Receptor-driven, multimodal mapping of cortical areas in the intraparietal sulcus of macaque monkey

Poster No:

1778

Submission Type:

Abstract Submission

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Introduction:

The macaque intraparietal sulcus (IPS) plays an important role in the integration of multimodal information from visual and somatosensory cortices [1]. Previous studies [2, 3] have revealed that it contains several architectonically distinct areas, each with specific functional roles and characteristic connectivity patterns. We hypothesized that the chemoarchitectonic organization of the cerebral cortex, as revealed by transmitter receptor distribution patterns [4], could reflect the commonalities of the cytoarchitectonic, connectional, and functional diversity of IPS areas. Therefore, goals of the present study are: (1) determine the number and extent of IPS areas and provide a refined map based on a quantitative multimodal architectonic analysis, and (2) explore the relationship between molecular

and functional heterogeneity of IPS areas based on the similarities and dissimilarities of their 'receptor fingerprints' [4] and functional and connectional data reported in the literature [1, 5].

Methods:

We analyzed four hemispheres from three adult male Macaca fascicularis monkeys. Unfixed and deep-frozen hemispheres were cut into series of coronal sections (20 µm thickness). Alternating sections were processed for quantitative in vitro receptor autoradiography [4] or for cell-body [6] or myelin [7] stainings. 15 receptors were labeled according to previously published protocols [4]. Ensuing autoradiographs were digitized and the gray value of each pixel converted into a receptor density in fmol/mg protein. Pseudo color coding of autoradiographs was carried out to provide a clear visualization of regional and laminar receptor distribution patterns. For delineation of areal borders, an observer-independent approach was carried out, for details see [8]. For each identified area, the mean density for each receptor was extracted and registered to a polar plot, which represents the 'receptor fingerprint' of that area [4]. Receptor fingerprints show the multi-receptor balance in each IPS area, and were the basis for subsequent multivariate analyses.

Results:

Seventeen (V3d, V3A, V4d, V6, V6Av, V6Ad, PIP, LOP, MIPd, MIPv, LIPd, LIPv, PEipe, PEipi, VIPl, VIPm and AIP) cortical areas could be identified in the IPS and its junction with the parieto-occipital sulcus (POS; Fig. 1). This parcellation includes three newly defined areas: external and internal subdivisions (PEipe and PEipi) of PEip, which was previously regarded as an anatomically homogeneous area [9]; a small area located in the dorsal part of the medial bank of IPS, dorsal to the previously defined area MIP, i.e. MIPd. MIP was consequently renamed as MIPv. The multivariate analyses of the receptor fingerprints revealed three clusters of areas with distinct macroanatomical locations along the rostro-caudal extent of the IPS (Fig. 2). The posterior cluster mainly encompasses areas associated with the processing of visual information [10]. The intermediate cluster (i.e. V6Ad, VIPm and VIPl) is involved in multisensory integration, particular for visual and somatosensory input [5]. Areas encompassed by the anterior cluster constitute a site of convergent visual and somatic-related information, and are directly involved in movement and decision-related processes in arm and eye movements [5].

Conclusions:

By combining information from cyto-, myelo- and multiple receptor architecture, the present study provides a complete multimodal architectonic map of the macaque IPS and the region of its junction with POS. The parcellation scheme using a 2D representation with the explicit position of area borders and their relationship with macroanatomical landmarks allows comparison of the present map with those from classical studies. Cluster analyses revealed that the functional segregation of IPS areas is underpinned by differences in their molecular organization.

This project was partially funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 785907 (HBP SGA2).

Neuroanatomy, Physiology, Metabolism and Neurotransmission:

Anatomy and Functional Systems
Cortical Anatomy and Brain Mapping [1]
Cortical Cyto- and Myeloarchitecture
Transmitter Receptors [2]

Neuroinformatics and Data Sharing:

Brain Atlases

Keywords:

ANIMAL STUDIES
Neurotransmitter
Other - intraparietal sulcus; macaque monkey; brain mapping

[1|2]Indicates the priority used for review

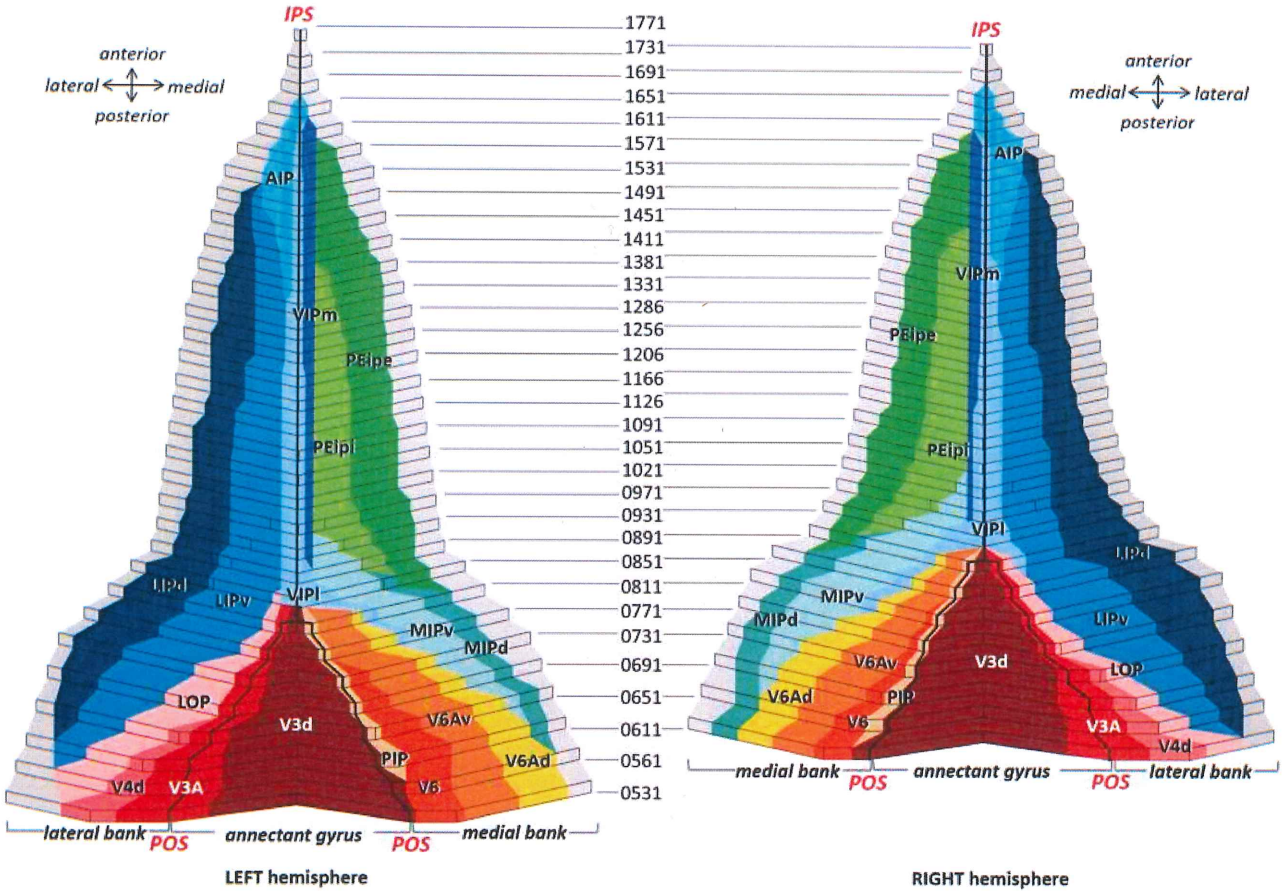

Figure 1. 2D cytoarchitectonic flat map of IPS areas in both hemispheres of *Macaca mulatta* (DP1). Bold lines represent fundi of the intraparietal (IPS) and parieto-occipital (POS) sulci. Arabic numerals mark section numbers.

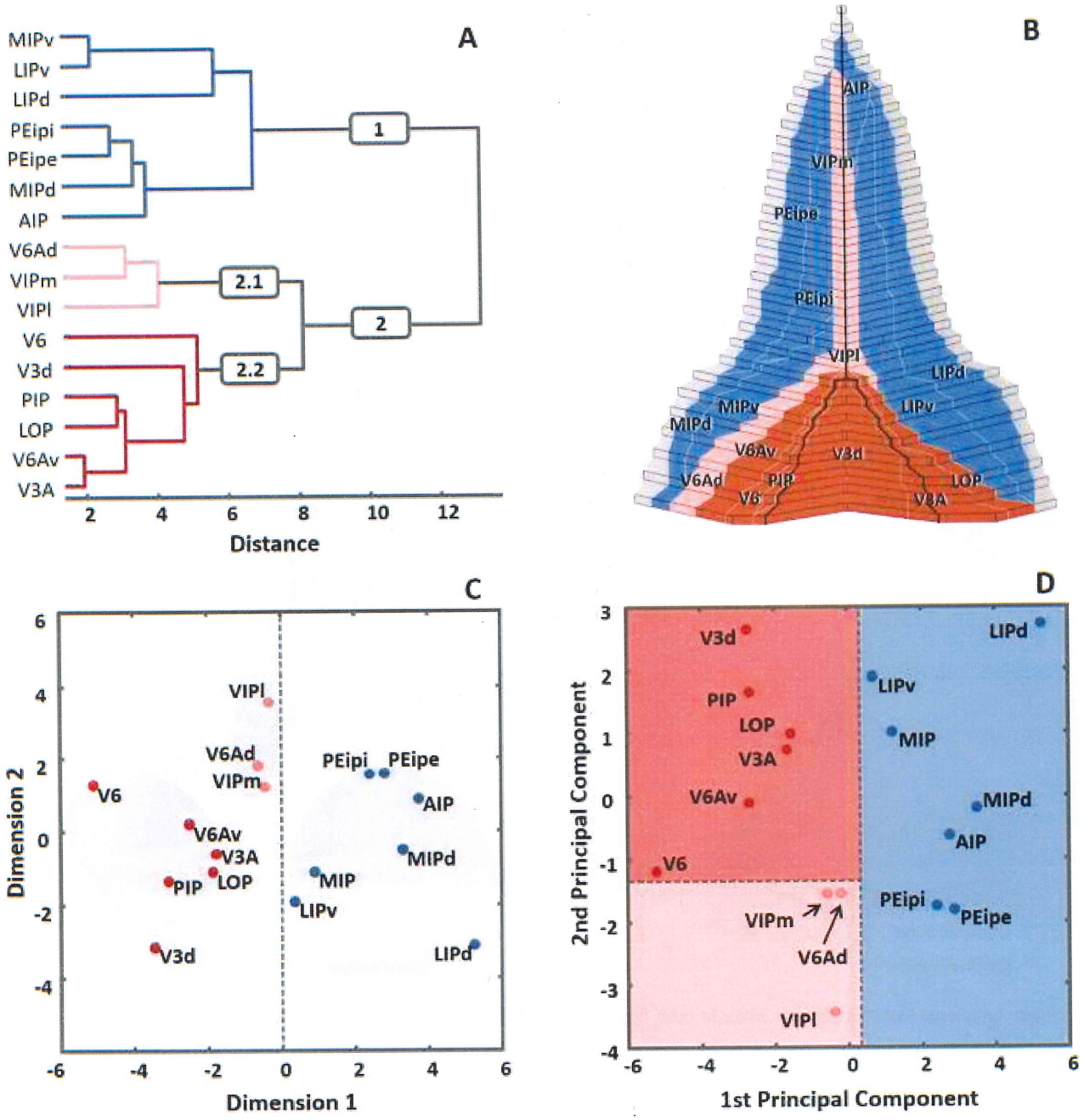

Figure 2. Receptor-driven clustering of IPS areas. A: Hierarchical cluster analysis reveals 3 receptor-architectonically distinct clusters: a caudal cluster with visual areas (red); an intermediate group of areas VIPm, VIPl and V6Ad (pink); and a rostral group consisting of all areas located on the bilateral walls of IPS (blue). B: The three clusters are displayed in the 2D flat map, same color coding as in A. C: Multidimensional scaling resulting in a 2D display of the 15-dimensional receptor feature vectors of the receptor fingerprints of IPS areas. The smaller the Euclidean distances, the higher the similarity in receptor-architectonic organization of IPS areas. Three clusters are labeled in red, pink and blue based on the results of hierarchical cluster analysis. D: Principal component analysis. The distances between areas represent the Eigenvalues of the first and second principal components, three clusters are clearly segregated by the first and second principal component, same color coding as in ABC

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Yes

Please indicate which methods were used in your research:

Postmortem anatomy

Provide references using author date format

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