Effects of Brain MRI Classification and Segmentation on Cortical Atlases and Maps

Abstract No:

2423

Authors:

Paul Rasser[1], Thai Vinh Nguyen[2], Ulrich Schall[3], Paul Thompson[4]

Institutions:

[1]Schizophrenia Research Institute, Darlinghurst, Australia, [2]Queensland Brain Institute, University of Queensland, St. Lucia, Australia, [3]University of Newcastle, Callaghan, Australia, [4]UCLA, Los Angeles, CA

Introduction:

Population-based atlases and statistical maps derived from structural MRI have become an important tool for examining cortical differences between clinical populations and matched healthy control subjects (Kuperberg et al., 2003, Thompson et al., 2004, Csernansky et al., 2008). Tissue classification (Atkins et al., 1998, Shattuck et al. 2001) and segmentation (Smith, 2002, Fennema-Notestine et al., 2006) are necessary steps in the generation these cerebral atlases. Prior evaluations of tissue classification and segmentation methods have compared results at the MRI level against 'gold standards' using indexes such as the Jaccard Similarity Coefficient (JSC) (Fennema-Notestine et al., 2006, Carass et al., 2007) and sensitivity and specificity (Fennema-Notestine et al., 2006, Klauschen et al., 2009). However, the effect of different tissue classification and segmentation procedures on the final statistical maps and cortical atlases has yet to be linked to these MRI level indices.

Methods:

To relate segmentation and tissue classification errors, measured using the JSC, to their ultimate effect on population-based cortical maps and atlases, we applied three different tissue classification procedures – PVC (Shattuck et al, 2001), FAST (Smith, et al 2004) and thresholding (Atkins et al., 1998) - in combination with manually segmented and randomly altered cerebral masks of 48 healthy subjects' T1-weighted brain MRI scans collected at 1.5 Tesla. The cerebral masks were randomly altered, with different probabilities, in three different ways. These included: addition or removal of incorrect voxels to the mask (i.e., over- or under-sampling), and mixed sampling where both over and under-sampling were performed. Noise was artificially added to the manually derived masks after applying edge detection to the mask and identifying all voxels falling within the intensity range of white/grey matter within a kernel of radius 3 mm. The inclusion/exclusion of these voxels in the mask was based on one of the five probabilities 5%, 10%, 15%, 20% and 25% (additionally, probabilities of 30% and 35% were also applied for over-masking). Comparisons were made using PVC for the tissue classification, and the manually derived masks against the mixed, over-, and under-sampled masks at the various probabilities. Similarly, comparisons were made using FAST and thresholding for tissue classification and the manually derived and under-sampling masks. The effects of these different procedures were examined at both the MRI level using the JSC, and on cortical grey matter density measures at the atlas level using cortical pattern matching and permutation tests on the resulting cortical maps (Thompson et al., 2004). Finally, we compared the resulting correlation maps (i.e. grey matter density resulting from the manually derived mask vs. under-sampled masks) at each probability level when PVC, FAST or thresholding are used.

Results:

By applying the randomly altered manually segmented masks and any one of the tissue classification procedures consistently, we found that small differences at the MRI level (as

indicated by the JSC) could be significantly detected at the atlas level (in the statistical maps). At the same time, very large differences across the tissue classification procedures at the MRI level as indicated by a small JSC, were not found to lead to differences detectable at the atlas level. The effects of attributing additional non-cerebral tissue as cerebrum in segmentation were less at the atlas level than the effects of cropping the cerebrum in the scans.

Conclusions:

The use of different tissue classification techniques had only a small effect on the results of cortical maps provided that a single technique was used for all subjects. Even so, small systematic segmentation errors in one group may appear as significant group differences when making statistical maps of group differences. We recommend that metrics of accuracy based on both the MRI scans and the final group statistical maps should be considered when comparing and validating tissue classification and segmentation algorithms.

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Categories

- Anatomical MRI (Imaging Techniques and Contrast Mechanism)
- Classification and Predictive Modeling (Modeling and Analysis)
- Flattening, Segmentation (Modeling and Analysis)
- Motion Correction/Spatial Normal, Atlas Construction (Modeling and Analysis)