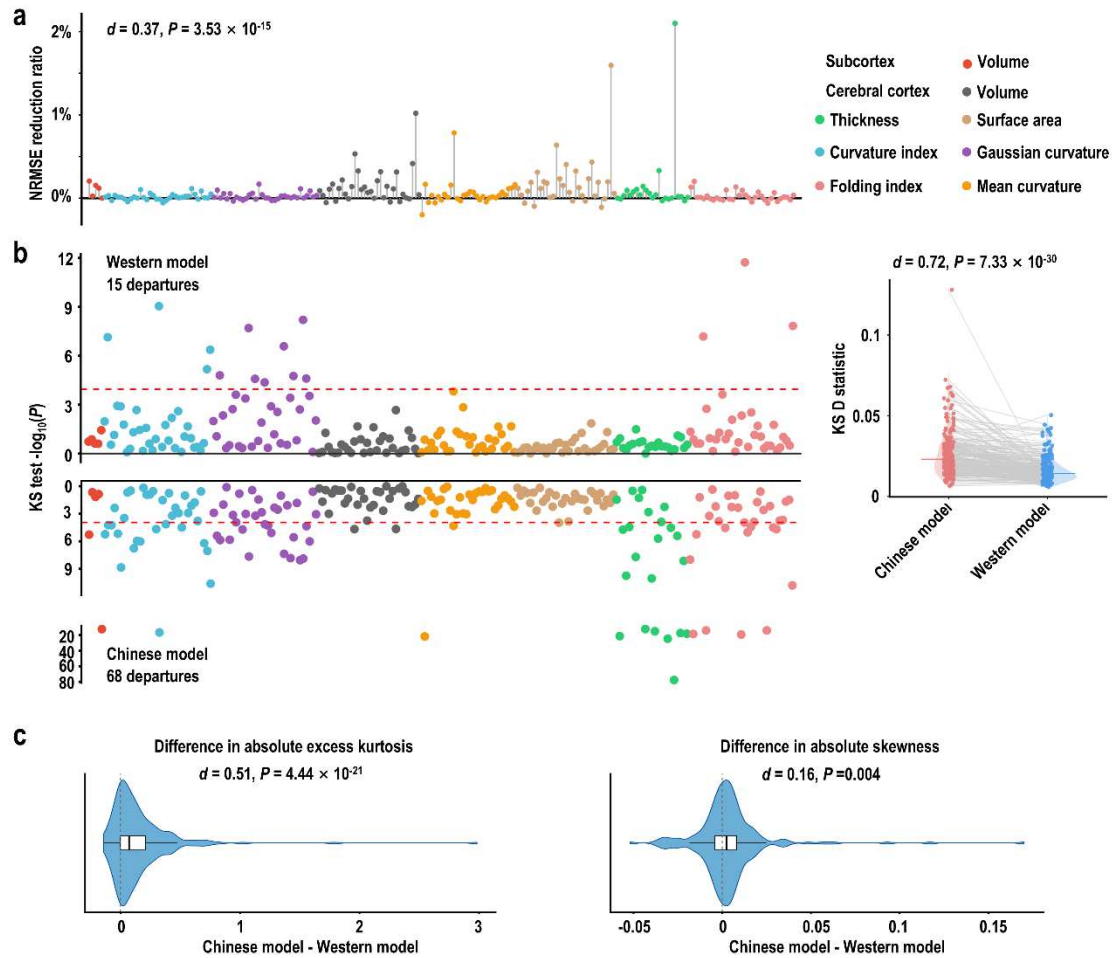
For each disorder, we assessed which normative models (population-matched or population-mismatched) better recapitulated observed case-control AI differences. For each normative model, we calculated intraclass correlation coefficients (ICCs) to evaluate across-phenotype agreement between model-derived and observed Cohen's d values of case-control AI differences. ICC differences between the two models were assessed using permutation tests (1,000 permutations) to determine whether population-matched models provided a more accurate characterization of disorder-associated AI deviations.

Sensitivity analyses of Chinese–Western asymmetry differences

To evaluate whether Chinese–Western asymmetry difference patterns were robust to age-specific sample-size imbalance, we derived resampled Chinese–Western difference curves for each of the 221 phenotypes using the age-matched resampled trajectories. Specifically, pairwise differences between 100 Chinese and 100 Western age-matched resampled trajectories were computed as Chinese minus Western, yielding age-specific 95% CIs from 10,000 resampled difference curves. Robustness was quantified using TCR. Each original Chinese–Western difference curve was sampled at 1,000 equally spaced age points between 1 and 100 years, and TCR was defined as the proportion of curve values at these sampled age points that fell within the corresponding age-specific 95% CIs from age-matched resampling. For each phenotype, the resampled Chinese–Western difference pattern was classified based on the age-specific 95% CIs from all resampled difference curves. The resulting resampling-based pattern assignments were then compared with the original assignments to evaluate the robustness of Chinese–Western difference-pattern classification.

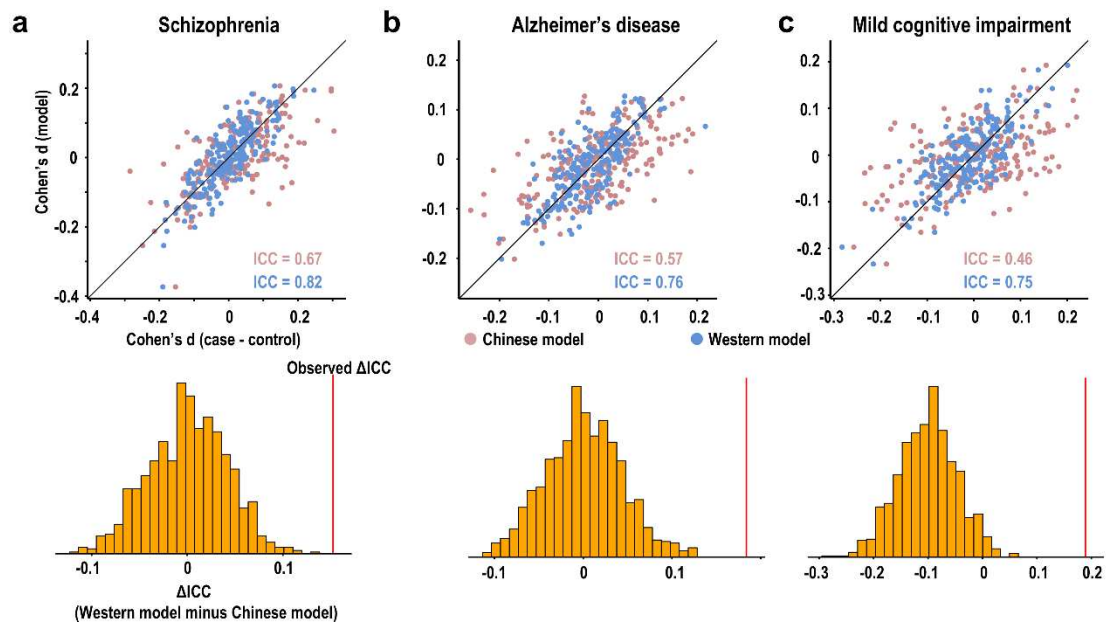


Extended Data Fig. 1 | Sex consistency of Chinese–Western asymmetry difference patterns. **a**, Assignments of Chinese–Western asymmetry difference patterns (Chinese minus Western) for brain asymmetry phenotypes in males and females, with phenotypes color-coded by their assignments. The bar chart shows the proportions of asymmetry difference patterns across the 221 phenotypes in males and females. **b**, Phenotypes with concordant (yellow) and discordant (green) Chinese–Western asymmetry difference patterns between sexes, with corresponding proportions shown in the pie chart. **c**, An example (supramarginal Gaussian curvature) of sex discordance in Chinese–Western asymmetry difference patterns. For this phenotype, males show rightward difference, whereas females show leftward difference. Abbreviation: CI, confidence interval.

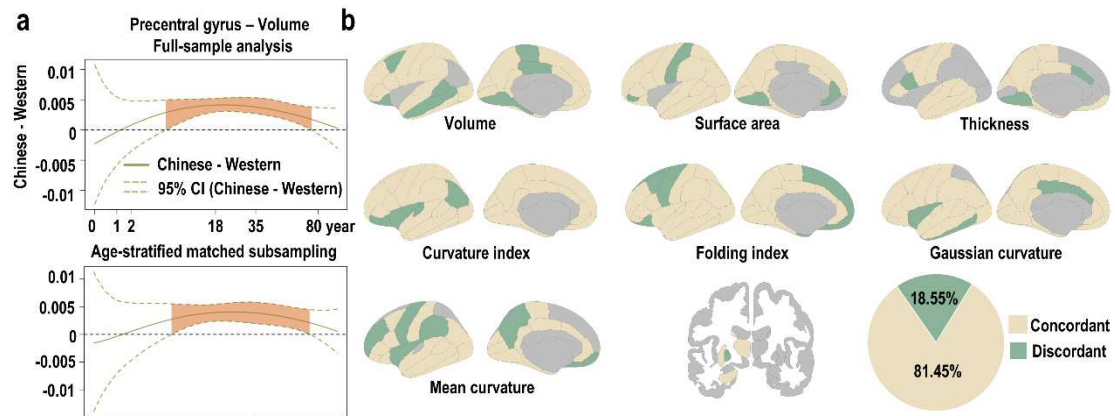


Extended Data Fig. 2 | Predictive accuracy and distributional calibration of Chinese and Western normative asymmetry models in an independent healthy Western sample. **a**, Lollipop plot shows NRMSE reduction ratios for brain asymmetry phenotypes. Positive values indicate better predictive performance of the Western model compared with the Chinese model. Points are color-coded by phenotype category. **b**, Distributional calibration of Chinese and Western models in the Western test sample. The left panel shows $-\log_{10}(P)$ values from phenotype-wise Kolmogorov–Smirnov tests assessing whether deviation z-scores in the test sample conform to the expected normal distribution; the horizontal dashed line indicates the Bonferroni-corrected significance threshold of $P = 1.13 \times 10^{-4}$. Overall, Western models yield fewer phenotypes with

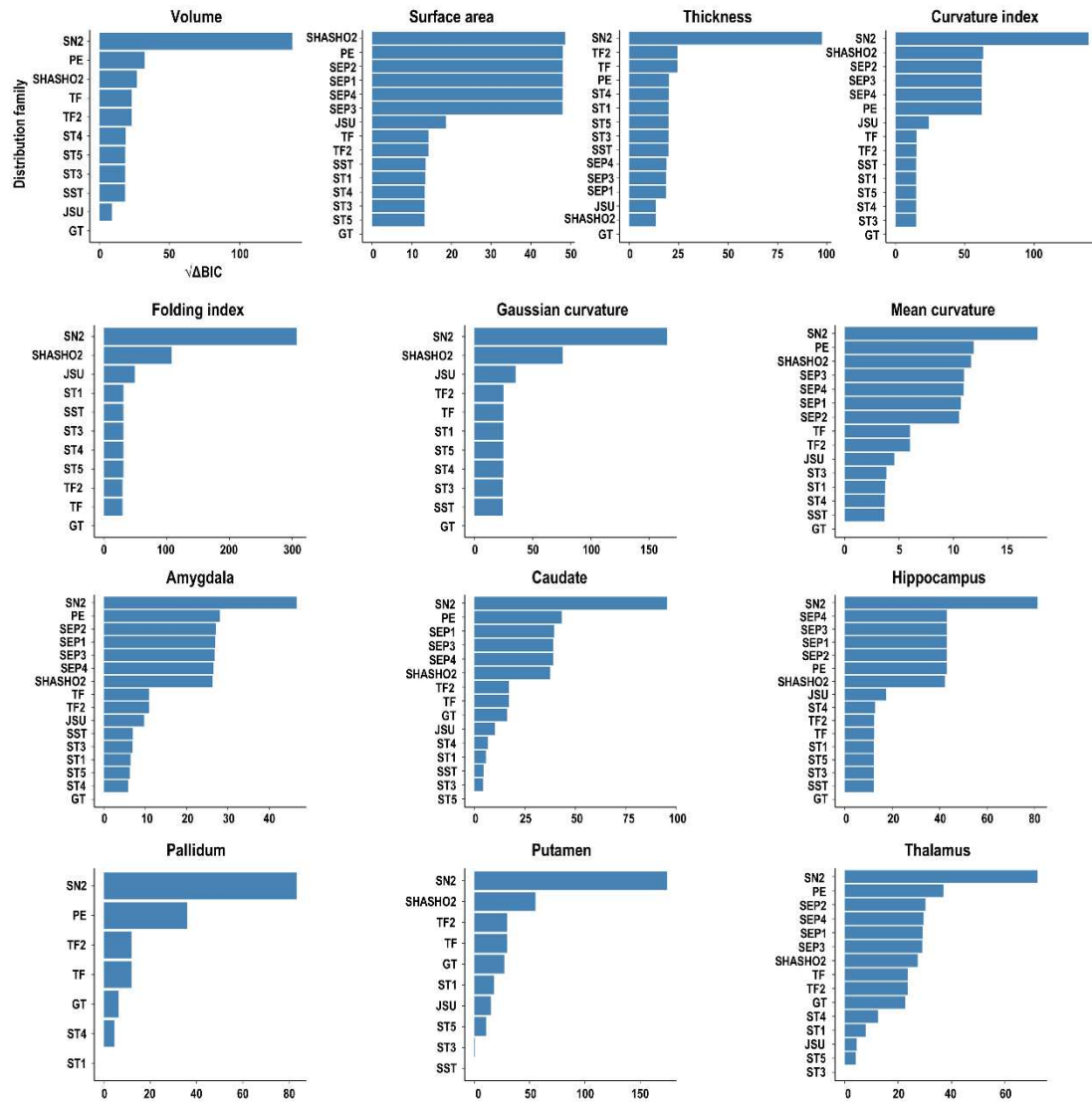
significant departures than Chinese models (15 vs. 68). The right panel compares D-statistics of all phenotypes between the two models. **c**, Violin plots show phenotype-wise differences in absolute excess kurtosis (left panel) and absolute skewness (right panel) of deviation z-scores (Chinese minus Western). Positive values indicate better calibration for Western models than for Chinese models. Abbreviations: AI, asymmetry index; KS, Kolmogorov–Smirnov; NRMSE, normalized root mean squared error.



Extended Data Fig. 3 | Differences in disorder-associated AI deviations estimated by Chinese and Western normative models in Western case-control pairs. a–c, AI deviations (Cohen's d values) for schizophrenia (a), Alzheimer's disease (b), and mild cognitive impairment (c) estimated by Chinese and Western normative models in the Western case-control pairs. The upper panels display scatter plots of the observed (x-axis) versus predicted (y-axis) Cohen's d values, and the lower panels show histograms of permutation distributions of ICC differences, with the observed differences marked by vertical red lines.



Extended Data Fig. 4 | Robustness assessment of between-population asymmetry difference under age-stratified matched subsampling. **a**, A representative example (leftward asymmetry in the precentral gyrus) of robust Chinese–Western asymmetry difference-patterns before (upper panel) and after (lower panel) age-stratified matched subsampling. **b**, Phenotypes are color-coded according to the consistency of Chinese–Western asymmetry difference-pattern assignments between the full-sample analysis and the age-stratified matched subsampling analysis. The pie chart shows proportions of phenotypes with concordant (81.45%) and discordant (18.55%) assignments.



Extended Data Fig. 5 | Selecting optimal distributions for GAMLSS modeling of brain asymmetry phenotypes. Bar plots show $\sqrt{\Delta\text{BIC}}$ values for candidate distribution families across seven cortical asymmetry phenotypes for the whole cerebral hemisphere and six subcortical volume asymmetry phenotypes. ΔBIC is calculated as the difference between each distribution family's BIC and the lowest BIC value for each phenotype. Smaller $\sqrt{\Delta\text{BIC}}$ values indicate better model fit, with 0 indicating the best-fitting. For regional cortical asymmetry phenotypes, the distribution selected for the corresponding hemisphere-level cortical asymmetry measure is applied. Abbreviations: BIC, Bayesian information criterion; GAMLSS, generalized additive models for location, scale and

shape.

Data Availability

The normative models for cerebral asymmetry in the Chinese population are publicly available on GitHub at <https://github.com/linliyuan-panda/chinese-western-cerebral-asymmetry>. The MRI datasets listed in **Supplementary Table 1** and **Supplementary Table 3** are partially publicly available at the Adolescent Brain Cognitive Development Study (<https://nda.nih.gov/>), the Autism Brain Imaging Data Exchange Initiative (https://fcon_1000.projects.nitrc.org/indi/abide/), the ADHD200 (https://fcon_1000.projects.nitrc.org/indi/adhd200/), the Alzheimer's Disease Neuroimaging Initiative (<https://adni.loni.usc.edu/>), the Age_ility Project (<https://www.nitrc.org/projects/age-ility>), the Baby Connectome Project (<https://nda.nih.gov/>), the Brain Genomics Superstruct Project (<https://doi.org/10.7910/DVN/25833>), the Calgary Preschool MRI Dataset (<https://osf.io/axz5r/>), the Cambridge Centre for Ageing and Neuroscience Dataset (<https://www.cam-can.org/index.php?content=dataset>), the Chinese Color Nest Project (<https://www.scidb.cn/en/detail?dataSetId=c81f0e90a51b4cfca348ce4da6ca734e>), the Chinese Human Connectome Project (<https://www.scidb.cn/en/detail?dataSetId=f512d085f3d3452a9b14689e9997ca94>), the Cincinnati MR Imaging of Neurodevelopment (https://nda.nih.gov/edit_collection.html?id=2329); the Consortium for Reliability and

1239 Reproducibility (https://fcon_1000.projects.nitrc.org/indi/CoRR/html/), the Dallas
 1240 Lifespan Brain Study (https://fcon_1000.projects.nitrc.org/indi/retro/dlbs.html), the
 1241 Developing Human Connectome Project
 1242 (<http://www.developingconnectome.org/data-release/second-data-release/>), the
 1243 University of North Carolina Early Brain Development Study
 1244 ([https://www.med.unc.edu/psych/research/psychiatry-department-research-](https://www.med.unc.edu/psych/research/psychiatry-department-research-programs/early-brain-development-research/)
 1245 [programs/early-brain-development-research/](https://www.med.unc.edu/psych/research/psychiatry-department-research-programs/early-brain-development-research/)), the FBIRN Phase II Multi-site fMRI
 1246 programs (<http://www.nbirn.net/Resources/Downloads>), the Healthy Brain Network
 1247 (https://fcon_1000.projects.nitrc.org/indi/cmi_healthy_brain_network/MRI_EEG.html
 1248), the Human Connectome Project (<https://www.humanconnectome.org>), the Lifespan
 1249 Human Connectome Project (<https://nda.nih.gov/>), the Nathan Kline Institute-
 1250 Rockland Sample Dataset (https://fcon_1000.projects.nitrc.org/indi/pro/nki.html), the
 1251 Neuroscience in Psychiatry Network Dataset (<https://nspn.org.uk/>), the Open Access
 1252 Series of Imaging Studies (<https://sites.wustl.edu/oasisbrains/>), the Pediatric Imaging,
 1253 Neurocognition, and Genetics (PING) Data Repository (<http://pingstudy.ucsd.edu/>),
 1254 the Pixar Dataset (<https://openfmri.org/dataset/ds000228/>), the Philadelphia
 1255 Neurodevelopmental Cohort
 1256 (<https://www.med.upenn.edu/bbl/philadelphianeurodevelopmentalcohort.html>), the
 1257 Queensland Twin Adolescent Brain
 1258 (<https://openneuro.org/datasets/ds004146/versions/1.0.4>), the Strategic Research
 1259 Program for Brain Sciences MRI Dataset (<https://bicr-resource.atr.jp/srpbsopen/>), the
 1260 OpenfMRI database ds000115 (<https://openfmri.org/dataset/ds000115/>), the

SchizConnect Project (including the BrainGluSchi, the COBRE, the MCICShare, and the NMorphCH dataset, <https://schizconnect.org/>), the Southwest University Adult Lifespan Dataset (http://fcon_1000.projects.nitrc.org/indi/retro/sald.html), the Southwest University Longitudinal Imaging Multimodal Brain Data Repository (http://fcon_1000.projects.nitrc.org/indi/retro/southwestuni_qiu_index.html), and the UK Biobank Brain Imaging Dataset (<https://www.ukbiobank.ac.uk/>). The dhcpSym surface atlases in aged from 40 to 44 postmenstrual weeks is available at <https://brain-development.org/brain-atlases/atlases-from-the-dhcp-project/cortical-surface-template/>. The UNC 4D infant cortical surface atlases are available at <https://bbm.web.unc.edu/tools/>. The fs_LR_32k surface atlas is available at <https://balsa.wustl.edu/>.

Code Availability

Analysis code is publicly available on GitHub at <https://github.com/linliyuanyan/panda/chinese-western-cerebral-asymmetry>. The code used to implement the GAMLSS models was adapted from Bethlehem et al.⁵² and is available on GitHub (<https://github.com/brainchart/Lifespan>). Software packages used in this manuscript include MRIQC v0.15.0 (<https://github.com/nipreps/mriqc>), QuNex v0.93.2 (<https://gitlab.qunex.yale.edu/>), HCP pipeline v4.4.0-rc-MOD-e7a6af9 (<https://github.com/Washington-University/HCPpipelines/releases>), dHCP structural pipeline v1 (<https://github.com/BioMedIA/dhcp-structural-pipeline>), iBEAT pipeline v2.0.0 (<https://github.com/iBEAT-V2/iBEAT-V2.0-Docker>), MSM v3.0

(https://github.com/ecr05/MSM_HOCR), FreeSurfer v6.0.0
(<https://surfer.nmr.mgh.harvard.edu/>), FSL v6.0.5
(<https://fsl.fmrib.ox.ac.uk/fsl/fslwiki>), Connectome Workbench v1.5.0
(<https://www.humanconnectome.org/software/connectome-workbench>), MATLAB
R2018b (<https://www.mathworks.com/products/matlab.html>), R v4.2.0
(<https://www.r-project.org>), GAMLSS package v5.4-3 (<https://www.gamlss.com/>), and
ggplot2 package v3.4.2 (<https://ggplot2.tidyverse.org/>).

Acknowledgements

This work was supported by the Science & Technology Fundamental Resources
Investigation Program (2025FY102300 and 2025FY102302 to C. Yu); the National
Natural Science Foundation of China (82430063 and 82030053 to C. Yu; 82021004,
82327807, and 31830034 to Y. He; T24B2012 to L. Sun; 824B2051 to X. Liang;
82472052 and 81971599 to W. Qin; and 32371142 and 32171083 to Jintao Zhang); the
Tianjin Key Medical Discipline Construction Project (TJYXZDXK-3-008C to W. Qin);
the Tianjin Natural Science Foundation (19JCYBJC25100 to W. Qin); and the TEDA–
UCB Science Innovation Award (to W. Qin). The funders had no role in study design,
data collection and analysis, decision to publish or preparation of the paper. We thank
Xinian Zuo, Xinlin Zhou, Dairong Cao, Xiangrong Zhang, Tao Wu, and Keith Kendrick
for collecting a subset of the data for this study. We thank Chenxuan Pang, Qian Wang,
Qian Yu, Maolin Li for their assistance with the visual inspection component of data
quality control. We are grateful to the Adolescent Brain Cognitive Development

1303 (ABCD) Study, the Autism Brain Imaging Data Exchange (ABIDE) Initiative, the
 1304 ADHD200 Initiative, the Alzheimer's Disease Neuroimaging Initiative (ADNI), the
 1305 Age_ility Project, the Baby Connectome Project (BCP), the Brain Genomics
 1306 Superstruct Project (BGSP), the Calgary Preschool MRI Dataset, the Cambridge Centre
 1307 for Ageing and Neuroscience (Cam-CAN) Dataset, the Beijing Cohort in Children
 1308 Brain Development Project (CBD), the Chinese Color Nest Project (CCNP), the
 1309 Chinese Human Connectome Project (CHCP), the Cincinnati MR Imaging of
 1310 Neurodevelopment Dataset (C-MIND), the Consortium for Reliability and
 1311 Reproducibility (CORR), the Dallas Lifespan Brain Study (DLBS), the developing
 1312 Human Connectome Project (dHCP), the University of North Carolina Early Brain
 1313 Development Study (EBDS), the FBIRN Phase II Multi-site fMRI programs, the
 1314 Healthy Brain Network (HBN), the Human Connectome Project (HCP), the Lifespan
 1315 Human Connectome Project (HCPA & HCPD), the Nathan Kline Institute-Rockland
 1316 Sample (NKI-RS) Dataset, the Neuroscience in Psychiatry Network (NSPN) Dataset,
 1317 the Open Access Series of Imaging Studies (OASIS), the OpenfMRI database ds000115,
 1318 the Pixar Dataset, the Philadelphia Neurodevelopmental Cohort (PNC), the Queensland
 1319 Twin Adolescent Brain (QTAB), the Southwest University Adult Lifespan Dataset
 1320 (SALD), the SchizConnect Project, the Southwest University Longitudinal Imaging
 1321 Multimodal (SLIM) Brain Data Repository, the UCLA dataset, the UK Biobank (UKB)
 1322 Brain Imaging Dataset, the Disease Imaging Data Archiving: major depressive disorder
 1323 (DIDA-MDD) Working Group, the Multi-center Alzheimer Disease Imaging (MCADI)
 1324 Consortium, the Chinese Imaging Genetics (CHIMGEN) Consortium, and the Chinese

Lifespan Brain Mapping (C-LBM) Consortium.

ABCD: data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development Study (<https://abcdstudy.org>), held in the NIMH Data Archive (NDA). This is a multisite, longitudinal study designed to recruit more than 10,000 children age 9-10 and follow them over 10 years into early adulthood. The ABCD Study® is supported by the National Institutes of Health and additional federal partners under award numbers U01DA041048, U01DA050989, U01DA051016, U01DA041022, U01DA051018, U01DA051037, U01DA050987, U01DA041174, U01DA041106, U01DA041117, U01DA041028, U01DA041134, U01DA050988, U01DA051039, U01DA041156, U01DA041025, U01DA041120, U01DA051038, U01DA041148, U01DA041093, U01DA041089, U24DA041123, U24DA041147. A full list of supporters is available at <https://abcdstudy.org/federal-partners.html>. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/consortium_members/. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or ABCD consortium investigators. The ABCD data repository grows and changes over time.

ABIDE I: primary support for the work by Adriana Di Martino was provided by the (NIMH K23MH087770) and the Leon Levy Foundation. Primary support for the work by Michael P. Milham and the INDI team was provided by gifts from Joseph P. Healy and the Stavros Niarchos Foundation to the Child Mind Institute, as well as by

an NIMH award to MPM (NIMH R03MH096321).

ABIDE II: primary support for the work by Adriana Di Martino and her team was provided by the National Institute of Mental Health (NIMH 5R21MH107045).

Primary support for the work by Michael P. Milham and his team provided by the National Institute of Mental Health (NIMH 5R21MH107045); Nathan S. Kline Institute of Psychiatric Research). Additional Support was provided by gifts from Joseph P. Healey, Phyllis Green and Randolph Cowen to the Child Mind Institute.

ADNI: Data used in preparation of this article were obtained from the Alzheimer’s Disease Neuroimaging Initiative (ADNI) database (adni.loni.usc.edu). As such, the investigators within the ADNI contributed to the design and implementation of ADNI and/or provided data but did not participate in analysis or writing of this report. A complete listing of ADNI investigators can be found at: http://adni.loni.usc.edu/wp-content/uploads/how_to_apply/ADNI_Acknowledgement_List.pdf. Data collection and sharing for this project was funded by the Alzheimer's Disease Neuroimaging Initiative (ADNI) (National Institutes of Health Grant U01 AG024904) and DOD ADNI (Department of Defense award number W81XWH-12-2-0012). ADNI is funded by the National Institute on Aging, the National Institute of Biomedical Imaging and Bioengineering, and through generous contributions from the following: AbbVie, Alzheimer's Association; Alzheimer's Drug Discovery Foundation; Araclon Biotech; BioClinica, Inc.; Biogen; Bristol-Myers Squibb Company; CereSpir, Inc.; Cogstate; Eisai Inc.; Elan Pharmaceuticals, Inc.; Eli Lilly and Company; EuroImmun; F. Hoffmann-La Roche Ltd and its affiliated company Genentech, Inc.; Fujirebio; GE

1369 Healthcare; IXICO Ltd.; Janssen Alzheimer Immunotherapy Research &
1370 Development, LLC.; Johnson & Johnson Pharmaceutical Research & Development
1371 LLC.; Lumosity; Lundbeck; Merck & Co., Inc.; Meso Scale Diagnostics, LLC.;
1372 NeuroRx Research; Neurotrack Technologies; Novartis Pharmaceuticals Corporation;
1373 Pfizer Inc.; Piramal Imaging; Servier; Takeda Pharmaceutical Company; and
1374 Transition Therapeutics. The Canadian Institutes of Health Research is providing
1375 funds to support ADNI clinical sites in Canada. Private sector contributions are
1376 facilitated by the Foundation for the National Institutes of Health (www.fnih.org). The
1377 grantee organization is the Northern California Institute for Research and Education,
1378 and the study is coordinated by the Alzheimer's Therapeutic Research Institute at the
1379 University of Southern California. ADNI data are disseminated by the Laboratory for
1380 Neuro Imaging at the University of Southern California.

1381 BCP: data used herein is supported by NIH grant (1U01MH110274) and the efforts of
1382 the UNC/UMN Baby Connectome Project Consortium.

1383 dHCP: data were provided by the developing Human Connectome Project, KCL-
1384 Imperial-Oxford Consortium funded by the European Research Council under the
1385 European Union Seventh Framework Programme (FP/2007-2013) / ERC Grant
1386 Agreement no. [319456]. We are grateful to the families who generously supported
1387 this trial.

1388 HCP: data were provided by the Human Connectome Project, WU-Minn Consortium
1389 (Principal Investigators: David Van Essen and Kamil Ugurbil; 1U54MH091657)
1390 funded by the 16 NIH Institutes and Centers which support the NIH Blueprint for

1391 Neuroscience Research; and by the Mc-Donnell Center for Systems Neuroscience at
1392 Washington University.

1393 HCP Lifespan: data used in this publication was supported by the National Institute of
1394 Mental Health of the National Institutes of Health under Award Number
1395 U01MH109589 and by funds provided by the McDonnell Center for Systems
1396 Neuroscience at Washington University in St. Louis. The content is solely
1397 the responsibility of the authors and does not necessarily represent the official views
1398 of the National Institutes of Health.

1399 NKI-RS: funding for key personnel provided in part by the New York State Office of
1400 Mental Health and Research Foundation for Mental Hygiene. Additional project
1401 support provided by the NKI Center for Advanced Brain Imaging (CABI), the Brain
1402 Research Foundation (Chicago, IL), the Stavros Niarchos Foundation, and NIH grant
1403 P50 MH086385-S1.

1404 NSPN: the NSPN study was funded by a Wellcome Trust award to the University of
1405 Cambridge and the University College London.

1406 UK Biobank: this research has been conducted using data from UK Biobank
1407 (www.ukbiobank.ac.uk). UK Biobank is generously supported by its founding funders
1408 the Wellcome Trust and UK Medical Research Council, as well as the Department of
1409 Health, Scottish Government, the Northwest Regional Development Agency, British
1410 Heart Foundation, and Cancer Research UK.

1411 **Author contributions**

1412 L. Lin, L. Sun, W. Qin, Y. He, and C. Yu conceptualized the study. C. Yu and Y. He
1413 supervised the project. L. Lin, L. Sun, W. Qin and C. Yu designed the methodology. L.
1414 Lin, L. Sun and W. Qin analyze the data. L. Lin and L. Sun developed visualizations.
1415 C. Yu, Y. He, Q. Dong, Z. Ye, Xiaochu Zhang, K. Li, F. Feng, C. Lin, J. Zhu, D. Wei, L.
1416 Zhang, Tian Tian, C. Wang, Jintao Zhang, Qi Huang, Jing Zhang, Chao Liu, Q. Qian,
1417 Bing Zhang, M. Meng, X. Liang, M. Xia, F. Liu, Huaigui Liu, N. Chen, Jinzhu Yang,
1418 B. Hou, Zeyu Liu, C. Huang, Y. Yu, H. Cai, J. Qiu, Q. Chen, Ying Wei, P. Miao, H.
1419 Song, W. Men, Yunxia Li, Yaou Liu, Y. Duan, P. Zhang, N. Yang, X. Fan, Q. Cai, X.
1420 Gao, S. Qiu, Yujie Liu, S. Tao, M. Wang, Y. Shen, Q. Gong, X. Huang, Y. Tian, G. Ji,
1421 W. Zhu, F. Xie, J. Feng, L. Hu, J. Gao, T. Jiang, X. Zhu, Yuhang Zhang, Liping Liu,
1422 Hanjun Liu, W. Liao, P. Liang, D. Wang, H. Wang, T. Guo, Z. Dai, S. Lui, K. Xu, L. Li,
1423 P. Xie, C. Feng, G. Cui, J. Wu, X. Yin, G. Ding, J. Xian, L. Zhao, J. Lu, Zhifen Liu, Y.
1424 Han, Z. Yuan, Xilin Zhang, T. Si, F. Zhou, Y. Bi, D. Wu, F. Gao, Fei Wang, S. Qin, G.
1425 Wang, Feng Chen, Z. Zhang, J. Sui, Huaifu Chen, J. Cai, S. Liu, Z. Geng, C. Zhang, N.
1426 Mao, H. Yin, B. Liu, H. Ma, B. Gao, Y. Miao, X. Kong, Y. Zhou, Li. Liu, J. Hu, L.
1427 Wang, Quan Zhang, H. Shu, Peijun Wang, T.M.C. Lee, Q. Cao, L. Yang, Xi Zhang, W.
1428 Luo, M. Liang, H. Yao, M. Li, H. Huang, Y. Peng, Z. Han, C. Zhou, H. Xu, M. Feng,
1429 W. Shen, Y. Hu, Huajun Chen, Ying Wang, G. Gong, Z. Yan, Xiaojun Xu, J. Liu, G.
1430 Chen, Pan Wang, Y. Yang, Cheng Luo, T. Han, Huiguang He, C. Chen, Q. Zou, Hesheng
1431 Liu, H. Zhang, C. Chai, C. Lu, Y. Tu, Yong Liu, D. Lin, W. Zhao, Xiufeng Xu, X. Liu,
1432 Z. Cui, Zheng Wang, R. Huang, Z. Li, Yunzhe Liu, X. Li, X. Yang, N. Zhang, A. Chen,

1433 Bin Zhang, P. Qin, Chen Liu, Z. Yao, Yanjun Wei, H. Yuan, Feng Wang, Yu Zhang,
1434 Quan Zhang, F. Hu, H. Xie, X. Wu, Jiaojian Wang, G. Fan, Zhiqun Wang, D. Zhang, H.
1435 Zhong, Yonggang Wang, L. Bai, Yongmei Li, X. Wei, Jinhui Wang, Yi Zhang, Hongjian
1436 He, S. Li, T. Zhang, F. Jiang, Jian Yang, Feiyan Chen collected a subset of the data for
1437 this study. L. Lin, W. Qin, and C. Yu wrote the manuscript. All authors reviewed the
1438 final manuscript.

1439

1440 **Competing Interests**

1441 The authors have declared that no competing interests exist.

1442

1443

References

- 1 Kong, X. Z. *et al.* Mapping cortical brain asymmetry in 17,141 healthy individuals worldwide via the ENIGMA Consortium. *Proc Natl Acad Sci U S A* **115**, E5154-E5163, doi:10.1073/pnas.1718418115 (2018).
- 2 Kong, X. Z. *et al.* Mapping brain asymmetry in health and disease through the ENIGMA consortium. *Hum Brain Mapp* **43**, 167-181, doi:10.1002/hbm.25033 (2022).
- 3 Roe, J. M. *et al.* Tracing the development and lifespan change of population-level structural asymmetry in the cerebral cortex. *Elife* **12**, doi:10.7554/eLife.84685 (2023).
- 4 Hartwigsen, G., Bengio, Y. & Bzdok, D. How does hemispheric specialization contribute to human-defining cognition? *Neuron* **109**, 2075-2090, doi:10.1016/j.neuron.2021.04.024 (2021).
- 5 Wu, X. *et al.* Developing brain asymmetry shapes cognitive and psychiatric outcomes in adolescence. *Nat Commun* **16**, 4480, doi:10.1038/s41467-025-59110-9 (2025).
- 6 Labache, L., Ge, T., Yeo, B. T. T. & Holmes, A. J. Language network lateralization is reflected throughout the macroscale functional organization of cortex. *Nature Communications* **14**, doi:10.1038/s41467-023-39131-y (2023).
- 7 Kopal, J. *et al.* Using rare genetic mutations to revisit structural brain asymmetry. *Nat Commun* **15**, 2639, doi:10.1038/s41467-024-46784-w (2024).
- 8 Thiebaut de Schotten, M. *et al.* A lateralized brain network for visuospatial attention. *Nat Neurosci* **14**, 1245-1246, doi:10.1038/nn.2905 (2011).
- 9 Turner, B. O., Marinsek, N., Ryhal, E. & Miller, M. B. Hemispheric lateralization in reasoning. *Ann N Y Acad Sci* **1359**, 47-64, doi:10.1111/nyas.12940 (2015).
- 10 Ocklenburg, S. *et al.* Clinical implications of brain asymmetries. *Nature Reviews Neurology* **20**, 383-394, doi:10.1038/s41582-024-00974-8 (2024).
- 11 Zuo, Z. *et al.* Asymmetry in cortical thickness and subcortical volume in treatment-naïve major depressive disorder. *Neuroimage Clin* **21**, 101614, doi:10.1016/j.nicl.2018.101614 (2019).
- 12 Schijven, D. *et al.* Large-scale analysis of structural brain asymmetries in schizophrenia via the ENIGMA consortium. *Proc Natl Acad Sci U S A* **120**, e2213880120, doi:10.1073/pnas.2213880120 (2023).
- 13 Roe, J. M. *et al.* Asymmetric thinning of the cerebral cortex across the adult lifespan is accelerated in Alzheimer's disease. *Nat Commun* **12**, 721, doi:10.1038/s41467-021-21057-y (2021).
- 14 Long, X. *et al.* Distinct laterality alterations distinguish mild cognitive impairment and Alzheimer's disease from healthy aging: statistical parametric mapping with high resolution MRI. *Hum Brain Mapp* **34**, 3400-3410, doi:10.1002/hbm.22157 (2013).
- 15 Bogdanov, S. *et al.* Lifespan Trajectories of Asymmetry in White Matter Tracts. *bioRxiv*, doi:10.1101/2025.09.29.678806 (2025).
- 16 Dorfschmidt, L. *et al.* Charting structural brain asymmetry across the human lifespan. *bioRxiv*, doi:10.1101/2025.07.21.665924 (2025).
- 17 Ge, J. *et al.* Increasing diversity in connectomics with the Chinese Human Connectome Project. *Nat Neurosci* **26**, 163-172, doi:10.1038/s41593-022-01215-1 (2023).
- 18 Tang, Y. *et al.* Brain structure differences between Chinese and Caucasian cohorts: A

comprehensive morphometry study. *Hum Brain Mapp* **39**, 2147-2155, doi:10.1002/hbm.23994 (2018).

19 Dong, H. M. *et al.* Charting brain growth in tandem with brain templates at school age. *Sci Bull (Beijing)* **65**, 1924-1934, doi:10.1016/j.scib.2020.07.027 (2020).

20 Fan, X. R. *et al.* A longitudinal resource for population neuroscience of school-age children and adolescents in China. *Sci Data* **10**, 545, doi:10.1038/s41597-023-02377-8 (2023).

21 Zhao, T. *et al.* Unbiased age-specific structural brain atlases for Chinese pediatric population. *Neuroimage* **189**, 55-70, doi:10.1016/j.neuroimage.2019.01.006 (2019).

22 Sun, L. *et al.* Population-specific brain charts reveal Chinese-Western differences in neurodevelopmental trajectories. *bioRxiv*, doi:10.1101/2025.06.17.659820 (2025).

23 Lou, Y. *et al.* Brain asymmetry differences between Chinese and Caucasian populations: a surface-based morphometric comparison study. *Brain Imaging Behav* **14**, 2323-2332, doi:10.1007/s11682-019-00184-7 (2020).

24 Li, J. *et al.* Cross-ethnicity/race generalization failure of behavioral prediction from resting-state functional connectivity. *Sci Adv* **8**, eabj1812, doi:10.1126/sciadv.abj1812 (2022).

25 Saige Rutherford, T. W., Charlotte Fraza, Nathaniel G. Harnett, Christian F. Beckmann, Henricus G. Ruhe, Andre F. Marquand. To which reference class do you belong? Measuring racial fairness of reference classes with normative modeling. *arXiv*, doi:<https://doi.org/10.48550/arXiv.2407.19114> (2024).

26 Koelkebeck, K. *et al.* The contribution of cortical thickness and surface area to gray matter asymmetries in the healthy human brain. *Hum Brain Mapp* **35**, 6011-6022, doi:10.1002/hbm.22601 (2014).

27 Xiang, L., Crow, T. J., Hopkins, W. D. & Roberts, N. Comparison of Surface Area and Cortical Thickness Asymmetry in the Human and Chimpanzee Brain. *Cereb Cortex* **34**, doi:10.1093/cercor/bhaa202 (2020).

28 Fu, J. *et al.* Cross-ancestry genome-wide association studies of brain imaging phenotypes. *Nat Genet* **56**, 1110-1120, doi:10.1038/s41588-024-01766-y (2024).

29 Sha, Z. *et al.* The genetic architecture of structural left-right asymmetry of the human brain. *Nat Hum Behav* **5**, 1226-1239, doi:10.1038/s41562-021-01069-w (2021).

30 Wang, J., Ma, S., Yu, P. & He, X. Evolution of Human Brain Left-Right Asymmetry: Old Genes with New Functions. *Mol Biol Evol* **40**, doi:10.1093/molbev/msad181 (2023).

31 Peterson, R. E. *et al.* Genome-wide Association Studies in Ancestrally Diverse Populations: Opportunities, Methods, Pitfalls, and Recommendations. *Cell* **179**, 589-603, doi:10.1016/j.cell.2019.08.051 (2019).

32 Liu, N. *et al.* Cross-ancestry genome-wide association meta-analyses of hippocampal and subfield volumes. *Nat Genet* **55**, 1126-1137, doi:10.1038/s41588-023-01425-8 (2023).

33 Collaborators, G. B. D. R. F. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* **396**, 1223-1249, doi:10.1016/S0140-6736(20)30752-2 (2020).

34 Huang, C. M., Doole, R., Wu, C. W., Huang, H. W. & Chao, Y. P. Culture-Related and Individual Differences in Regional Brain Volumes: A Cross-Cultural Voxel-Based Morphometry Study. *Front Hum Neurosci* **13**, 313, doi:10.3389/fnhum.2019.00313 (2019).

35 Marquand, A. F. *et al.* Conceptualizing mental disorders as deviations from normative

functioning. *Mol Psychiatry* **24**, 1415-1424, doi:10.1038/s41380-019-0441-1 (2019).

36 Rutherford, S. *et al.* The normative modeling framework for computational psychiatry. *Nat Protoc* **17**, 1711-1734, doi:10.1038/s41596-022-00696-5 (2022).

37 Echocardiographic Normal Ranges Meta-Analysis of the Left Heart, C. Ethnic-Specific Normative Reference Values for Echocardiographic LA and LV Size, LV Mass, and Systolic Function: The EchoNoRMAL Study. *JACC Cardiovasc Imaging* **8**, 656-665, doi:10.1016/j.jcmg.2015.02.014 (2015).

38 Zhao, J. *et al.* Which fetal growth charts should be used? A retrospective observational study in China. *Chin Med J (Engl)* **135**, 1969-1977, doi:10.1097/CM9.0000000000002335 (2022).

39 Lo, J. C., Kim, S., Chandra, M. & Ettinger, B. Applying ethnic-specific bone mineral density T-scores to Chinese women in the USA. *Osteoporos Int* **27**, 3477-3484, doi:10.1007/s00198-016-3673-9 (2016).

40 Kong, X. Z. *et al.* Large-Scale Phenomic and Genomic Analysis of Brain Asymmetrical Skew. *Cereb Cortex* **31**, 4151-4168, doi:10.1093/cercor/bhab075 (2021).

41 Guadalupe, T. *et al.* Human subcortical brain asymmetries in 15,847 people worldwide reveal effects of age and sex. *Brain Imaging Behav* **11**, 1497-1514, doi:10.1007/s11682-016-9629-z (2017).

42 Alfaro-Almagro, F. *et al.* Image processing and Quality Control for the first 10,000 brain imaging datasets from UK Biobank. *Neuroimage* **166**, 400-424, doi:10.1016/j.neuroimage.2017.10.034 (2018).

43 Glasser, M. F. *et al.* The minimal preprocessing pipelines for the Human Connectome Project. *Neuroimage* **80**, 105-124, doi:10.1016/j.neuroimage.2013.04.127 (2013).

44 Wang, L. *et al.* iBEAT V2.0: a multisite-applicable, deep learning-based pipeline for infant cerebral cortical surface reconstruction. *Nat Protoc* **18**, 1488-1509, doi:10.1038/s41596-023-00806-x (2023).

45 Makropoulos, A. *et al.* The developing human connectome project: A minimal processing pipeline for neonatal cortical surface reconstruction. *NeuroImage* **173**, 88-112, doi:10.1016/j.neuroimage.2018.01.054 (2018).

46 Williams, L. Z. J. *et al.* Structural and functional asymmetry of the neonatal cerebral cortex. *Nat Hum Behav* **7**, 942-955, doi:10.1038/s41562-023-01542-8 (2023).

47 Wu, Z. *et al.* Construction of 4D infant cortical surface atlases with sharp folding patterns via spherical patch-based group-wise sparse representation. *Hum Brain Mapp* **40**, 3860-3880, doi:10.1002/hbm.24636 (2019).

48 Sun, L. *et al.* Human lifespan changes in the brain's functional connectome. *Nature Neuroscience* **28**, 891-901, doi:10.1038/s41593-025-01907-4 (2025).

49 R. A. Rigby, D. M. S. Generalized additive models for location, scale and shape. *Journal of the Royal Statistical Society*, doi:<https://doi.org/10.1111/j.1467-9876.2005.00510.x> (2005).

50 D. Mikis Stasinopoulos, R. A. R. Generalized Additive Models for Location Scale and Shape (GAMLSS) in R. *Journal of Statistical Software*, doi:<https://doi.org/10.18637/jss.v023.i07> (2008).

51 Borghi, E. *et al.* Construction of the World Health Organization child growth standards: selection of methods for attained growth curves. *Statistics in Medicine* **25**, 247-265, doi:10.1002/sim.2227 (2006).

1575 52 Bethlehem, R. A. I. *et al.* Brain charts for the human lifespan. *Nature* **604**, 525-533,
1576 doi:10.1038/s41586-022-04554-y (2022).
1577 53 Marquand, A., Rutherford, S. & Dinga, R. Fairly evaluating the performance of normative
1578 models. *Lancet Digit Health* **6**, e775, doi:10.1016/S2589-7500(24)00200-0 (2024).
1579 54 Nida Alyas, J. H., Bethany Little, Peter N. Taylor, Yujiang Wang, Karoline Leiberg. Normative
1580 Modelling in Neuroimaging: A Practical Guide for Researchers. *arXiv*,
1581 doi:<https://doi.org/10.48550/arXiv.2509.07237> (2025).
1582 55 Postema, M. C. *et al.* Altered structural brain asymmetry in autism spectrum disorder in a
1583 study of 54 datasets. *Nat Commun* **10**, 4958, doi:10.1038/s41467-019-13005-8 (2019).
1584

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryTables.xlsx](#)