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Short parietal lobe connections of the human and monkey brain

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ABSTRACT

The parietal lobe has a unique place in the human brain. Anatomically, it is at the crossroad between the frontal, occipital, and temporal lobes, thus providing a middle ground for multimodal sensory integration. Functionally, it supports higher cognitive functions that are characteristic of the human species, such as mathematical cognition, semantic and pragmatic aspects of language, and abstract thinking. Despite its importance, a comprehensive comparison of human and simian intraparietal networks is missing.

In this study, we used diffusion imaging tractography to reconstruct the major intra-lobar parietal tracts in twenty-one datasets acquired in vivo from healthy human subjects and eleven ex vivo datasets from five vervet and six macaque monkeys. Three regions of interest (postcentral gyrus, superior parietal lobule and inferior parietal lobule) were used to identify the tracts. Surface projections were reconstructed for both species and results

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compared to identify similarities or differences in tract anatomy (i.e., trajectories and cortical projections). In addition, post-mortem dissections were performed in a human brain.

The largest tract identified in both human and monkey brains is a vertical pathway between the superior and inferior parietal lobules. This tract can be divided into an anterior (supramarginal gyrus) and a posterior (angular gyrus) component in both humans and monkey brains. The second prominent intraparietal tract connects the postcentral gyrus to both supramarginal and angular gyri of the inferior parietal lobule in humans but only to the supramarginal gyrus in the monkey brain. The third tract connects the postcentral gyrus to the anterior region of the superior parietal lobule and is more prominent in monkeys compared to humans. Finally, short U-shaped fibres in the medial and lateral aspects of the parietal lobe were identified in both species. A tract connecting the medial parietal cortex to the lateral inferior parietal cortex was observed in the monkey brain only.

Our findings suggest a consistent pattern of intralobar parietal connections between humans and monkeys with some differences for those areas that have cytoarchitectonically distinct features in humans. The overall pattern of intraparietal connectivity supports the special role of the inferior parietal lobule in cognitive functions characteristic of humans.

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1. Introduction

Despite proposed functional homologies (Culham & Kanwisher, 2001), studies comparing the anatomy of the human and monkey brain have suggested differences between these two species in some regions of the parietal lobe (Critchley, 1953; Geschwind, 1965; Scheperjans et al., 2008). Earlier studies had already come to this conclusion by comparing the surface anatomy of the parietal sulci and measuring the extension of the gyral cortex comprised in between the folding (Papez, 1929). A major problem of this approach is the lack of correspondence between sulcal anatomy and the functional delimitation of specialised areas. Further, some of the human sulci, such as the postcentral sulcus, are absent or barely visible in brains of different monkey species (Bonin & Bailey, 1947).

Divisions of the parietal cortex into fields or areas based on cytoarchitectonics have provided a viable and necessary alternative. Initial studies showed interspecies differences that were particularly significant for the inferior parietal lobule (Campbell, 1905). Recent findings using an operator-independent parcellation approach have found more interspecies analogies in the inferior parietal cortex (Caspers et al., 2006) but also differences in the superior parietal lobule (Scheperjans et al., 2008). These discrepancies in the results may depend on different methods utilised to define boundaries between areas. There is however, an even more concerning limitation of this approach when differences in cytoarchitectonic variations are used to imply functional specialisation. While this is certainly true for grosser types of cellular difference (e.g., granular vs agranular), the same cannot be assumed for all cytoarchitectonic distinctions (Critchley, 1953). For example, in the human brain, area 40 has different functions in the left and right hemisphere. Clearly, anatomical homologies do not necessarily imply functional

homologies within a species, let alone across species. This limitation has led many anatomists to pursue another approach to comparative anatomy based on the delineation of the connectivity pattern of cortical areas (Jones & Powell, 1970).

The first studies in monkey brains used methods for staining degenerating fibres following a cortical lesion (e.g., Marchi's or Nauta's method) and physiological neuronography (e.g., strychninization and recording of amplified impulses) to demonstrate the existence of short connections between distinct parietal regions (Bonin & Bailey, 1947; Jones & Powell, 1969; Warren, 1944). These results were directly transposed to humans based on the assumption of great similarity between the brains of the two species (Bailey & Bonin, 1951). The development of axonal tracing methods led to a more detailed description of intralobar parietal connectivity in the monkey brain (Cavada & Goldman-Rakic, 1989; Pandya & Seltzer, 1982). The pioneering work of Pandya and Seltzer (1982) has identified two parallel main streams of intrinsic connections in the parietal lobe of the rhesus monkey: a dorsal stream of short connections between the postcentral gyrus (area 2) and the dorsal (PE, PEc) and medial (PGm) parietal cortex, and a ventral stream between postcentral gyrus and inferior parietal cortex (PF, PFG, PG, Opt). The two streams seem to be weakly interconnected, except for the most posterior regions (i.e., PG on the inferior parietal surface and PGm in the medial surface). These results have been repeatedly confirmed (Cavada & Goldman-Rakic, 1989; Rozzi et al., 2006) but they are, in part, at odds with imaging data in the human brain indicating a close functional and structural link between superior and inferior parietal lobules (Caspers et al., 2011; Castiello, 2005; Lewis, 2006; Sestieri, Shulman, & Corbetta, 2017).

More recently, the development of MRI diffusion tractography has allowed for the visualisation of long association and projection pathways of the parietal lobe in humans and comparison between species (Catani & de Schotten, 2012;

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