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The Talairach coordinate of a point in the MNI space: how to interpret it

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To perform group studies using functional imaging data, the individual brain images are usually transformed into a common coordinate space. The two most widely used spaces in the neuroscience community are the Talairach space and the Montreal Neurological Institute (MNI) space. The Talairach coordinate system has become the standard reference for reporting the brain locations in scientific publication, even when the data have been spatially transformed into different brain templates (e.g., MNI space). When expressed in terms of individual subjects, the mapping of a coordinate in MNI space to the Talairach space generates distinct coordinates for different subjects. In this paper, we describe two approaches to derive the Talairach coordinates from the MNI space, which is based on the ICBM152 template from the International Consortium of Brain Mapping. One approach is the Talairach Method of Piecewise Linear Scaling (TMPLS) as implemented in the AFNI software package; and the other is a template-matching approach using the linear transformation in SPM99. The uncertainty measurements of the mapping results are presented. This may allow researchers to better interpret results reporting in the Talairach coordinates obtained from the MNI space. This study also examines the discrepancy between the derived Talairach coordinates and those obtained from the *mni2tal* script, a tool commonly used by the neuroimaging community. Large discrepancies are found in the inferior regions, superior frontal and occipital regions.

Keywords: Talairach space; MNI space; Spatial normalization; Brain mapping

Introduction

Functional neuroimaging studies typically rely on group studies to identify the most consistent pattern of activation associated with a given cognitive operation. The neuroanatomical difference between individuals make it important to accurately co-register the brain images of multiple subjects. One approach is based on anatomical landmarks, which requires manually identification of the region of interest (ROI) in each individual brain. This is very costly in terms of time and sometimes ROIs may cross functional boundaries. Most researchers use an alternative approach that based on transformation to a particular brain atlas coordinate system. This approach usually involves an automated process to spatially transform the individual brain image into the coordinate space. However, it does not guarantee that an identical point in the space corresponds to the same anatomical feature for all subjects. The two most widely used spaces in the neuroscience community are the Talairach space (Talairach and Szikla, 1967; Talairach and Tournoux, 1988) and the Montreal Neurological Institute (MNI) spaces (Evans et al., 1993).

The Talairach space is based on a stereotaxic atlas of the human brain published by Talairach and Tournoux (Talairach and Szikla, 1967; Talairach and Tournoux, 1988). They identified the anatomical features from the atlas and created a coordinate system related to anatomical landmarks. The Talairach coordinate space has its origin defined at the anterior commissure (AC), with x- and y-axes on a horizontal plan and z-axis on a vertical plane. The y-axis is defined by the line connecting the most superior of AC and the most inferior of the posterior commissure (PC); the x-axis is defined by the line that passes through the AC point and orthogonal to the AC-PC line; whereas the z-axis is the line that passes through the interhemispheric fissure and the AC point. Given a 3-D coordinate in the Talairach space, the anatomical labels can be obtained manually through inspection of the atlas.

To accommodate the differences between individual brains, Talairach and Tournoux defined a proportional grid system to align an individual brain to the atlas. The procedure involves dividing the brain into 12 regions by using one horizontal plane, passing through the x- and y-axes, and three vertical planes. Two vertical planes are parallel to the x-axis, one passing through the z-axis and another through the PC point, and one is parallel to the y-axis, dividing the left and right hemispheres. Each region is then scaled, separately for each direction, to match the atlas. This piecewise linear scaling method provides a simple means of

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converting an individual brain to the Talairach space; however, there is no guarantee that the transformed brain would completely match either the shape or the anatomical features of the Talairach atlas. This linear scaling method performs poorly in terms of matching the anatomical landmark locations to the atlas, especially cortical regions, compared to other methods that use nonlinear transformation.

The major criticism about the Talairach atlas is that it was created based on the postmortem brain of single subject, which is not a good representation of the neuroanatomy for the general population. To allow better representation of average neuroanatomy, the MNI created an average brain template based on the MRI scans from several hundred individuals. The first template, known as the MNI305, was created in two steps. The first step was to obtain the average brain of 241 brains; each of them had been reoriented and scaled to match a set of manually selected anatomical landmarks to those of Talairach atlas. The second step was to create the MNI305 template by averaging the 305 normal MRI scans, which had been normalized with a linear transformation matrix to match the average brain created in the first step. Later, a template using the 152 brains normalized to MNI305 template was created. The International Consortium of Brain Mapping (ICBM) has adopted the template as an international standard, known as the ICBM152. This template is used by several functional imaging analysis packages, such as SPM99 (Wellcome Department of Cognitive Neurology, London, UK; http://www.fil.ion.ucl.ac.uk/spm) and FSL (Image Analysis Group, FMRIB, Oxford, UK; http://www.fmrib.ox.ac.uk/fsl). The MNI templates are not perfectly matched with the Talairach standard brain due to large differences in brain shape and size between the two templates. Moreover, individual differences also prompted the ICBM to develop a probabilistic atlas of the human brain (Mazziotta et al., 1995).

Since the Talairach coordinate system has become the standard reference for reporting the brain locations in scientific publication, researchers often need to report their findings using this system, even though their data were analyzed in different coordinate space, such as the ICBM152. There is no simple way to transform multiple subject data from the MNI space to the Talairach space. It is quite possible that the coordinate location in MNI space of two subjects would map to different points of Talairach space (Fig. 1a). The discrepancy becomes an issue when the data are analyzed in the MNI space but the results are reported using the Talairach space (Brett et al., 2002).

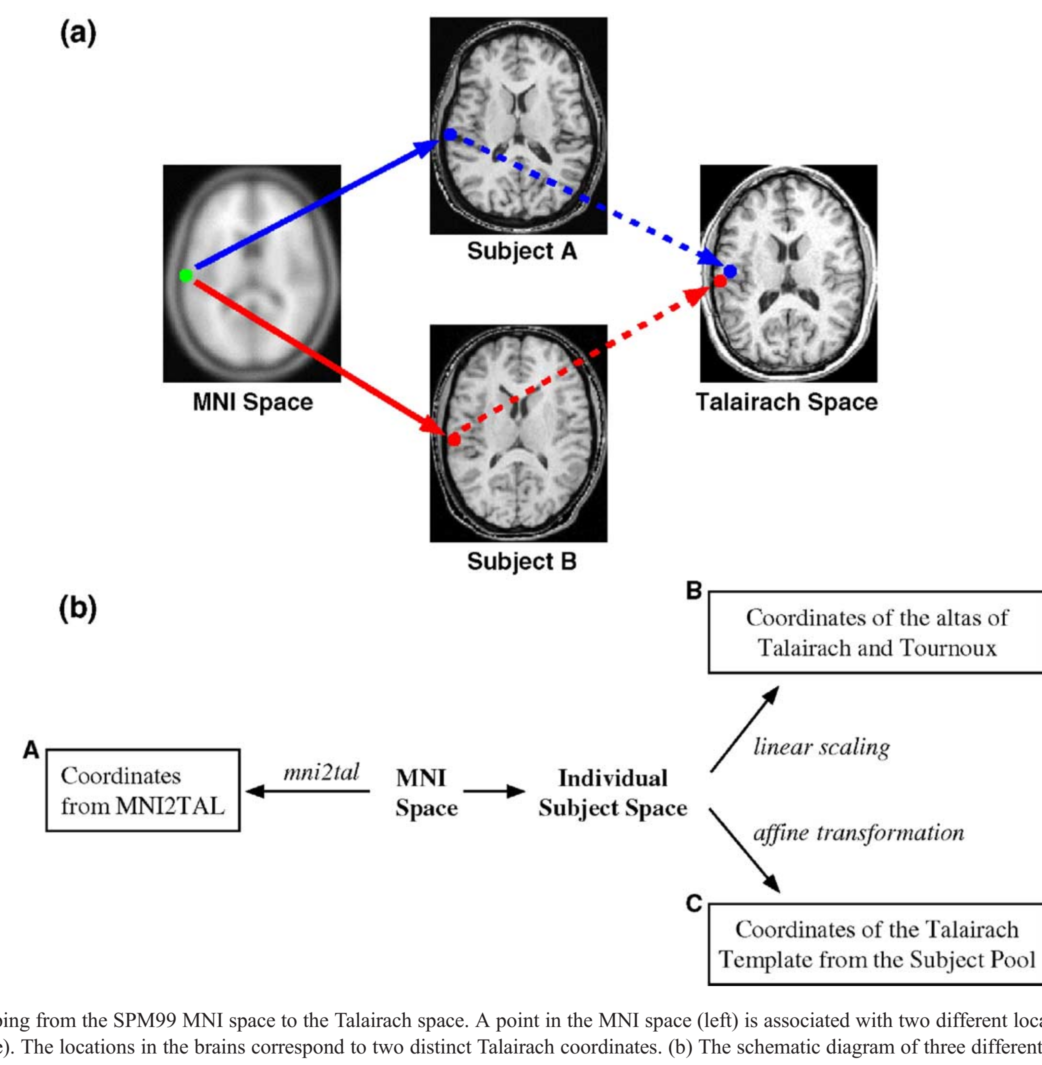

Fig. 1. (a) Mapping from the SPM99 MNI space to the Talairach space. A point in the MNI space (left) is associated with two different locations of two of the subjects (middle). The locations in the brains correspond to two distinct Talairach coordinates. (b) The schematic diagram of three different ways to obtain the Talairach coordinates of a point in the MNI space. (A) Converted from the MNI space using *mni2tal* script; (B) using TMPLS approach; (C) using the template-matching approach.