Multi-channel (T1, T2, PD) segmentation improves grey-matter estimates for voxel-based morphometry (VBM) within and across age groups

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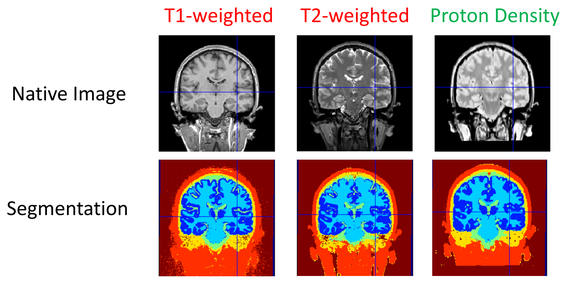
BACKGROUND

Automated segmentation of MRI images into separate tissue compartments (grey matter [GM], white matter [WM], cerebrospinal fluid [CSF], etc.) is non-trivial, and difficulties are exacerbated when sample ages span a wide range (Peelle et al., 2012; Streitburger et al., in press). Different MRI sequences have unique tissue contrast profiles and therefore provide complementary information that may be of use to the segmentation algorithm. The present study investigated whether including additional sequences (T2, PD) to supplement T1 images would improve segmentation results.



METHODS

PARTICIPANTS

Re-Test Sample: N=15 (9 female), age M=27y (21-41), Scanned twice, delay M=28d (7-42) days.
CamCAN Sample: N=250 (122 female), age M=57y (18-88), Scanned once only.

MRI ACQUISITION

Structural brain images were acquired using a 3T Siemens TimTrio MRI scanner (at the MRC Cognition and Brain Sciences Unit, Cambridge, UK) with a 32-channel head coil. Image sequences:

T1: TR=2250ms; TE=2.98ms; FA=9 degrees
T1np: TR=2250ms; TE=2.98ms; FA=9 degrees (no parallel acceleration; Re-Test sample only)
T2: TR=2800ms; TE=408ms; FA=120 degrees
PD: TR=2500ms; TE=23ms; FA=110 degrees (Re-Test sample only)

All were whole-brain, 192-slice volumes with FOV 256x256 and voxel size 1x1x1mm (except PD: 92 slices, 1x1x2mm).

AUTOMATED SEGMENTATION

Segmentation and normalisation were conducted using the SPM8 Seg toolbox, which is an update of 'unified' segmentation (Ashburner & Friston, 2005). For each participant and session, images for each scan type were coregistered to the T1 image, bias-corrected (regularisation=.001), then normalised into MNI space and segmented (tissue types N=6; sampling distance=1; segmented image voxel size=1.5mm). Segmentation was performed for each scan type separately and for multi-channel combinations.

VBM ANALYSIS

GM density images were smoothed (8mm FWHM) and submitted to a VBM analysis (Ashburner & Friston, 2000) with scan types as groups in the GLM, and with an explicit mask that included only voxels for which the template GM p>.1. In the CamCAN sample, age and sex were added to the GLM. We report an analysis of age masked by a contrast of scan type (mask p<.001 uncorrected). All maps are thresholded at p<.05 FWE.

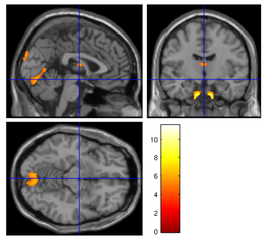
LABELLING CONSISTENCY

For the Re-Test sample, voxel-wise labelling consistency for each tissue class was defined as: p1*p2+q1*q2, where pN is the probability of that tissue class in session N; and qN is 1-pN. We report significant t-tests for consistency values that are greater than that for T1 alone.

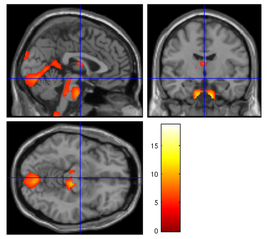
ANALYSES AND RESULTS

VBM of Grey Matter Density

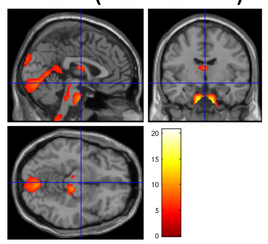
T1 > (T1+T2)



T1 > (T1+PD)



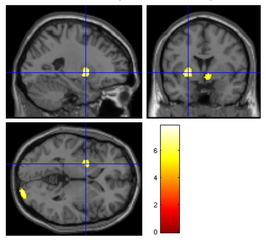
T1 > (T1+T2+PD)



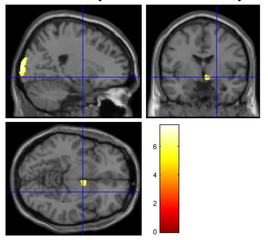
T1 < (T1+T2)

n.s.

T1 < (T1+PD)



T1 < (T1+T2+PD)

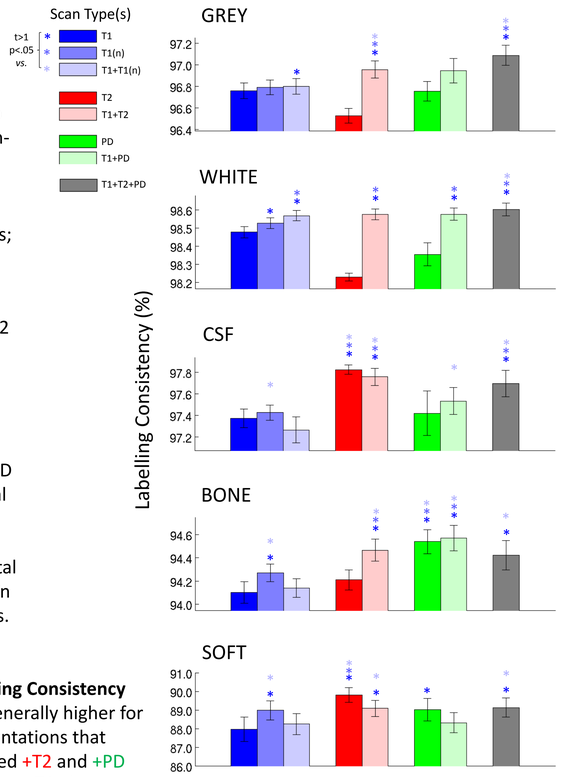


Single-channel (T1 only) segmentations assigned higher GM probabilities to ("misclassified") some non-brain tissue laying on the extremes of the GM template (between and beneath the occipital lobes; medial to anterior MTL).

Multi-channel (+T2) segmentations including T2 produced no significant increases in GM signal relative to T1-only.

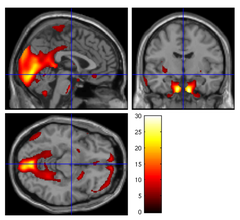
Multi-channel (+PD) segmentations including PD produced higher GM signal in some subcortical structures (thalamus, caudate) and in the occipital poles, and less GM signal in some brainstem structures.

Labelling Consistency

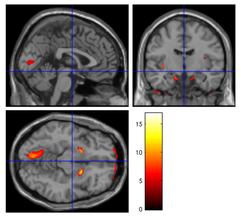


Labelling Consistency was generally higher for segmentations that included +T2 and +PD relative to T1 alone.

Age Effects (VBM of Grey Matter Density)



Single-channel (T1) misclassification pattern was replicated in the CamCAN Ageing study sample.



Age-related decline in GM density was found in regions misclassified as GM on single-channel (T1) segmentation.

SUMMARY

Segmentation with multiple scan types (T1+T2(+PD)) improves upon that with T1 alone (parallel, non-parallel, or both combined) by sharpening the distinction between GM and surrounding non-brain tissues.

Errors in GM estimates relying on a single scan type may inflate differences attributed to age.

Multi-channel segmentations including T2 and/or PD improved GM (but not WM) labelling consistency across scanning sessions.

Information gained by adding scans with complementary tissue-contrast profiles overcomes potential errors incurred at coregistration stage.

REFERENCES

Ashburner & Friston (2000). Voxel-based morphometry – the methods. *NeuroImage*, *11*, 805-821.

Ashburner & Friston (2005). Unified segmentation. *NeuroImage*, *26*, 839-851.

Peelle, Cusack, & Henson (2012). Adjusting for global effects in voxel-based morphometry: gray matter decline in normal aging. *NeuroImage*, *60*, 1503-1516.

Streitburger et al. (in press). Impact of image acquisition on voxel-based morphometry investigations of age-related structural brain changes. *NeuroImage*.

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