Analysis of automated methods for spatial normalization of lesioned brains

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Normalization of brain images is a crucial step in MRI data analysis, especially when dealing with abnormal brains. Although cost function masking (CFM) appears to successfully solve this problem and seems to be necessary for patients with chronic stroke lesions, this procedure is very time consuming. The present study sought to find viable, fully automated alternatives to cost function masking, such as Automatic Lesion Identification (ALI) and Diffeomorphic Anatomical Registration using Exponentiated Lie algebra (DARTEL). It also sought to quantitatively assess, for the first time, Symmetrical Normalization (SyN) with constrained cost function masking. The second aim of this study was to investigate the normalization process in a group of drug-resistant epileptic patients with large resected regions (temporal lobe and amygdala) and in a group of stroke patients. A dataset of 500 artificially generated lesions was created using ten patients with brain-resected regions (temporal lobectomy), ten stroke patients and twenty five-healthy subjects. The results indicated that although a fully automated method such as DARTEL using New Segment with an extra prior (the mean of the white matter and cerebro-spinal fluid) obtained the most accurate normalization in both patient groups, it produced a shrinkage in lesion volume when compared to Uni

Introduction

Spatial normalization is one of the most important steps in second-level group magnetic resonance imaging (MRI) analyses. Structural images of participants are normalized to a template (standard or group), ensuring that a one-to-one correspondence among the brains of each individual in the group is created. Normalization becomes more complex when it has to deal with patients with brain lesions. These brains have often greater differences than those individual variations characterizing healthy brains due to important lesions or pathologies (Brett et al., 2001). Correct normalization of individual brains is essential to ensure that brain areas are properly aligned, maximizing sensitivity and minimizing false-negative results. To this end, multiple normalization algorithms have been implemented in fully automated software programs.

Two of the most used normalization algorithms are the Diffeomorphic Anatomical Registration using Lie Algebra (DARTEL) (Ashburner, 2007) and its predecessor, Unified Segmentation (Ashburner and Friston, 2005), implemented in the Statistical Parametric Mapping software (SPM, Wellcome Department of Imaging Neuroscience, University College, London, UK, www.fil.ion.ucl.ac.uk/spm/). Unified Segmentation combines segmentation, bias correction and spatial normalization under the same iterative model using white matter (WM), gray matter (GM) and cerebrospinal fluid (CSF) tissue maps as priors (TPMs). These TPMs are deformed by a linear combination of a thousand cosine transform bases, and several Gaussian distributions are used to model the intensity of each tissue class. Unlike Unified Segmentation, DARTEL utilizes a large deformation framework to preserve topology, assuring that the deformations are invertible, diffeomorphic and parameterised by a flow field. Rather than using a thousand parameters for the registration process as Unified Segmentation, DARTEL uses about six million and the registration itself involves alternating between computing an average template of the GM and WM TPMs from all subjects and warping all subjects’ TPMs into a better alignment with the template created (Ashburner, 2009). Both of these algorithms are segmentation-dependant, as
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Appendix A. Supplementary data

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References