Similar connectivity profiles in humans and monkeys used to generate a Theory of Mind

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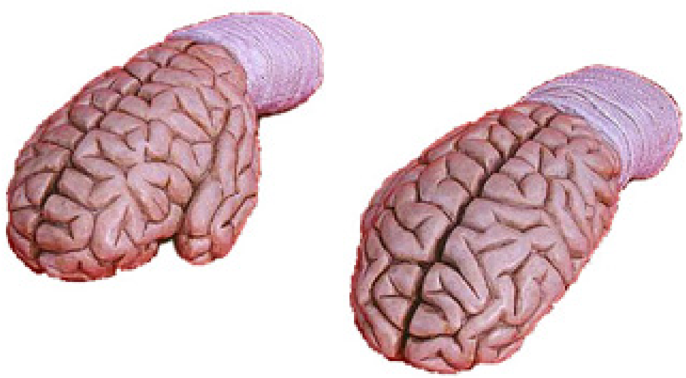

The outward appearance of the brain is like a boxing glove. Credit: slatervecchio.com

(Medical Xpress)—The ability to infer emotion or intention in others from their outward appearance and behavior, has been called a "Theory of Mind" (TOM). While cognitive scientists have debated whether animals other than humans possess a TOM, many animals (like monkeys) clearly react to facial expression or body movements. One area of the human brain that has received considerable attention in discussions of TOM, is the temporo-parietal junction (TPJ). If each half of the brain is viewed as a boxing glove, the TPA corresponds to the junction between the "thumb" and body of the glove. To explore whether the TPJ regions of humans and monkeys have similar "functional connectivity" profiles, a group of Oxford researchers turned to high resolution at-rest fMRI. The researchers generated correlation maps between each time series obtained for specific voxel regions of interest. Their results, just published in *PNAS*, show that the most similar TPJ connectivity profiles correspond to areas that process, among other things, faces and social stimuli within the temporal cortex.

When the brain first begins to develop in the womb, the cortex is basically a smooth sheet. The most noticeable topological feature in the cortex of all higher vertebrates, the lateral or Sylvian fissure, begins to take shape as an invagination in the side that proceeds from front to back. This fold, with the TPA at its apex, remains as the primary feature of the cortex even as it grows increasingly convoluted. It is little wonder that many of the most interesting mental phenomena, and malady, are often attributed to this region. Stimulation of this area has produced effects as widespread as out of body experiences, impostor syndromes, and even phantom body doubles with precise geometrically offsets to the primary body position.

It is a bit of a paradox perhaps, that many studies which look for uniform or predictable features in the brain have instead hit upon the very region where any such pigeonholing is most labile. In other words, when the brain folds, the TPA is precisely the region where the most scrunching happens, with the result the mature structure typically shows the most variance. In animals like cats and many monkeys, the cortical gyri and sulci, have virtually the same pattern in each individual. In humans however, attempts to assign names to specific folds of the TPA region is like playing a game of pin the tail on the donkey. For example, the Angular gyrus, Wernicke's area, Supramarginal gyrus, and Inferior parietal area, can all be variously designated as part of the TPA.

Recent attempts to define a default mode network (DMN) using fMRI have included this same region. In theory, the DMN can be used to distinguish sleep from arousal. It was noted that neurons which project out of the cortex in this region have, in effect, more options open to them than those virtually anywhere else in the brain. For example, directly under the angular gyrus is the area known as the temporo-parietal fiber association area. It includes at least seven long range white matter superhighways. That is not to say TPA neurons have free reign to board any tract they choose, (especially those like the optic radiations whose foundations are strongly and quickly set by myelin), but certainly the wide variance in behavioral correlates of these cells has an anatomical basis.

The Oxford study used Macaques, a monkey which has been on a separate evolutionary path from humans for around 30 million years. They note that the superior temporal (STS) region of the Macaque contains face cells that have been found to be more responsive to social cues rather than to identity. The researchers included the STS in their MRI meta-analysis, and also incorporated information from the BrainMap database, a large repository of neuroimaging data. While it is encouraging to see big data being put to use, it is often difficult to follow exactly how the data is processed to yield the so-called "activation likelihood estimation maps for activity elicited by theory of mind paradigms and by face discrimination or processing."

As various federal projects begin to assemble connectomes for the human brain, functional connectivity studies that use highly processed MRI data, will need to be made as simple and straightforward as possible if they are to be put to widespread use. MRI tractography is a related technology that can assign physical connectivity by performing a meta-analysis on diffusion tensor data. Using scans and connectomes to generate theories to explain some of the strange mental phenomena generated secondary to stroke or by various kinds of electromagnetic stimulation are the best approaches we have at the moment. New technologies generated by the BRAIN Initiative will hopefully allow a finer-grained exploration of theory of mind.

More information: Connectivity profiles reveal the relationship between brain areas for social cognition in human and monkey temporoparietal cortex, *PNAS*, Published online before print June 10, 2013, doi: 10.1073/pnas.1302956110

Abstract
The human ability to infer the thoughts and beliefs of others, often referred to as "theory of mind," as well as the predisposition to even consider others, are associated with activity in the temporoparietal junction (TPJ) area. Unlike the case of most human brain areas, we have little sense of whether or how TPJ is related to brain areas in other nonhuman primates. It is not possible to address this question by looking for similar task-related activations in nonhuman primates because there is no evidence that nonhuman primates engage in theory-of-mind tasks in the same manner as humans. Here, instead, we explore the relationship by searching for areas in the macaque brain that interact with other macaque brain regions in the same manner as human TPJ interacts with other human brain regions. In other words, we look for brain regions with similar positions within a distributed neural circuit in the two species. We exploited the fact that human TPJ has a unique functional connectivity profile with cortical areas with known homologs in the macaque. For each voxel in the macaque temporal and parietal cortex we evaluated the similarity of its functional connectivity profile to that of human TPJ. We found that areas in the middle part of the superior temporal cortex, often associated with the processing of faces and other social stimuli, have the most similar connectivity profile. These results suggest that macaque face processing areas and human mentalizing areas might have a similar precursor.

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