Using the Talairach Atlas with the MNI template

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Summary
Many functional imaging studies match their data to a brain template from the Monteal Neurological Institute (MNI). It is common for such studies to report activation coordinates and estimated Brodmann areas (BAs) in terms of the 1988 atlas of Talairach and Tournoux. This can be problematic, as the brains in the Talairach atlas and MNI template differ significantly in shape and size. This poster describes the differences between the atlas and MNI template, and presents an automated non-linear transform to convert a coordinate for one brain to the corresponding point in the other.

The Talairach atlas
The Talairach and Tournoux atlas of 1988 contained three important innovations:

1. a brain coordinate system ("the Talairach coordinate system") defining an origin and X,Y and Z planes. In their system, the brain is first oriented so that a line joining the anterior commissure (AC) and the posterior commisure (PC) is horizontal. The AC is the origin (X=0,Y=0,Z=0).
2. a spatial transform ("the Talairach transform") to match brains of different shape and size, using quadrant by quadrant linear scaling
3. an atlas of an individual brain ("the Talairach brain"), oriented according to the coordinate system.

The Talairach brain was a postmortem specimen from a 60 year old female. It was sliced sagittally; photographs of these slices were used to create drawings of corresponding axial and coronal sections. The authors estimated the position of Brodmann areas on the atlas brain by comparing the anatomy by eye to that shown in Brodmann's original illustrations.

The MNI templates
The MNI templates are based on averages of many MRI scans of healthy young adults. The templates were created in several stages;
1) **First pass - manual scaling to the Talairach brain**; 241 brains were oriented according to a line that was calculated as a best fit through various easily identifiable landmarks; this line is similar to but not the same as the AC-PC line of the Talairach system. For this reason, the MNI templates are often described as being oriented to a 'Talairach-like' coordinate system. Each brain was then scaled to the Talairach brain using manually defined landmarks. The first pass template was the average of these reoriented / rescaled brains.
2) **Second pass - automated registration to first pass template**; The distributed MNI templates are the average of the brains that have been registered to the first pass template. The MNI templates therefore represent a brain of average shape. As yet, there is no published estimate of Brodmann areas corresponding to the anatomy of the MNI template. The MNI template used here is the average of 152 normal brains - the 152 T1 template.

The Talairach Daemon
In order to assess differences between the MNI template and the Talairach brain, we have used data from the Talairach daemon (http://ric.uthscsa.edu/projects/talairachdaemon.html). The daemon contains a database of information for each voxel of 1mm^3 in the Talairach atlas. The plates from the atlas were digitized, and corresponding tissue type (grey matter, white matter, brainstem or cerebellum) and Brodmann's area were estimated from the atlas, for each cubic millimetre in the brain volume. We have used the classification of the voxel tissue type from the daemon, to create a binary brain image, with voxels set to one that were classified as any of the above tissue types. This can be compared directly to the MNI templates.

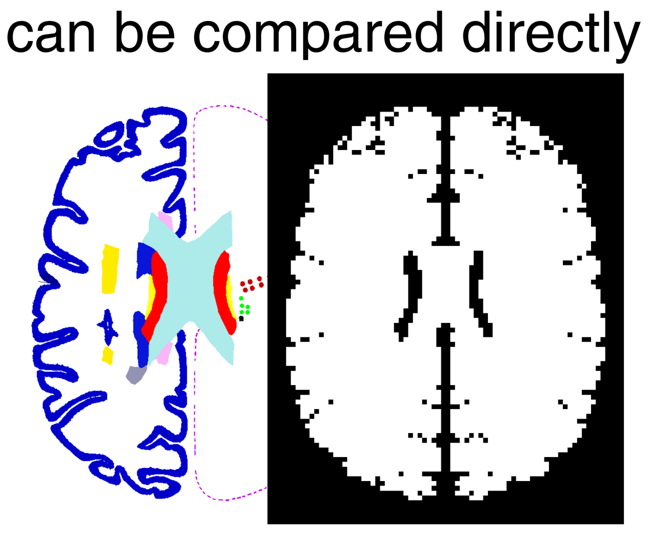


Fig 1: digitized plate for +24mm from the Talairach atlas, and corresponding binary brain outline from data from Talairach daemon

Difference between the MNI templates and the Talairach brain
The MNI template is larger than the Talairach brain; this is most marked for the Z (inferior-superior) dimension; the lowest part of the temporal lobe for the MNI template is 1cm below that of the Talairach brain.

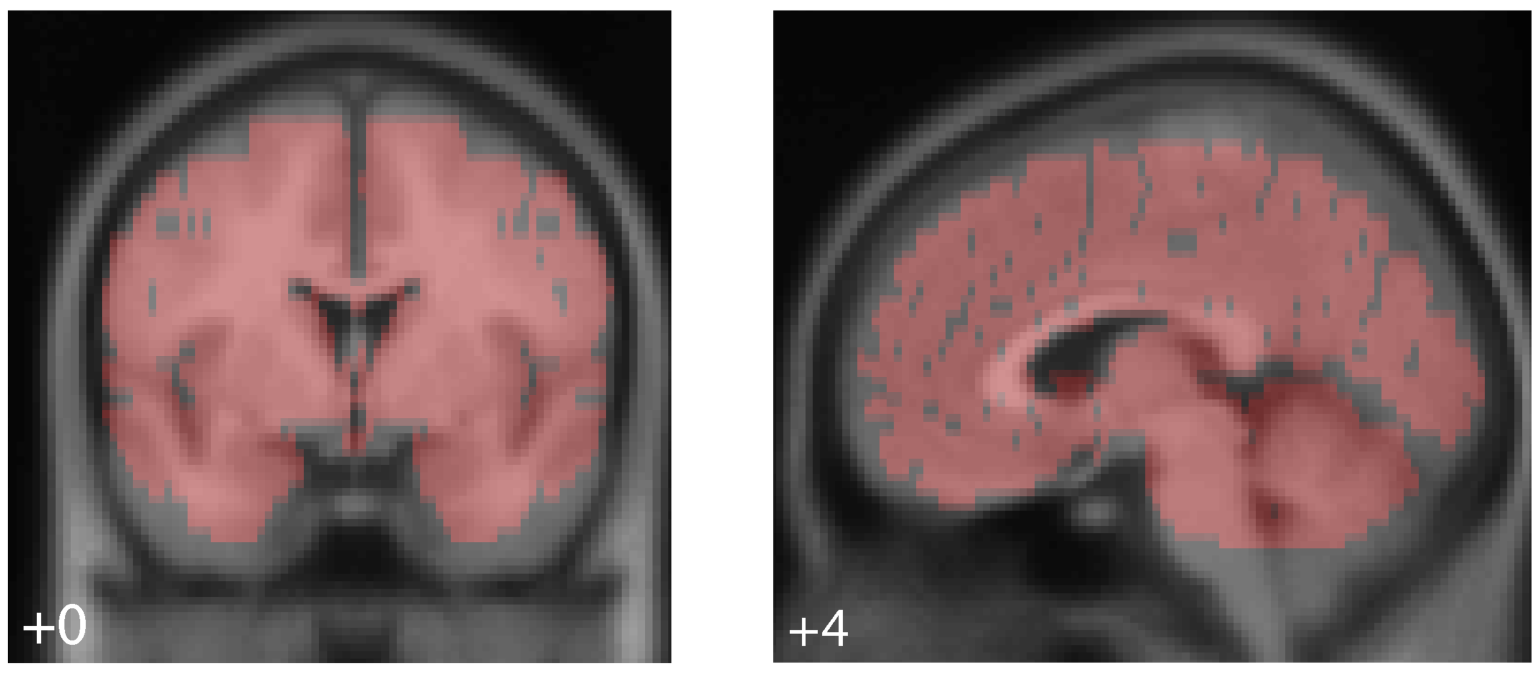
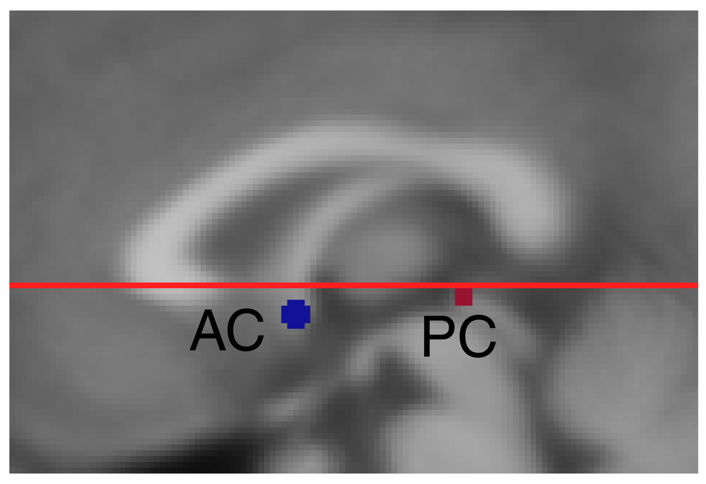


Fig 2: outline of the Talairach brain (in red) overlaid on the MNI 152 T1 template.

The AC is about 4mm below the line at X=0,Z=0, and the AC and PC are not aligned horizontally:

Fig 3: MNI 152 template, with AC marked in blue and PC marked in dark red. The X=0,Z=0 line is marked in light red



Non-linear transformation: MNI to Talairach
To match the two brains, we created a binary brain outline of the MNI template, using the grey and white matter segmentation provided with the MNI templates. These images give the probability of each voxel being grey or white matter. The brain outline is given by taking the sum of grey and white matter probability images. We then calculated the transformation matching the outline of the MNI brain to that for the Talairach brain using the default normalization settings in SPM99, and a masking image to remove the influence of the cerebellum in the Talairach brain from the normalization (the cerebellum is of highly unusual shape in the atlas).

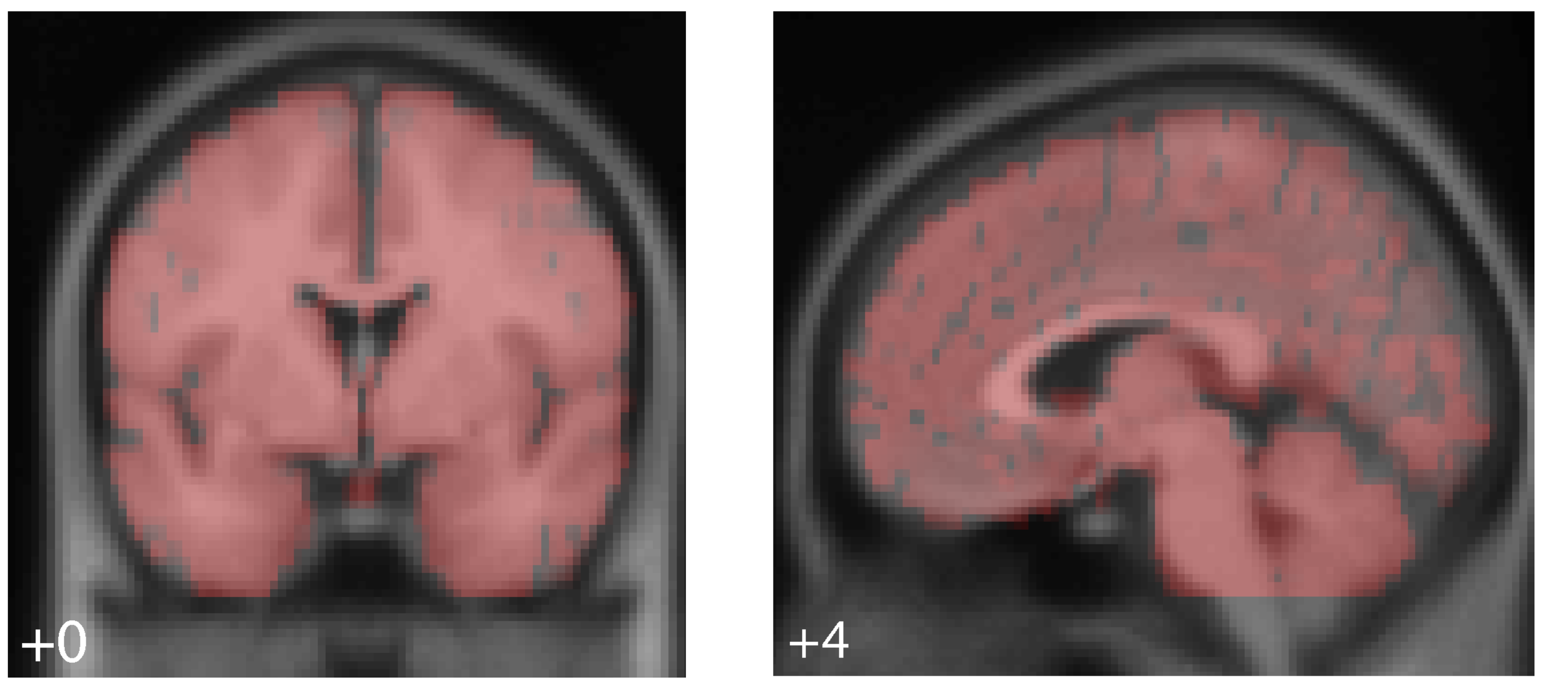


Fig 4: outline of the Talairach brain after normalization (in red) after normalization to an MNI template outline, overlaid on the MNI 152 T1 template.

This transform results in a considerable improvement in the match of the brain outlines. The transformation can be inverted using deformation fields to allow conversion from MNI to Talairach, as well as Talairach to MNI. The same transformations can be used, along with the Talairach BA labels to create BA regions of interest for the MNI brain. Such regions of interest can be important in reducing the multiple comparison problem when there is a clear hypothesis about a given Brodmann area.

Are Talairach Brodmann areas useful?
The primary use of the Talairach atlas has been to estimate the BA in which activation has occurred. The transformation we have suggested may improve the correspondence of the MNI template to the Talairach brain, but does not of course address the approximate nature of the Talairach BA labels. Accurate BA allocation will require advances in spatial normalization, and in the definition of the relation of human cytoarchitecture to neuroanatomy.