



**Fig. 1** MRI image of the brain. **a)** A coronal T1-weighted MRI image at the level of the head of the caudate. **b)** Results of anatomic segmentation of this image are demonstrated. Unique anatomic regions are color coded and labeled. Abbreviations: F1, first frontal gyrus; F2, second frontal gyrus; Cga, anterior cingulate gyrus; PAC, paracingulate gyrus; PRG, precentral gyrus; TP, temporal pole; INS, insula; CO, central operculum; FOC, frontoorbital cortex; Aput, anterior putamen; CauH, head of caudate; NA, nucleus accumbens; V, ventricle.

structure and of neural systems organization to what is actually visible in the gray scale MR images. For example the continuous cortical gray compartment at the surface of the cerebral hemisphere includes neocortex, archicortex and paleocortex.<sup>2</sup> The extent of each of these structures is revealed by reliable topographic landmarks, principally with reference to hemispheric location and the local course and intersections of fissures. The neocortex is thrown into convolutions which in the normal brain conform to a canonical pattern, though with substantial variations in the details of this pattern among individuals.<sup>3</sup> The neocortex internally is composed of several dozen architectonic fields, each with its specific role in the systems operation of the forebrain. To a substantial extent there is good correlation between specific gyrus and the location of architectonic field.<sup>4–6</sup> Central gray masses, similarly, are divisible into nuclei by local topographic landmarks.<sup>7</sup> Finally, the white matter is subcompartmentalized respecting the course and quality of principal associative, projection and commissural axon fascicles, and the course of specific fascicles is systematically and reliably positioned with respect to the three dimensional conformation of the white matter stratification.<sup>8</sup>

The extensive knowledge base which correlates topographic anatomy of the human brain with gray scale MR images may be tapped only after extensive processing of the topographic anatomy. We illustrate here in outline an approach that has usefully allowed such correlations. In brief, we work from a computer assisted system of analysis that allows us first of all to segment apart, the gray, white and CSF compartments and to partition the neocortex according to the principal set of

gyri, the nuclear masses according to approximate nuclear groups and the white matter into strata which distinguish the principal fascicular groupings.<sup>9–12</sup> For each gray and white matter parcellation unit, generally each only a few percent or less of the total volume of the hemisphere, we have formulated an atlas of systems related structural components. For each gray matter parcellation unit, whether cortical or subcortical, we have developed a reasoned atlas of principal connectivity, based upon dissection and, by extrapolation, upon hodologic experiment in primates. For each parcellation unit of white matter there is a companion atlas of traversing principal fascicles given both in terms of provenance and destination (Fig. 2). Standard anatomic images may be complemented to this end by explicit 3 dimensional demonstration of specific fiber tracts by diffusion tensor imaging (Fig. 3).<sup>13</sup> Finally, this presentation may be complemented by spectroscopy, EEG or MEG where the overlays from these additional technologies may be registered computationally with those of the basic 3 dimensional anatomic image sets (Fig. 4).<sup>14,15</sup>

Applications in general will apply to any analysis where the objective is to deduce inferences about systems organization from the pattern data set. In the case of lesion analysis in cognitive neuroscience, for example, the method first characterizes the lesion itself in terms of the underlying gray and white matter structures destroyed where characterization extends to the domains of localization and size.<sup>16,17</sup> In the domain of connectivity, an estimate of interrupted connectivity may be inferred from the mapping of destroyed gray and white matter parcellation units with reference to