Magnetic Resonance Imaging 33 (2015) 816–821

Contents lists available at ScienceDirect

Magnetic Resonance Imaging

journal homepage: www.mrijournal.com

Brain morphology is individual-specific information

Hidemasa Takao [a,*], Naoto Hayashi [b], Kuni Ohtomo [a]

[a] Department of Radiology, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan
[b] Department of Computational Diagnostic Radiology and Preventive Medicine, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan

ARTICLE INFO

Article history:
Received 22 February 2015
Accepted 30 March 2015

Keywords:
Biometrics
Brain morphology
Eigenbrain
Magnetic resonance imaging
Recognition
Voxel-based morphometry

ABSTRACT

The identification of individual differences in brain morphology is important to understand the background of individual differences in brain functions. In the present study, we investigated whether brain morphology is discernibly different among individuals and is personally identifiable information. Using structural magnetic resonance imaging data from 215 healthy subjects scanned twice (scan interval = 1.0 ± 0.1 years), we performed brain recognition by image normalization using a voxel-based morphometry approach, feature extraction based on principal component analysis, and calculating the Euclidean distances between image pairs projected into the subspace. Even with only 32 dimensions used for projection, the rank-one identification rate was 99.5%. With ≥112 dimensions used, the rank-one identification rate was 100%. At a false accept rate of 0.01%, the genuine accept rates were 95.8% and 100% with 32 and ≥128 dimensions used for projection, respectively. There was little difference in the Euclidean distances among different combinations of scanners used or between probe–gallery image pairs with and without scanner upgrade. These results indicate that brain morphology can identify a specific individual; i.e., brain morphology is personally identifiable information. Individually different brain morphology may occur as a collection of differences in brain structures that reflect individual differences in a variety of performances and various psychological characteristics and behavior patterns, and may provide the background of individual differences in personality and brain function.

1. Introduction

To understand the background of individual differences in brain functions, it is important to identify individual differences in brain morphology. Brain morphology is the study of the size and shape of the brain and its structures. With recent advances in magnetic resonance imaging (MRI) and image analysis techniques, brain morphometry has been widely used to study brain structures and their differences in normal brains, in developing and aging brains, and in a variety of neurological and neuropsychiatric disorders. Structural changes occur during brain development, maturation, and aging that are related to changes in brain functions. Moreover, a variety of neurological and neuropsychiatric disorders cause and/or are related to changes in brain structures. In addition to its association with brain development and aging, as well as neurological and neuropsychiatric disorders, brain morphology is also related to various types of high-level performance such as those displayed by taxi drivers [1], musicians [2,3], mathematicians [4], and bilingual individuals [5]. Even learning and training have been shown to cause changes in brain structures [6]. In addition, brain morphometry has been performed to investigate the relationship of brain structures to a wide range of personality dimensions and behavioral traits. Morphometric changes in the brain manifest as a gain or loss of brain tissue, which can be detected by structural MRI. Most typically, T1-weighted images are used for morphometric analysis of the brain with MRI.

Techniques for morphometric analysis of these brain images include visual assessment, manual tracing of regions of interest, and automated methods such as voxel-based morphometry (VBM) [7]. Manual tracing of regions of interest is a widely used form of brain morphometry; however, it is a subjective and time-consuming procedure, requires considerable anatomical expertise, and is generally limited to brain structures that have constant anatomical boundaries. Recently, a number of automated, unbiased, objective techniques have been developed and widely used to examine brain morphology, including volume-based methods such as VBM [7], tensor-based morphometry, and deformation-based morphometry; and surface-based methods such as cortical thickness analysis. VBM is one of the most commonly used automated techniques for assessing brain structures. Briefly, VBM involves segmenting images into gray matter, white matter, and cerebrospinal fluid; warping these tissue maps into standard space; smoothing these spatially normalized tissue maps; before performing voxel-by-voxel statistical analysis.

* Corresponding author at: Department of Radiology, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113–8655, Japan.Tel.: +81 3 5800 8666; fax: +81 3 5800 8935.
E-mail address: takaoh-tky@umin.ac.jp (H. Takao).

http://dx.doi.org/10.1016/j.mri.2015.03.010
0730-725X/

Recently, large-scale brain imaging studies have been conducted to overcome the limited power of smaller studies and to increase reliability of the findings. These studies include the Alzheimer's Disease Neuroimaging Initiative study [8], a multi-center observational study of healthy elders and patients with mild cognitive impairment and Alzheimer's disease; and the Human Connectome Project [9], a project to construct a map of the complete structural and functional neural connections in vivo within and across healthy individuals. These large-scale brain imaging studies have made "de-identified" data, including imaging and clinical information and DNA sequences, widely available to the scientific community for examination and exploration.

The recent proliferation of digital networks and the growth of the information society have further enhanced the need for information security and reliable personal identification. Biometrics use physical characteristics such as fingerprints, iris properties, and face extraction to establish the identity of a person. The unique nature of the fingerprint is one of the most well-known and commonly used biometric traits. Fingerprint recognition has been in use for over a century and has recently become automated following advances in computer technology. In contrast, humans most commonly recognize individuals on the basis of facial features. Although automated face recognition by computers has improved, this method is more difficult than automated fingerprint recognition, and the need for a high-accuracy system remains.

In the present study, we investigated whether brain morphology is discernibly different among individuals and is personally identifiable information. Using structural MRI data from 215 healthy subjects who were scanned twice, for this purpose, we performed brain recognition by image normalization using the VBM approach [10], feature extraction based on principal component analysis (PCA), and calculation of the Euclidean distances between image pairs in the subspace.

2. Materials and methods

2.1. Subjects

The present study included data from 215 healthy subjects (153 males, 62 females, mean age = 56 ± 9 years, age range = 40–83 years) [11]. None of the subjects had a history of neuropsychiatric disorders, including serious head trauma, psychiatric disorder, or alcohol/substance abuse or dependence. The mean mini-mental state examination score was 29.6 ± 0.7 (range = 27–30). A board-certified radiologist reviewed all scans including T1-weighted and T2-weighted images and found no gross abnormalities such as infarct, hemorrhage, or brain tumor in any subject. Fazekas score (range, 0–3) was 0 (absence) or 1 (caps, pencil-thin lining and/or punctate foci) [12]. The Ethical Committee of the University of Tokyo Hospital approved the study. After a complete explanation of the study to each subject, written informed consent was obtained.

2.2. Imaging data acquisition

Magnetic resonance data were obtained on two 3.0-T Signa scanners (GE Medical Systems, Milwaukee, WI) with an 8-channel brain phased-array coil. The scanners were the exact same model, and were simultaneously upgraded from HDx to HDxt. Each subject was scanned twice, at an interval of about 1 year (mean interval = 1.0 ± 0.1 years, range = 0.6–1.3 years) [11]. Of the 215 subjects, (A) 67 were scanned twice with scanner 1; (B) 44 were first scanned with scanner 1 and then with scanner 2; (C) 56 were first scanned with scanner 2 and then with scanner 1; and (D) the remaining 48 were scanned twice with scanner 2. Of the 215 subjects, 151 underwent both scans before scanner upgrade, and the remaining 64 underwent the first scan before upgrade and the second after the upgrade.

T1-weighted images were acquired using three-dimensional inversion recovery prepared fast spoiled gradient recalled acquisition in the steady state in 176 sagittal slices (repetition time = 5.3–5.4 ms; echo time = 1.7 ms; inversion time = 450 ms; flip angle = 15°; field of view = 250 mm; slice thickness = 1.0 mm with no gap; acquisition matrix = 256 × 256; number of excitations = 0.5; image matrix = 256 × 256). Parallel imaging (array spatial sensitivity encoding technique) was used with an acceleration factor of 2.0. Voxel dimensions were 0.977 mm × 0.977 mm × 1.0 mm. The images were corrected for spatial distortion due to gradient non-linearity using grad_unwarp [13–15] and for intensity non-uniformity using the nonparametric non-uniform intensity normalization algorithm N3 [14–16].

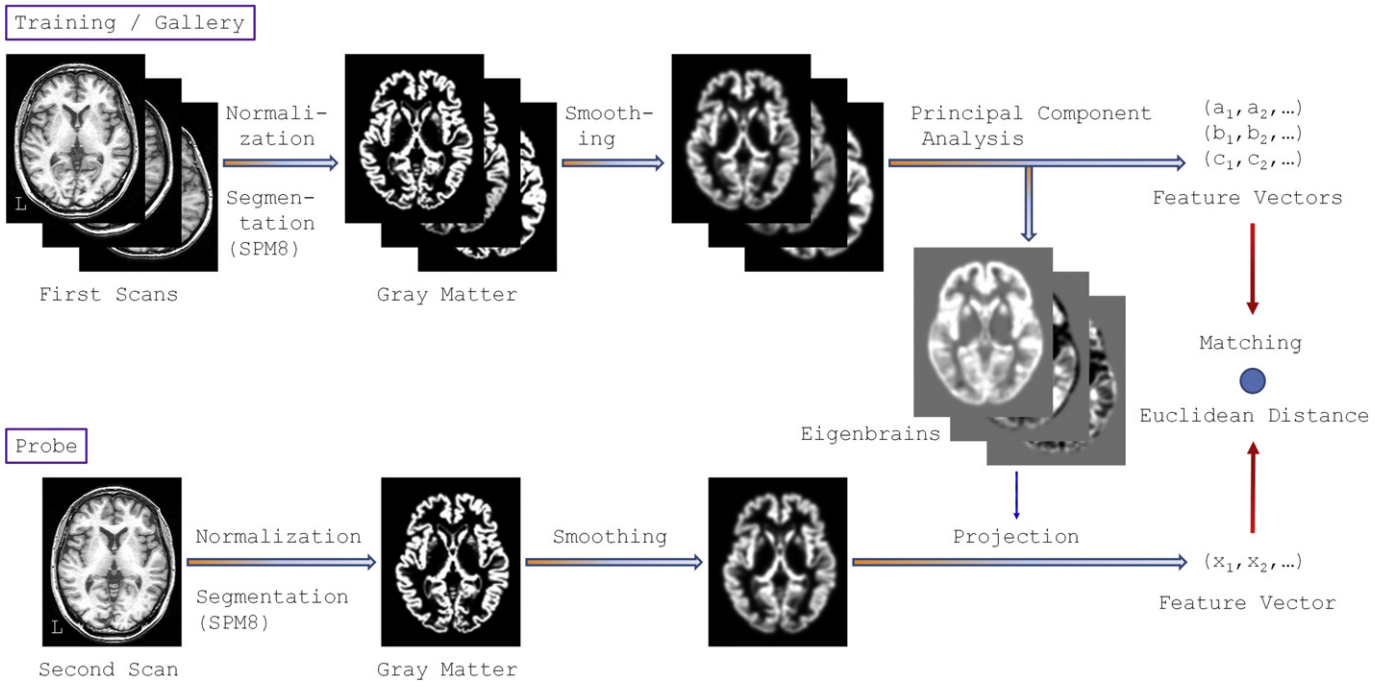

Fig. 1. Summary of image processing for brain recognition using PCA.