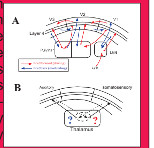
Anatomical support for a role of the thalamo-cortical pathway in multisensory integration in monkeys

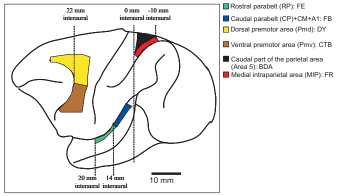
Cappe C.* (1,2), Barone P. (2) and Rouiller E.M. (1)
(1) Unit of Physiology, Department of Medicine, University of Fribourg, 1700 Fribourg, Switzerland
(2) Centre de Recherche Cerveau et Cognition, CNRS/UPS UMR 5549, Faculty of Medicine Rangueil, 31000 Toulouse, France.
* E-mail : Celine.Cappe@unifr.ch

Introduction

Although multisensory integration has been shown to take place essentially in the cerebral cortex and the superior colliculus, the thalamus may play a role as well. The aim of this study is to investigate thalamo-cortical networks possibly involved in multisensory integration.



Methods



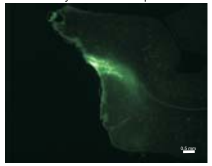
Injections sites

In one macaque monkey, seven neuroanatomical tracers were injected simultaneously in the auditory cortex (rostral -RP- and caudal -CP- parabelt areas), the posterior visual parietal cortex (medial intraparietal area (MIP), the caudal part of parietal somatosensory area (Area 5)) and the premotor cortex (the dorsal and ventral premotor areas (PMd and PMv)). The monkey was sacrified by intracardiac perfusion with PFA mixture, the brain was removed, blocked and 40 microns thick sections were cut on a freezing microtome. Five series of sections were treated separately to visualize the different tracers and markers for cytoarchitecture. Retrogradely labeled neurons in the thalamus were plotted using a microscope assisted with Neurolucida. Histochemical staining (acetylcholinesterase) was used to define arcitectonic borders and allocate labeled neurons to invidual nuclei in the thalamus.

Auditory cortex: caudal parabelt

A Fast Blue (FB) injection site seen on a frontal section in the ventral bank of lateral sulcus corresponding to CM and to the caudal auditory parabelt.parabelt.

Auditory cortex: rostral parabelt

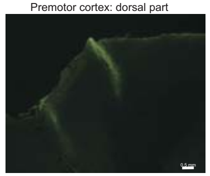


A Fluoroemerald (FE) injection site seen on a frontal section in the ventral bank of lateral sulcus corresponding to the rostral auditory parabelt.

Parietal cortex : MIP

A Fluororuby (FR) injection site seen on a frontal section in the posterior visual parietal cortex (medial intraparietal area (MIP)).

Premotor cortex: dorsal part



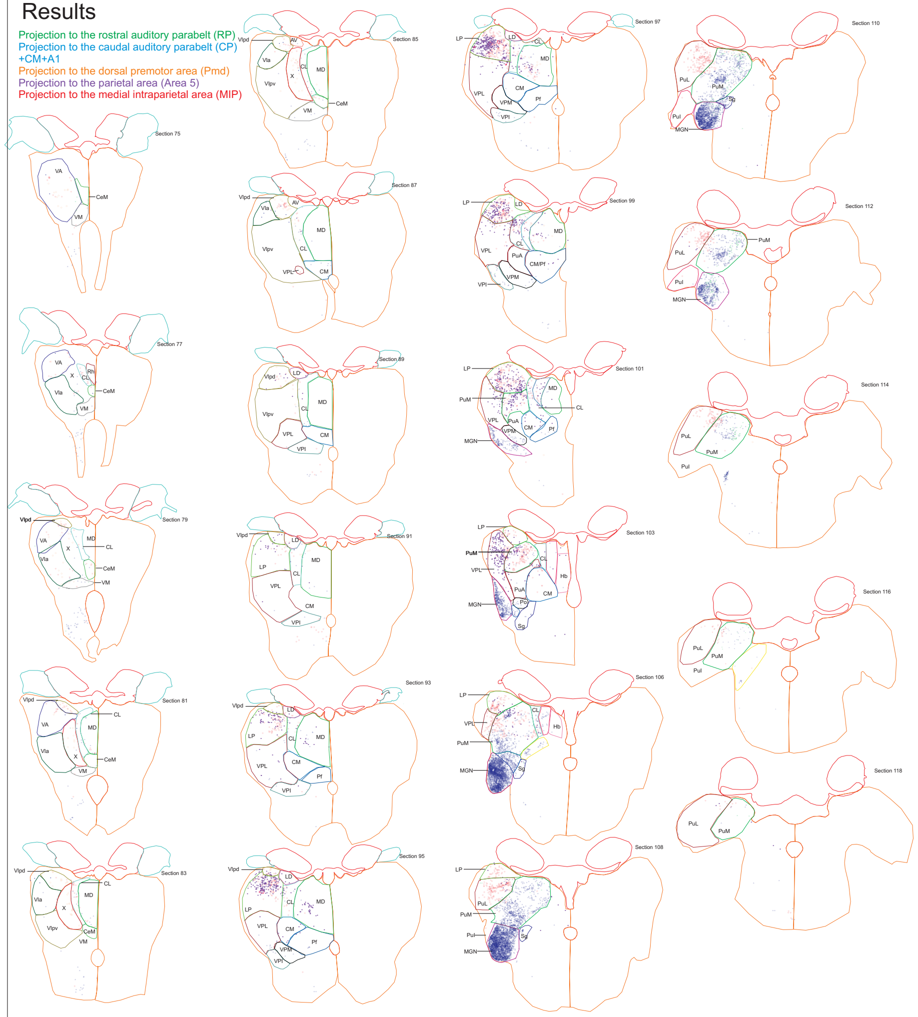
A Diamidino-Yellow (DY) injection site seen on a frontal section in the dorsal premotor cortex (Pmd).

Parietal cortex : Area 5

A BDA injection siteseen on a frontal section in the caudal part of parietal somatosensory area (Area 5).

Results

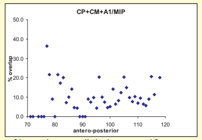
Projection to the rostral auditory parabelt (RP)
Projection to the caudal auditory parabelt (CP) +CM+A1
Projection to the dorsal premotor area (Pmd)
Projection to the parietal area (Area 5)
Projection to the medial intraparietal area (MIP)



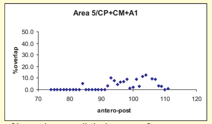
Overlap vs. Segregation of thalamocortical projections

An index of overlap was calculated according to the method described by Tanné-Gariépy et al. (2002a). In brief, a grid of 0.5 x 0.5 mm units was aligned to the medial thalamic border of plots of labelling on 200 µm distant frontal sections of the monkey brain. In each plot, counts were made for the whole thalamus, without considering internal nuclear boundaries, of (i) number of square units containing only neurons labelled with the first tracer (N1), (ii) number of square units containing only neurons labelled with the second tracer (N2) and (iii) number of square units containing neurons labelled with one or the other tracer (N3). The N1, N2 and N3 values were averaged over all the thalamus. A mean 'global' index of overlap was calculated for all or part of the thalamus from [N3 / (N1 + N2 + N3) · 100]. A value of 0% (with N3 = 0) corresponds to a complete segregation of neurons labelled by each tracer, whereas a mean value of 100% (N3 = Ntot, with N1 = 0 and N2= 0) corresponds to a complete overlap between the two populations of labelled neurons. This procedure was applied for each combination of two tracers (i.e. Areas).

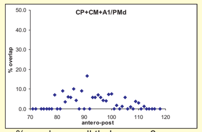
Representations of the degree of overlap vs. segregation of neurons labelled by paired injections in different cortical areas.



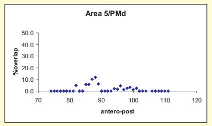
% overlap on all thalamus = 10
% overlap from section 76 to 88 = 13



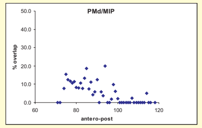
% overlap on all thalamus = 3
% overlap from section 103 to 107= 11



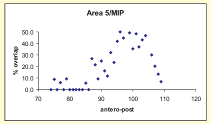
% overlap on all thalamus = 3
% overlap from section 82 to 100 = 6



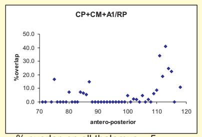
% overlap on all thalamus = 2
% overlap from section 94 to 101= 2



% overlap on all thalamus = 5
% overlap from section 75 to 95 = 10



% overlap on all thalamus = 20
% overlap from section 90 to 107= 36

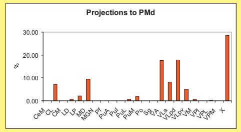


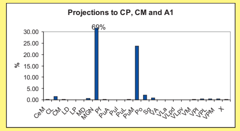
% overlap on all thalamus = 5
% overlap from section 109 to 115= 22

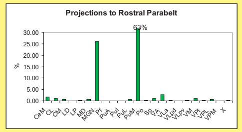
These representations allow to assess quantitatively the degree of overlap between the territories of origin of thalamo-cortical projections to different sensory and/or motor cortical areas.

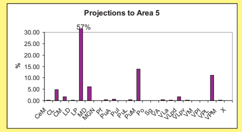
Thalamocortical projections

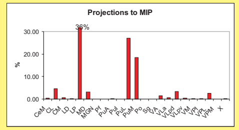
Histograms of the percentages of labelled cells in each thalamic nucleus reportedas a function of the total number of cells in the thalamus labelled by each of the injected cortical areas.











Thus, the main nuclei projecting in parallel to PMd, CP, CM, A1, RP, area 5 and MIP are the medial pulvinar nucleus (PuM), the dorsal division of the ventral lateral posterior nucleus (VLpd) and the central lateral nucleus (CL).

Conclusion

The present results are consistent with the presence of thalamic territories possibly integrating different sensory modalities with motor attributes. Thus, our results suggest that the thalamus could represent an alternative pathway to the cortico-cortical networks by which information can be transferred between cortical areas belonging to different sensory and/or motor modalities.

Multisensory integration between remote cortical areas may involve the so-called feedforward cortico-thalamic projection, consisting of secure and fast transmission via giant endings, directing the information to another cortical area via a thalamo-cortical projection (see cartoon in the introduction).