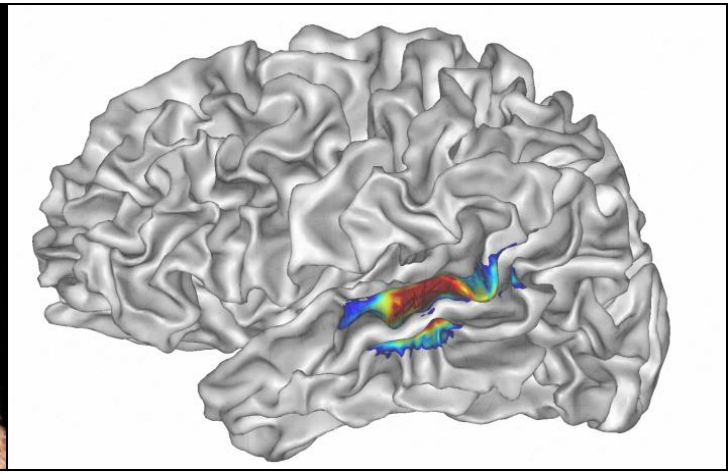
RMN report meeting

Project :

FMRI investigation of voice-selective areas in macaques and humans

Main investigators: Clémentine Bodin, Régis Trapeau, Pascal Belin (INT, Banco)



Thank you !

INT colleagues
Pascal Belin
Olivier Coulon
Régis Trapeau
Sylvain Takerkart
Thomas Brochier
Bastien Cagna
David Meunier
Kep-Kee Loh

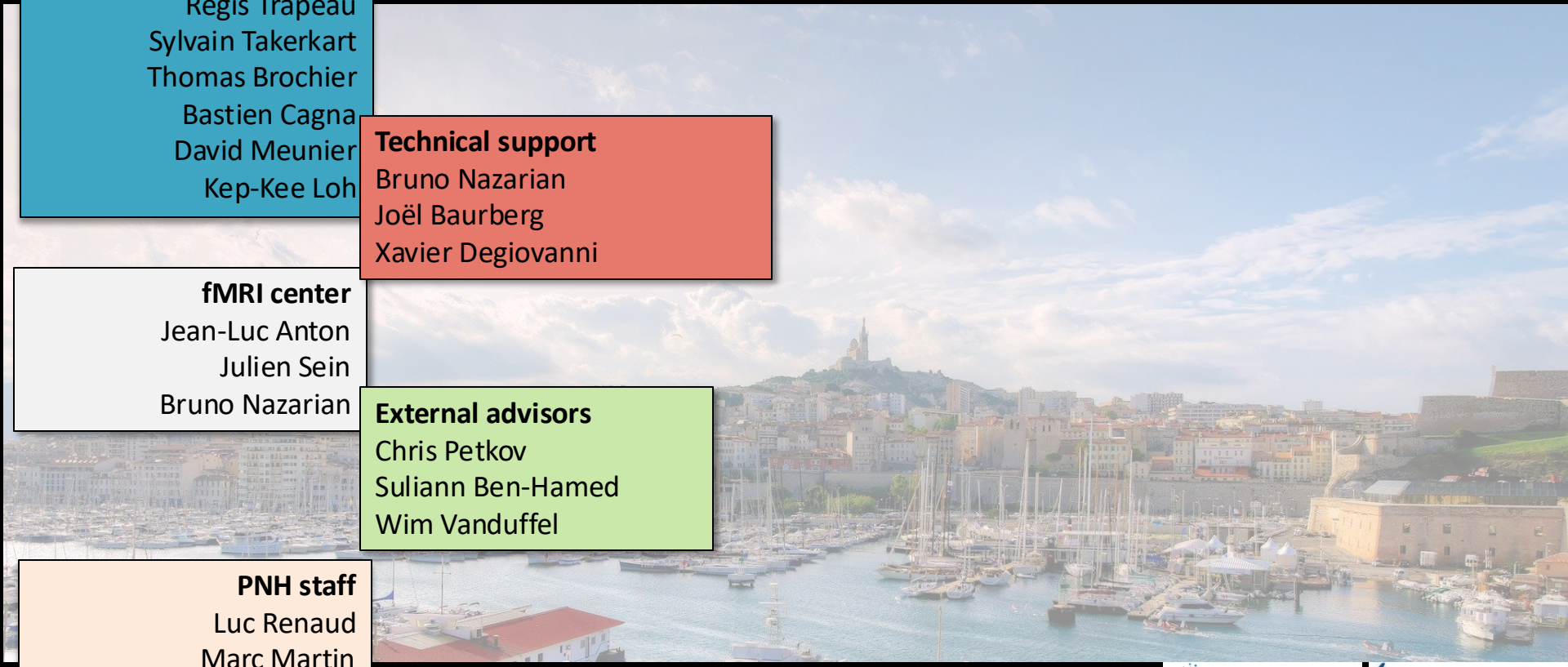
Technical support
Bruno Nazarian
Joël Baurberg
Xavier Degiovanni

fMRI center
Jean-Luc Anton
Julien Sein
Bruno Nazarian

External advisors
Chris Petkov
Suliann Ben-Hamed
Wim Vanduffel

PNH staff
Luc Renaud
Marc Martin
Laurence Boes
Emilie Rapha
Frédéric Charlin

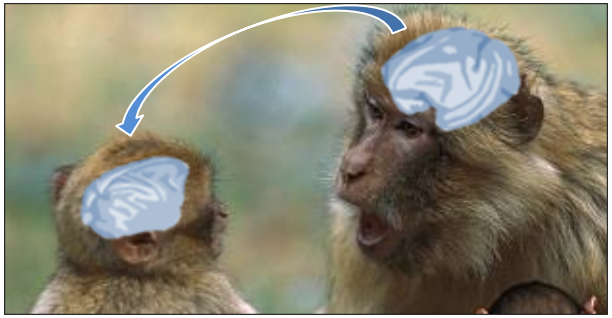
Macaques
Elouk
Apache
Maga

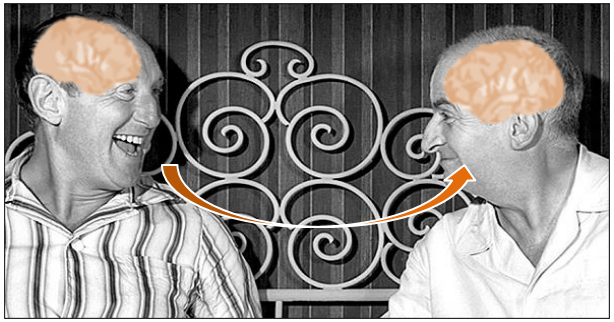


ILCB Institute of Language Communication and the Brain
Aix*Marseille université
cnrs
erc European Research Council Established by the European Commission
AGENCE NATIONALE DE LA RECHERCHE ANR
FRM FONDATION RECHERCHE MÉDICALE

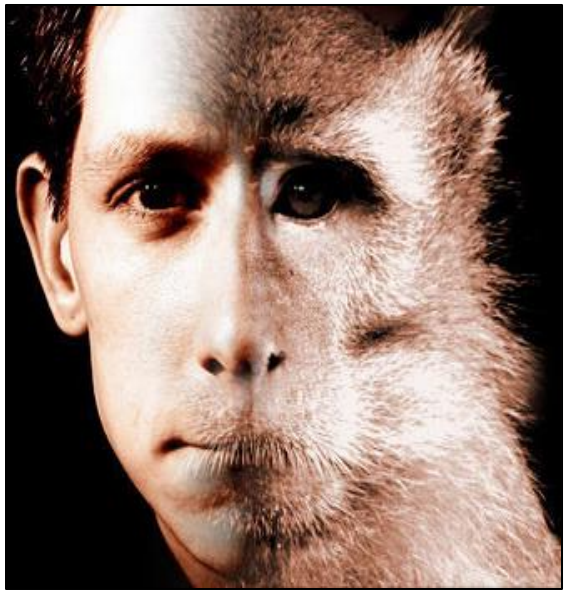
- **Main objective**

Conspecific voice perception





Human / Macaque



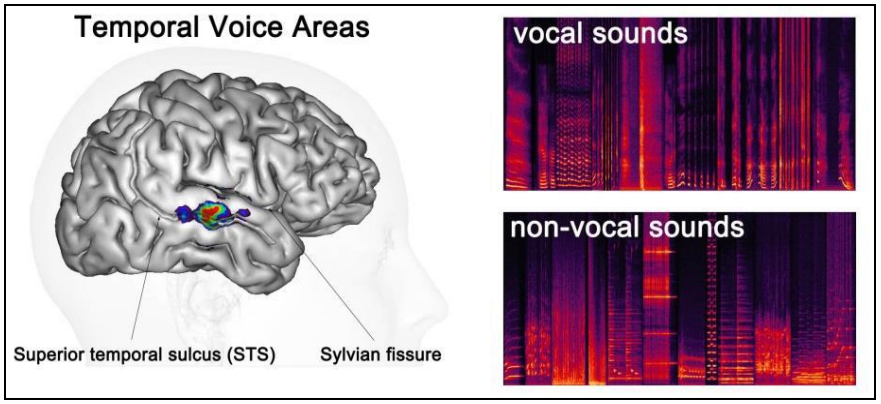
Functional MRI

→ Identify and compare the cerebral substrate of **CV perception**

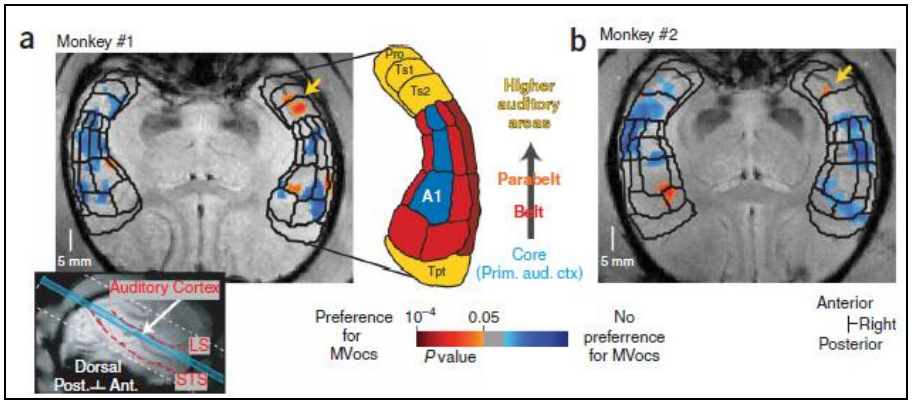
→ → Understanding common grounds before major changes

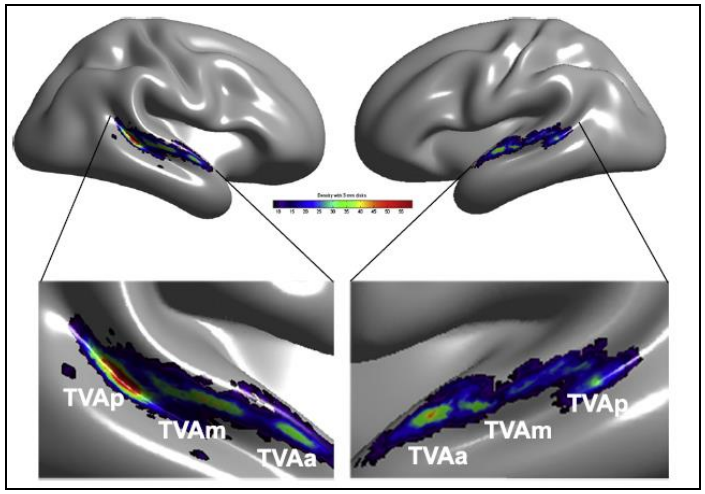
- **Previously done**

Human

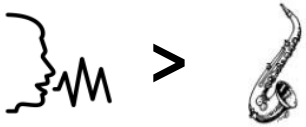


Macaque



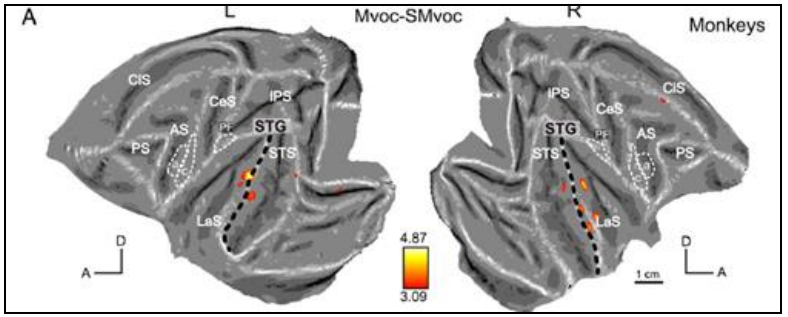


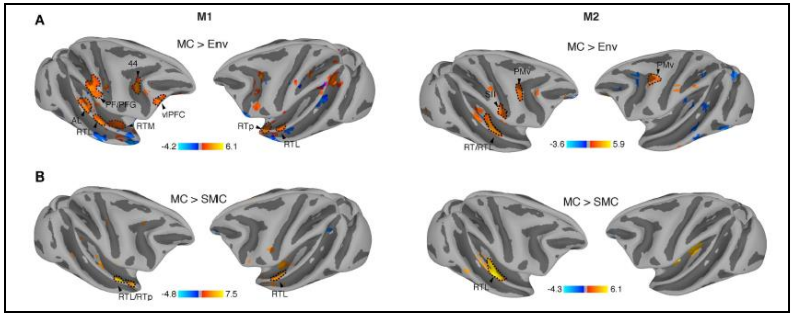
Voice Areas



Voice **Non voice**

(Env, Altered, heterospecific..)





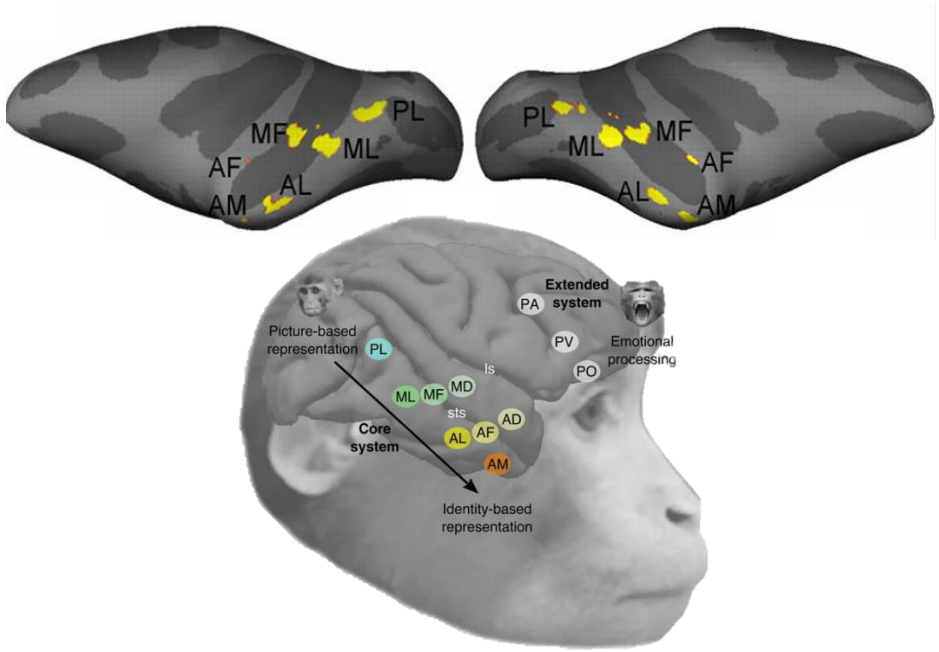
Belin, Zatorre et al. 2000; Belin, Zatorre et al. 2002; Pernet et al. 2015

Joly et al. 2012; Ortiz-Rios et al. 2015. Petkov et al. 2008.

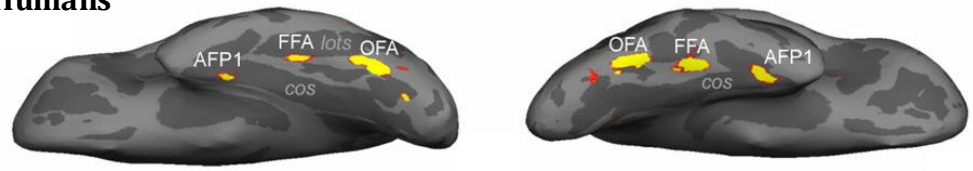
Hypothesis : a « voice patches » cortical organization

The face patch system in primates

Macaques

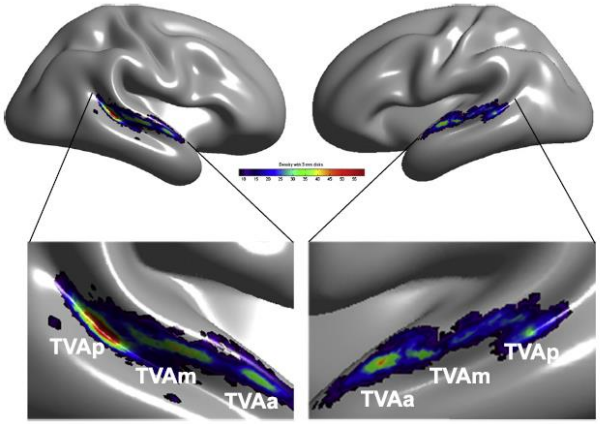


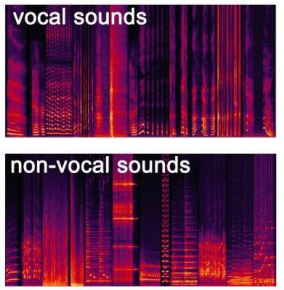
Humans



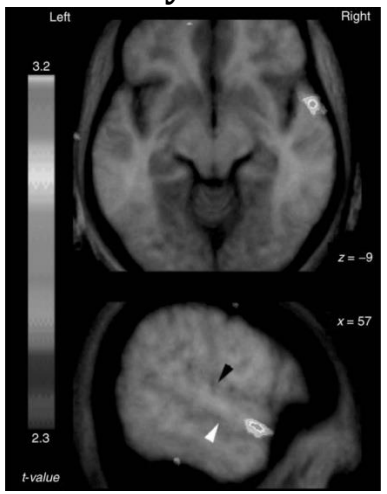
Landi et Freiwald, 2017; Tsao et al., 2008

Temporal voice areas in humans





Identity cluster



Belin et al., 2000; Belin et Zatorre, 2003; Latinus et al., 2013 ; Pernet et al., 2015

Hypothesis : a « voice patches » cortical organization

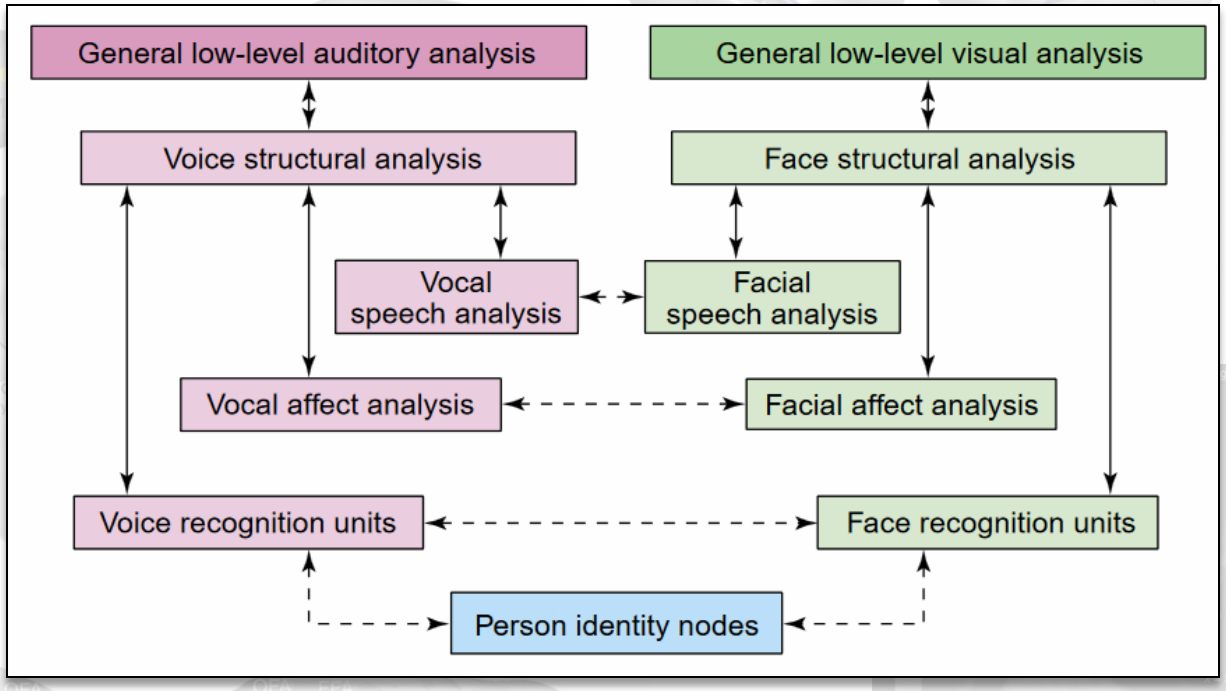
The face patch system in primates

Temporal voice areas in humans

Macaques

Humans

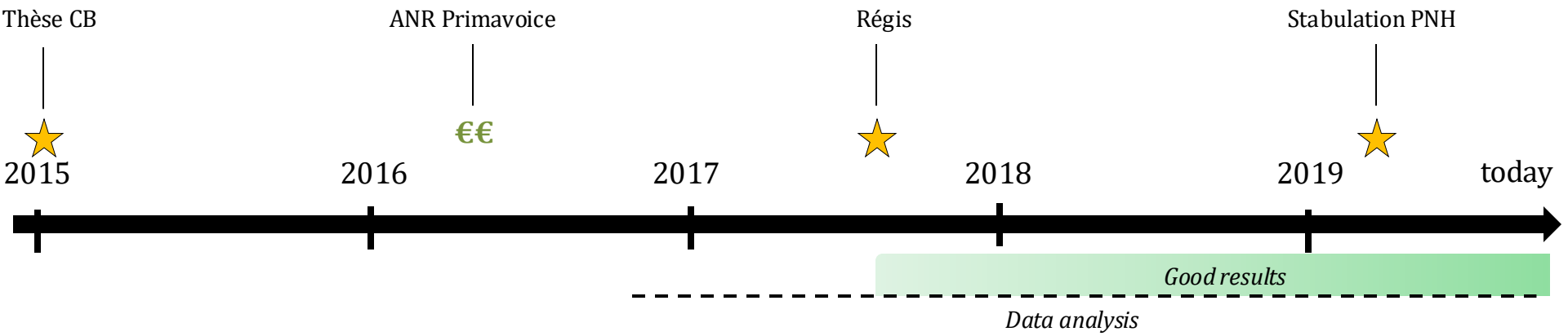
Belin et al. 2004; Yovel et Belin 2013, TICS



Landi et Freiwald, 2017; Tsao et al., 2008

Belin et al., 2000; Belin et Zatorre, 2003; Latinus et al., 2013 ; Pernet et al., 2015

Project overview :



Training M1

Scanning M1

Event-related
Bloc design
MION (contrast agent)

Training M2/M3

Scanning M2/M3

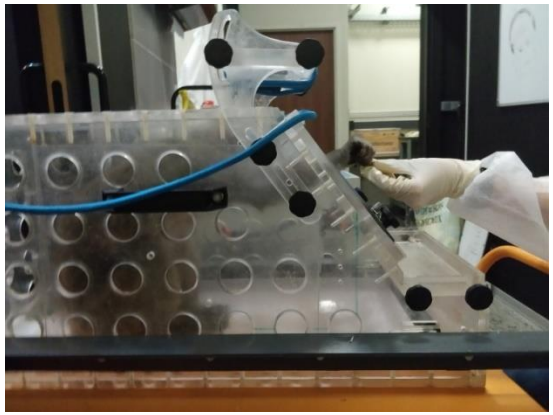
Clustered sparse
MION

+ scan HUMANS

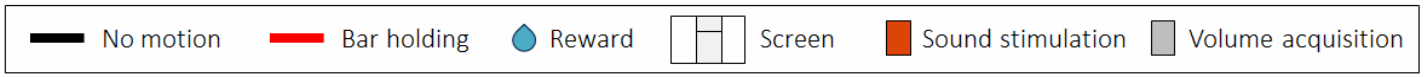
- **Daily training** (several months to one year per animal)

In a monkey chair , sphinx position

Conditions as close as possible to the real fMRI sessions
(sound stimulation, head fixation, coils, mock scanner...)

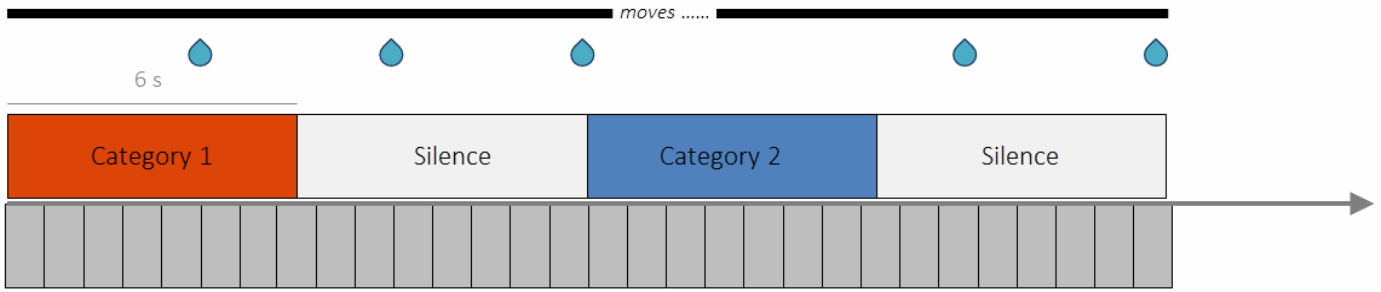


- Task designs



- **Protocol 1 (M1)**

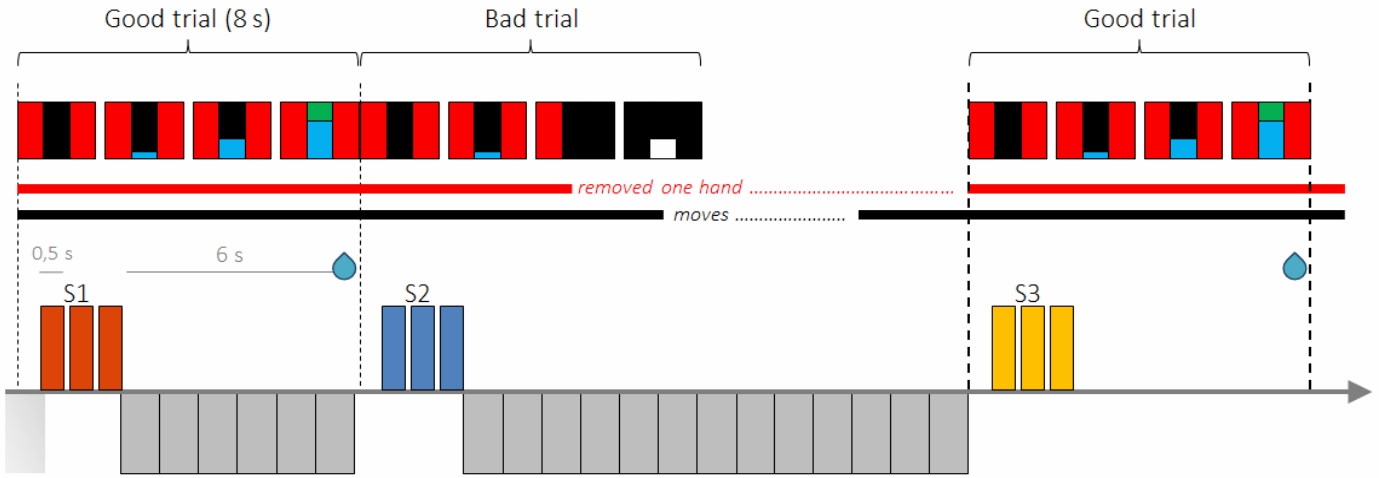
Protocol 1: Bloc design



- **Protocol 2 (M2 & M3, H1-H5)**

Visual feedback on a screen
→ determines the acquisitions

Protocol 2: Clustered sparse design

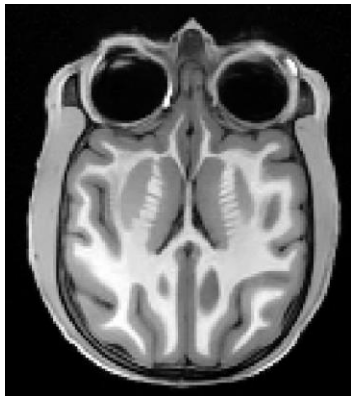


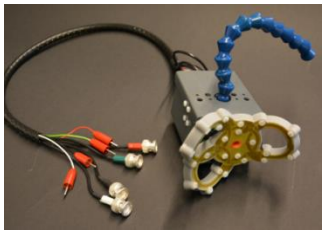
MONKEY TRAINING AND SCANNING

- Task designs: differences

	Protocol 1	Protocol 2
Animals	M1	M2, M3 , all humans
Contrast agent	No *	Yes (M)
Stimuli categories	H, M, NV	H, M, MT, NV
Stimuli duration	Mean durations (ms): M (400), H(550), NV (536)	Fixed to 500 ms
fMRI design	Block design	Clustered sparse design
Behavior and acquisitions	Independent	Dependent
Func res.	1.5 x 1.5 x 3 mm	1.5 mm iso (M) ; 2.5 mm iso (H)
Coils	Single loop	2x4 ch. Leuven (M) ; 64-ch. Siemens (H)

* But complementary data using MION





- Data acquired

- **Protocol 1**

No visual feedback

M1
10 sessions (no MION)
6 sessions (MION)

- **Protocol 2**

Visual feedback on a screen
→ determines the acquistions

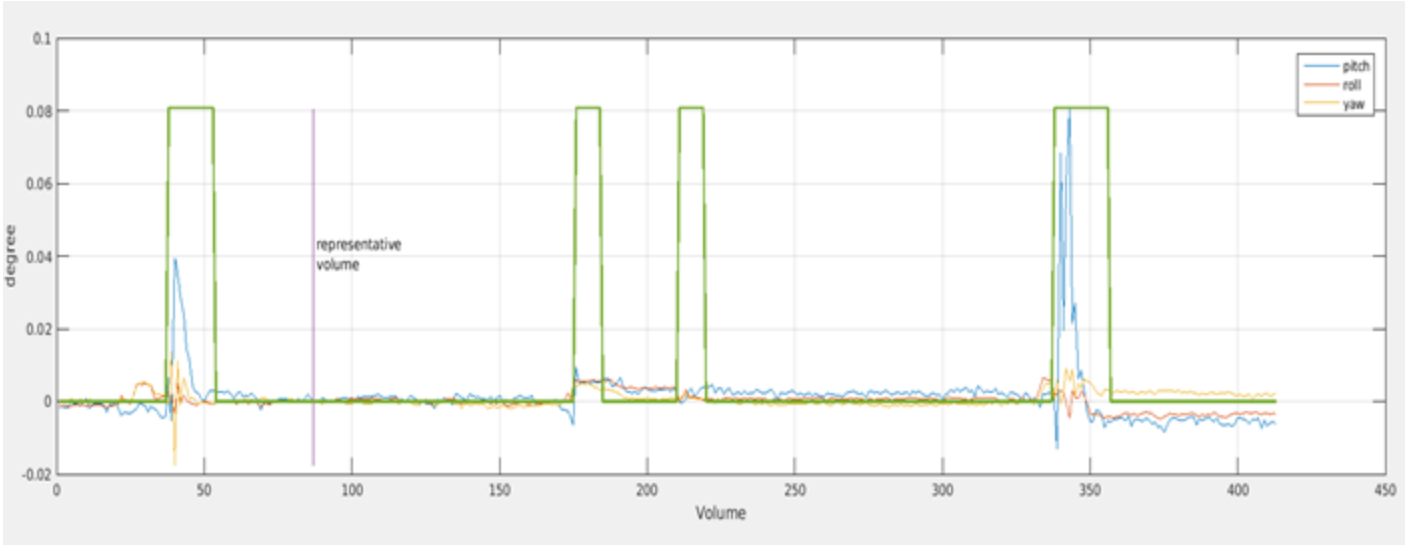
M2
24 sessions (MION)

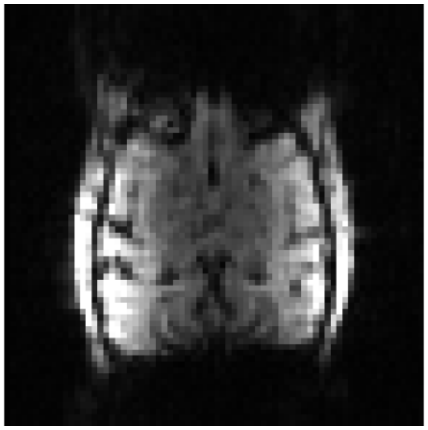
M3
22 sessions (MION)

H1-H5
1 session (2 runs)/ subject

- Data preprocessing

Motion params → Volume selection → Reference volume selection → Realign & unwarp → Smoothing (x2 res)





- Data preprocessing

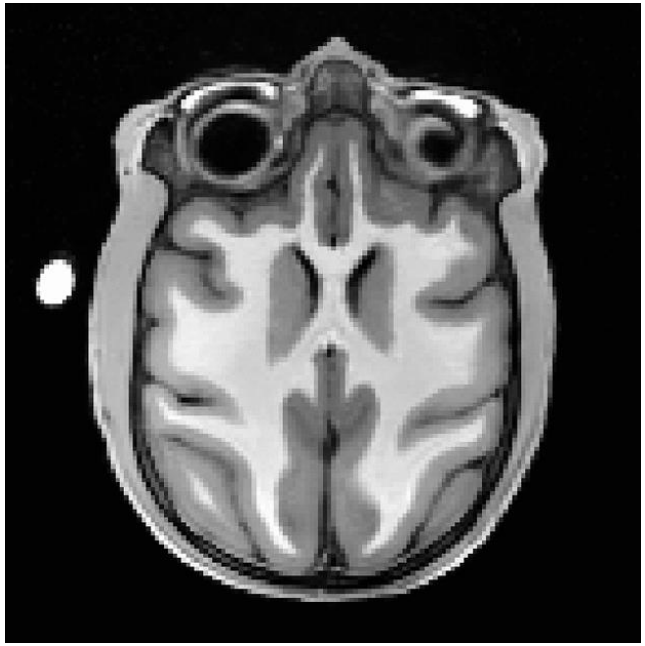
FSL SPM ANTs

Motion params → Identify moving periods → Reference volume selection → Realign & unwarp → Smoothing (x2 res)

Structural scans → Crop → Bias correction & denoising → Brain extraction

Tissue Segmentation → Brain extraction

NMT macaque template → Brain extraction



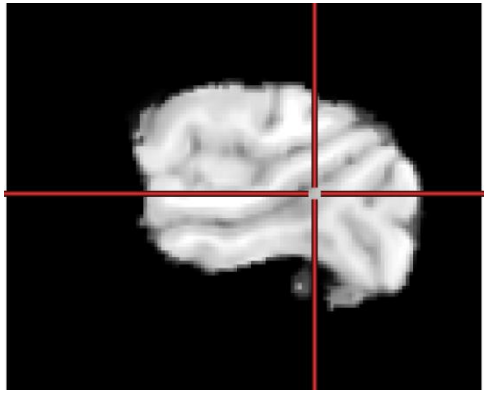
- Data preprocessing

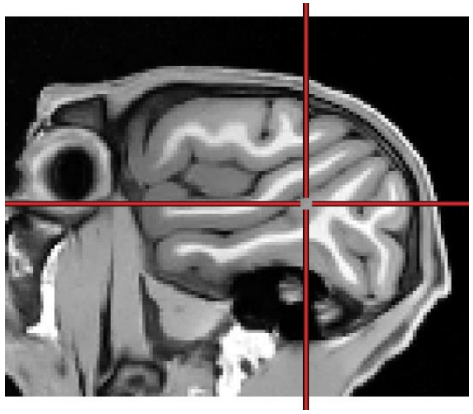
Motion params → Identify moving periods → Reference volume selection → Realign & unwarp → Smoothing (x2 res)

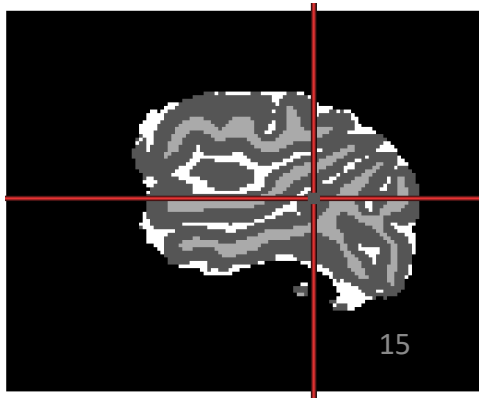
Structural scans → Crop → Bias correction → Denoise → Brain extraction → Tissue Segmentation

NMT macaque template

Coregistration → Functional images → *anat low res* → anat high res







- Data analysis

SPM FMRISTAT

GLM analysis

No interest
6 mvt + squared
First 7 PCA components (CSF & WM)
Moving volumes

Response functions
BOLD HRF humans and monkeys (Baumann 2010)
MION HRF monkeys (Vauduffel 2001)

T-test
Multiple comparison correction

Auditory activity

Sound > silence

Jackknife sorting
→ Run selection

-Spatial extent
-Max t value

Contrast of interest

Sound > silence

Conspecific Voice (CV) > non CV

8-3
11-4
14-6
3-3
11-6
8-4
15-6
12-5
13-1
14-1
11-5
12-4
15-1
14-7
5-1
18-1
14-5
13-2
13-3
13-4
8-5
15-5
5-3
5-2
10-3
11-3
20-3
5-4
20-1
23-2
15-4
21-3
10-2
18-2
17-4
20-4
15-3
19-3
23-1
All runs
11-7
10-4
16-1
19-2
10-1
12-3
23-3
8-1
17-2
21-1
4-1
21-4
18-3
11-2
12-1
15-2
8-2
20-2
16-3
12-2

Human voices. (H) > **Macaque voc. (M)** | **Marmoset voc. (MT)** | **Non Vocal (NV)**

- Data analysis

SPM FMRISTAT

GLM analysis

No interest
6 mvt + squared
First 7 PCA components (CSF & WM)
Moving volumes

Response functions
BOLD HRF humans and monkeys (Baumann 2010)
MION HRF monkeys (Vauduffel 2001)

T-test
Multiple comparison correction

Auditory activity

Sound > silence

Jackknife sorting
→ Run selection

-Spatial extent
-Max t value

Contrast of interest

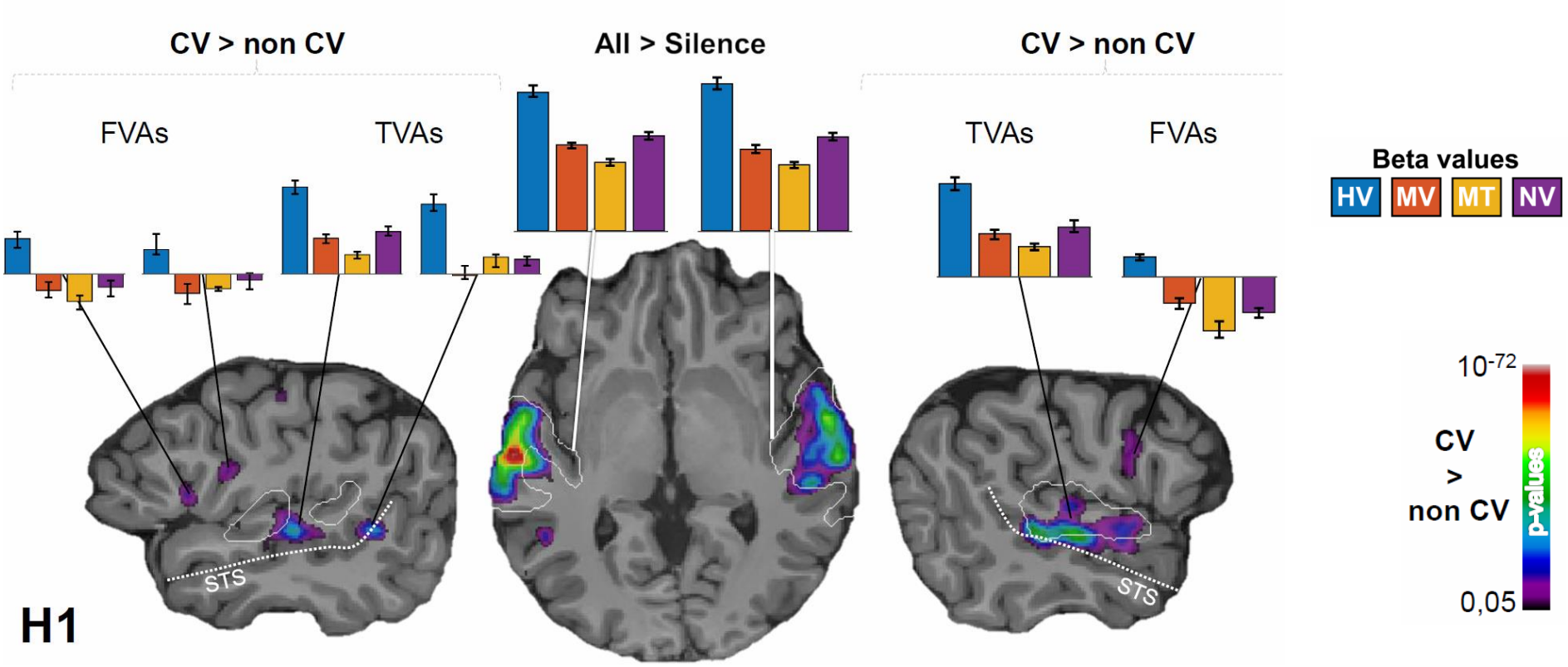
Sound > silence

Conspecific Voice (CV) > non CV

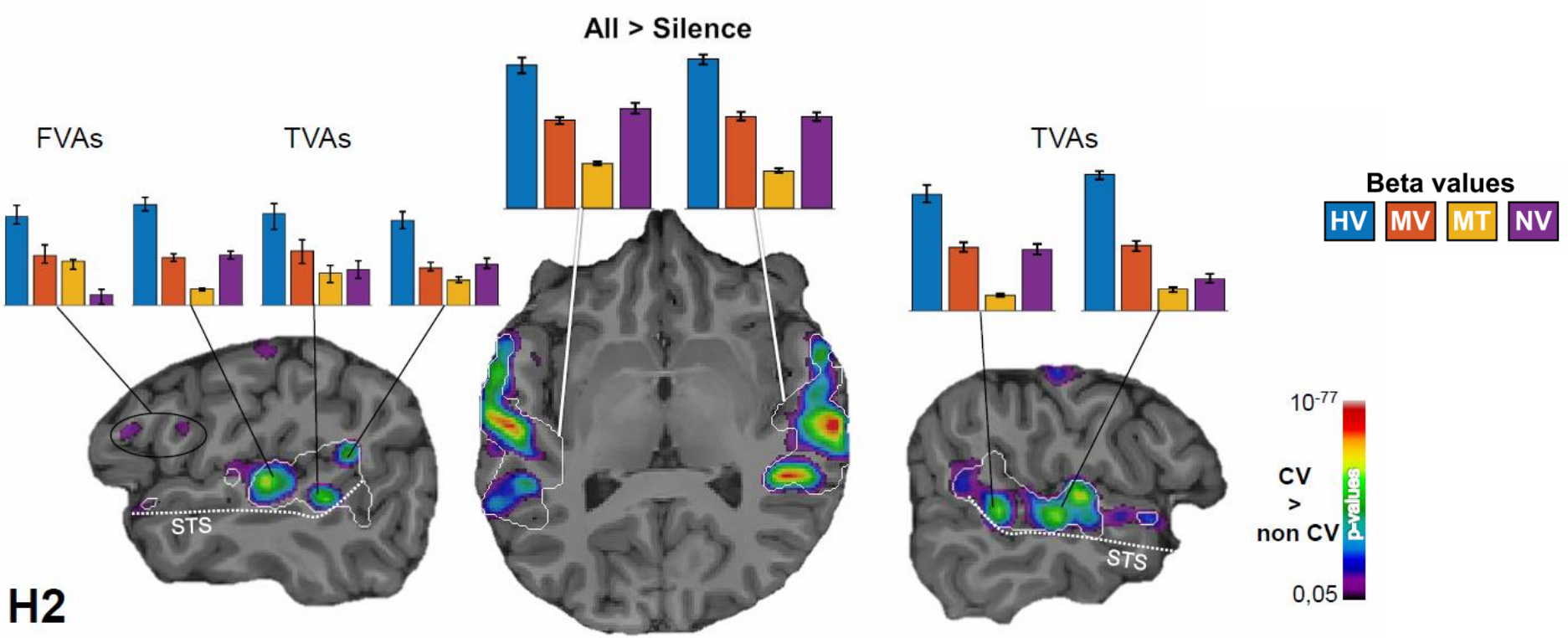
Macaque voc. (M) > **Human voices. (H)** | **Marmoset voc. (MT)** | **Non Vocal (NV)**

Human voice areas : Conspecific voice (H) > non CV (M+MT+NV)

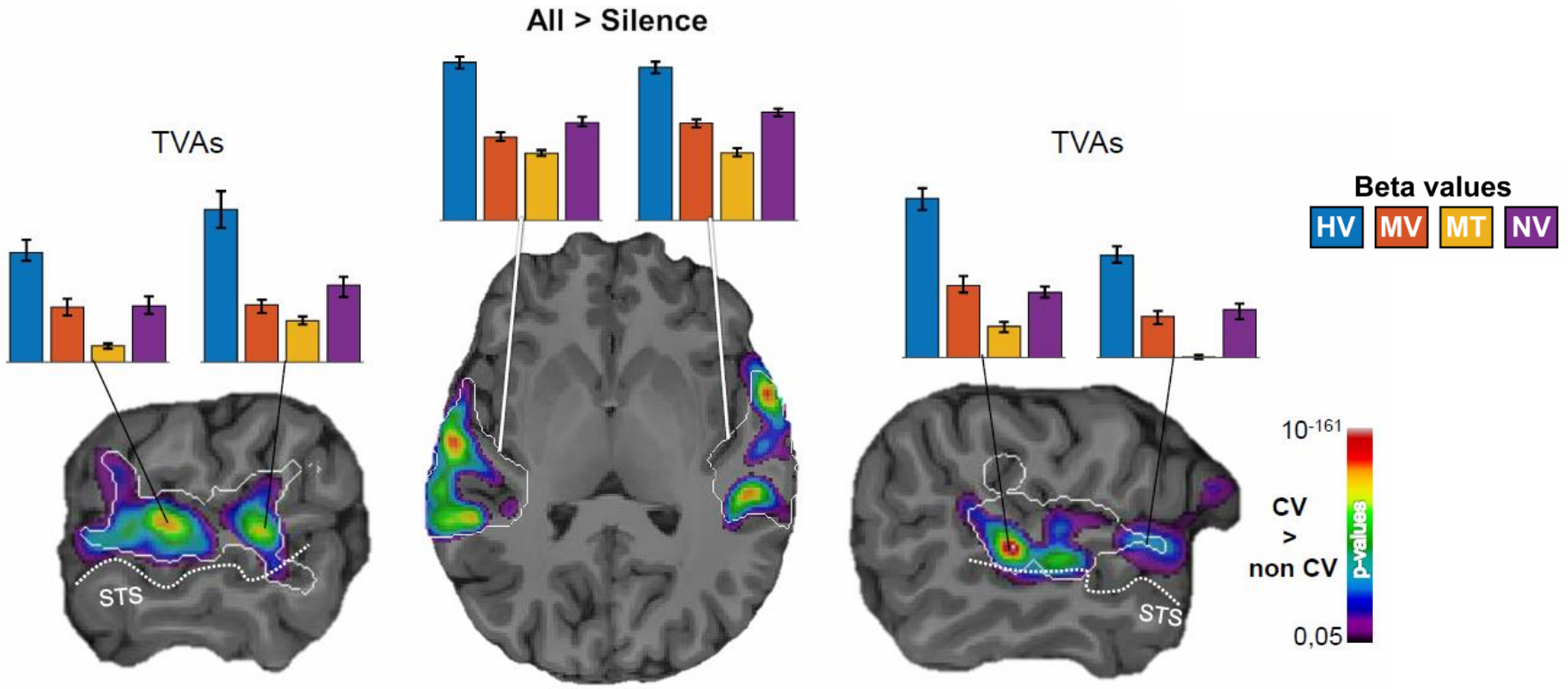
Recruits **Temporal voice areas (TVAs)** (Belin et al. 2000; Pernet et al. 2015) and **Frontal Voice Areas (FVAs)** (Aglieri et al. 2018)



Human voice areas : Conspecific voice (H) > non CV (M+MT+NV)



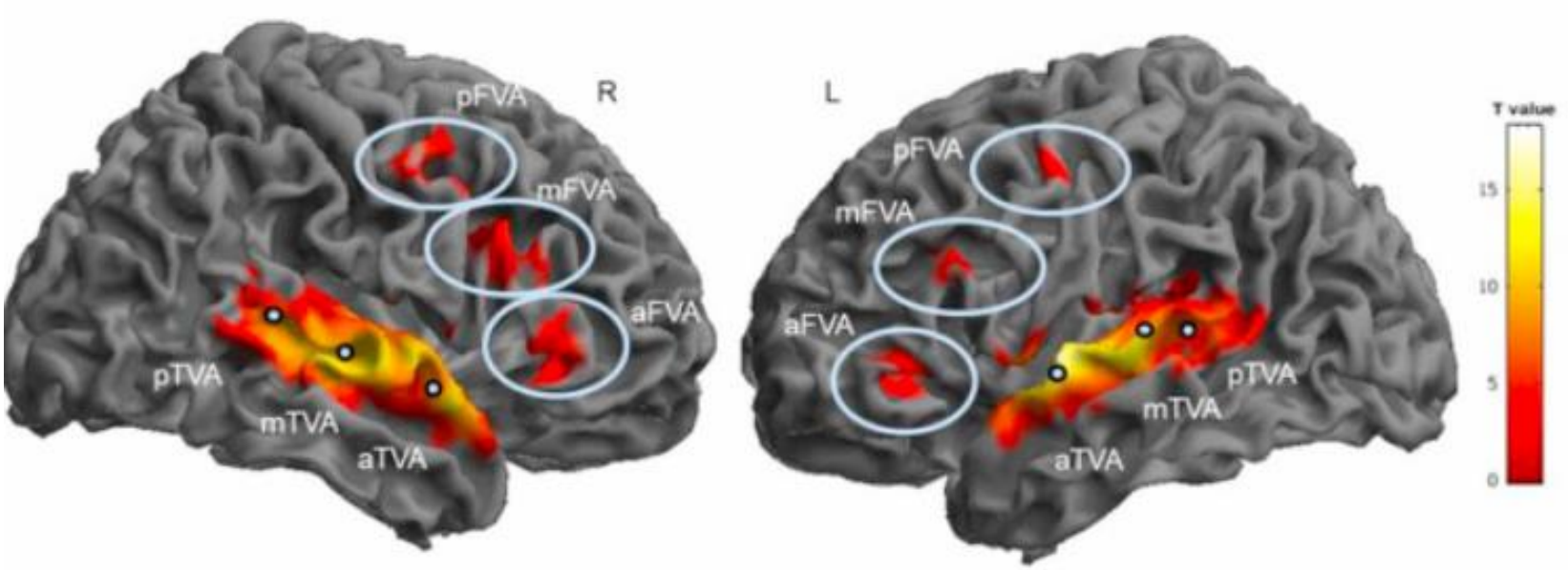
Human voice areas : Conspecific voice (H) > non CV (M+MT+NV)



H3

Close to what has been observed at the group level !

Aglieri et al. (2018) ; n=92

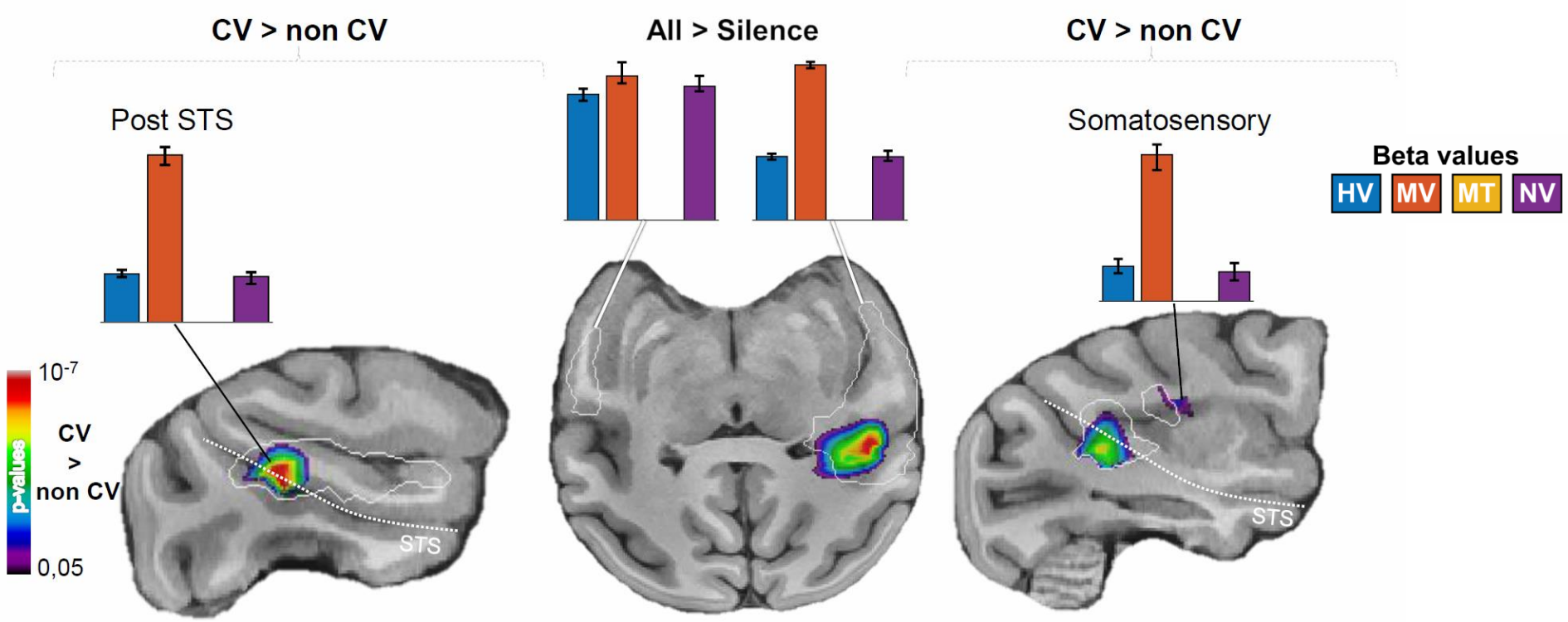


Voice patch	Coordinates (x y z)	Labelling – Anatomy toolbox	Labelling – Harvard Oxford atlas
Right aTVA	58 2 -8	Temporal pole	STG anterior division
Right mTVA	58 -20 -2	STG	STG posterior division
Right pTVA	50 -32 4	STG	STG posterior division
Right aFVA	54 32 0	IFG (triangularis)	IFG (triangularis)
Right mFVA	48 18 24	IFG (triangularis)	IFG (opercularis)
Right pFVA	51 -2 48	Precentral gyrus	Precentral gyrus

Voice patch	Coordinates (x y z)	Labelling – Anatomy toolbox	Labelling – Harvard Oxford atlas
Left aTVA	–62 -4 0	STG	STG anterior division
Left mTVA	–66 -28 4	MTG	STG posterior division
Left pTVA	–58 -38 6	MTG	STG posterior division
Left aFVA	–39 27 -3	IFG (orbitalis)	IFG (orbitalis)
Left mFVA	–48 16 21	IFG (opercularis)	IFG (opercularis)
Left pFVA	–52 -8 48	Postcentral gyrus	Precentral gyrus

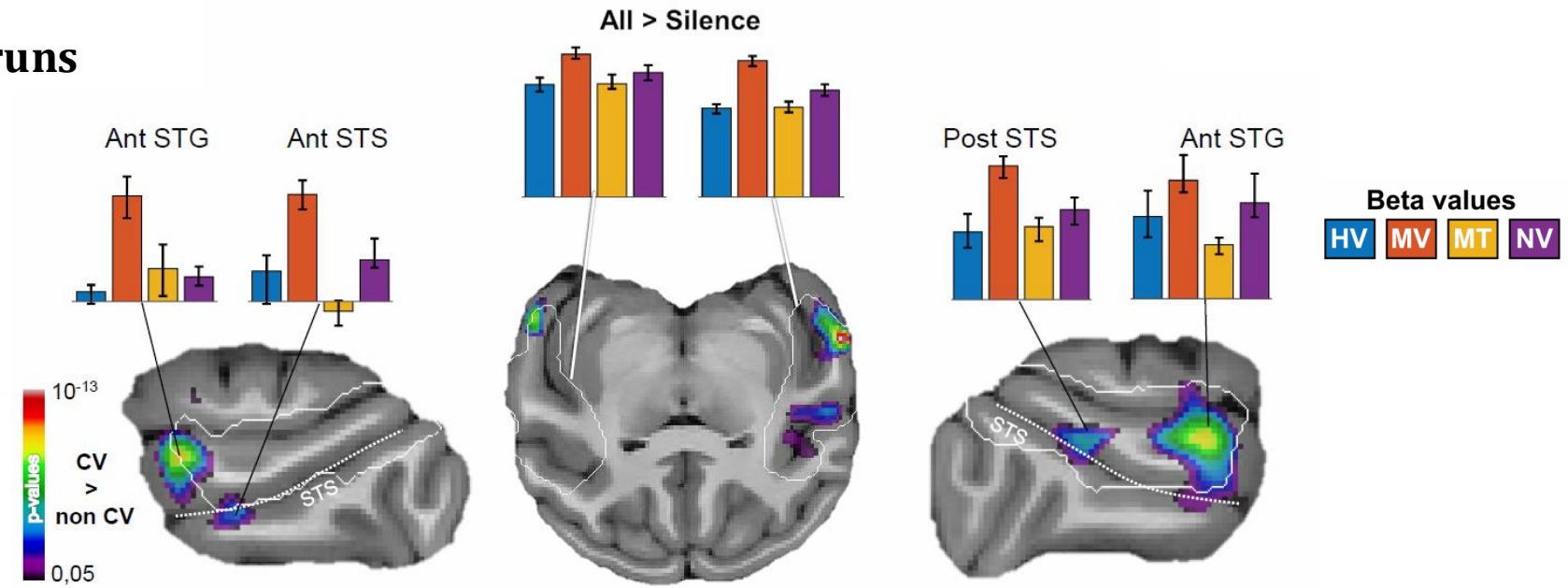
Monkey voice areas : Conspecific voice (M) > non CV (H+MT+NV)

M1

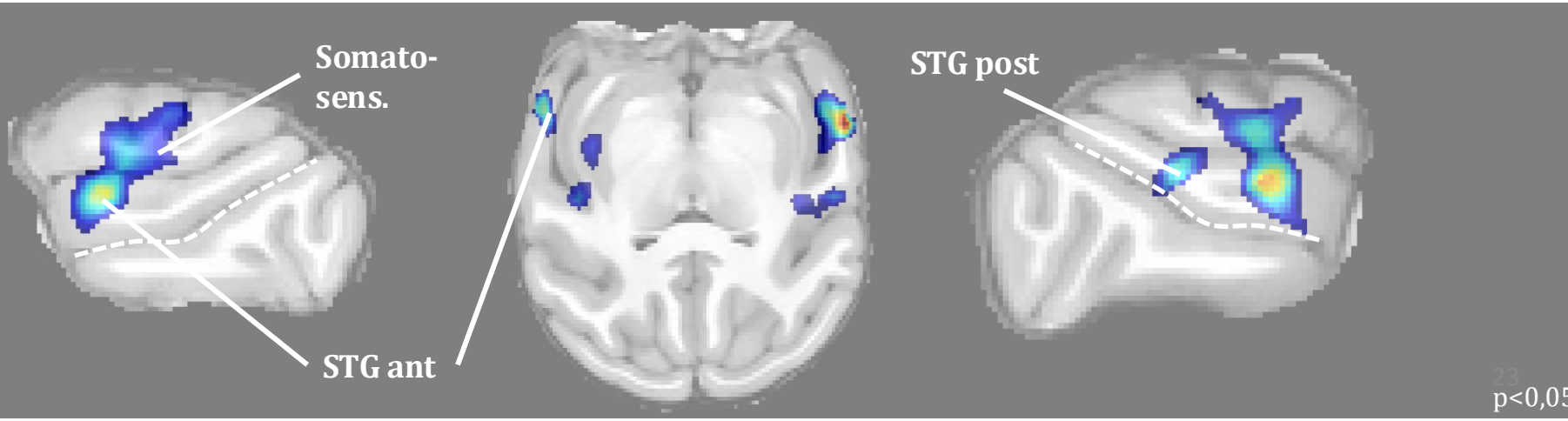


Monkey voice areas : Conspecific voice (M) > non CV (H+MT+NV)

M2: 26 runs



M2: 51 runs

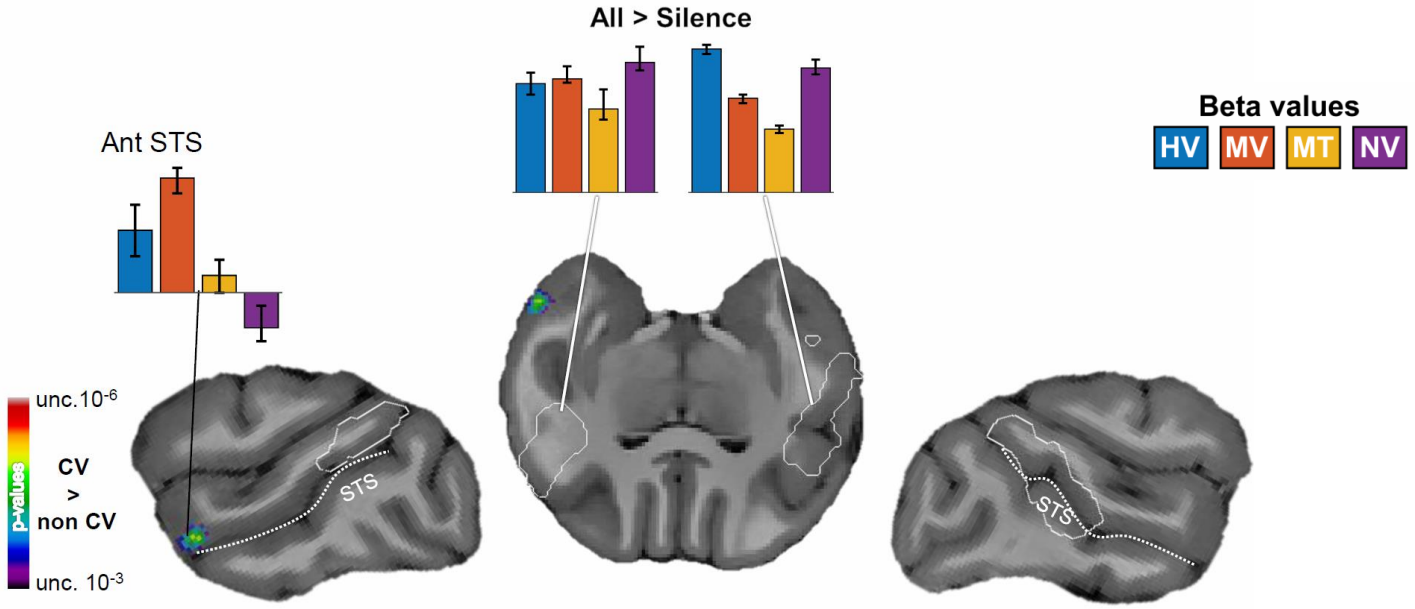


Axial view

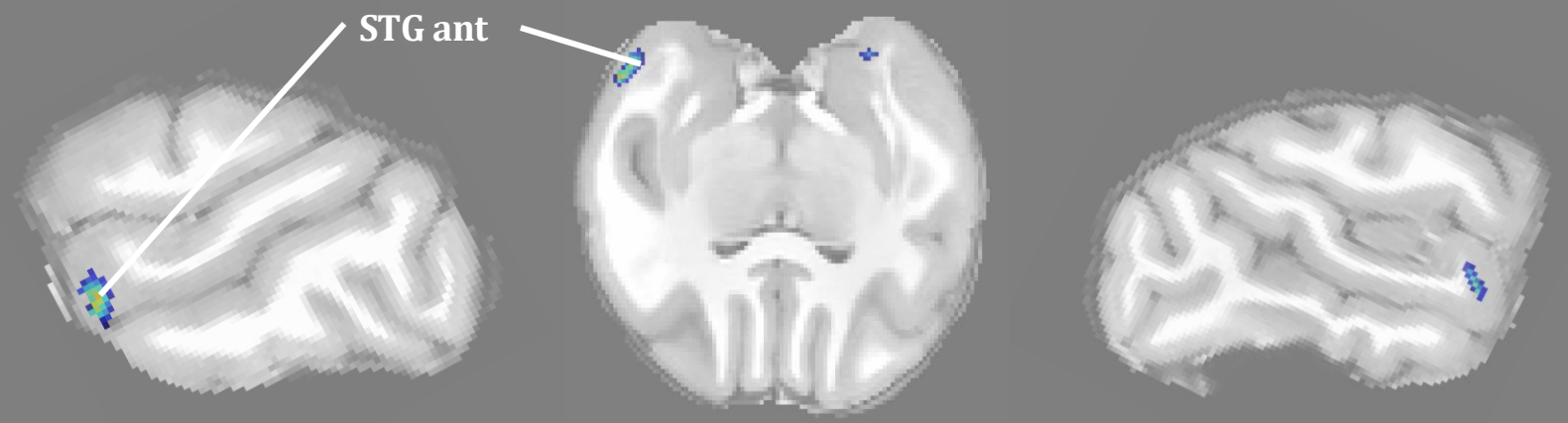
Sagittal view

Monkey voice areas : Conspecific voice (M) > non CV (H+MT+NV)

M3: 42 runs

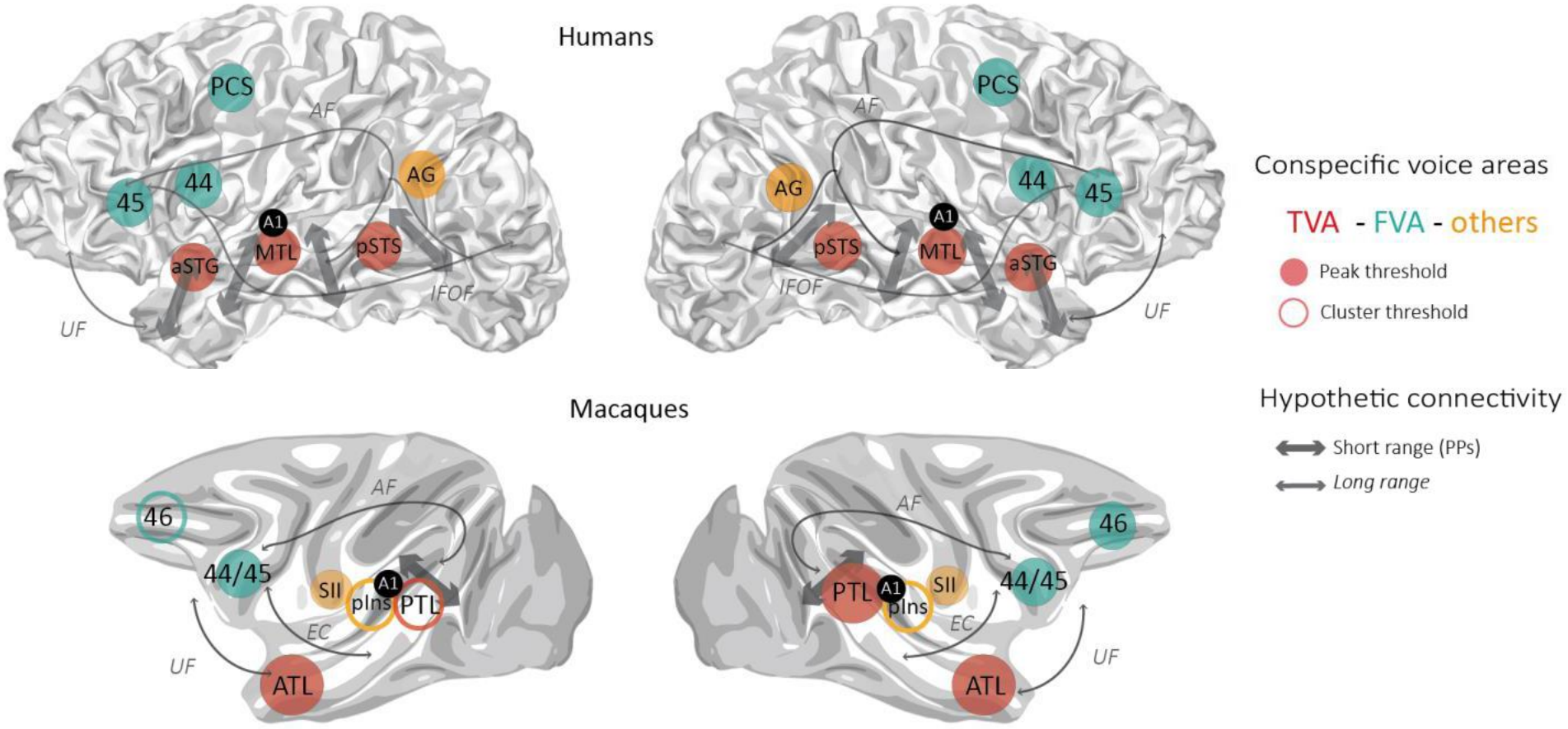


M3: 68 runs

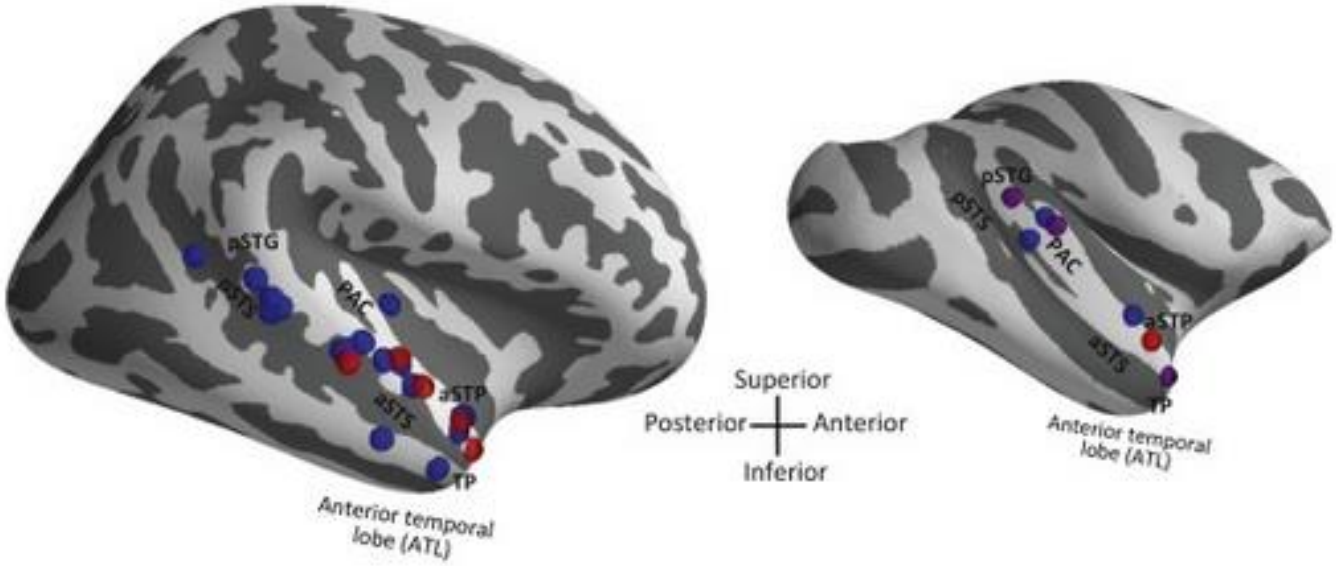


p<0,05 unc.

Conspecific Voice areas



Consistency with voice areas in the literature :

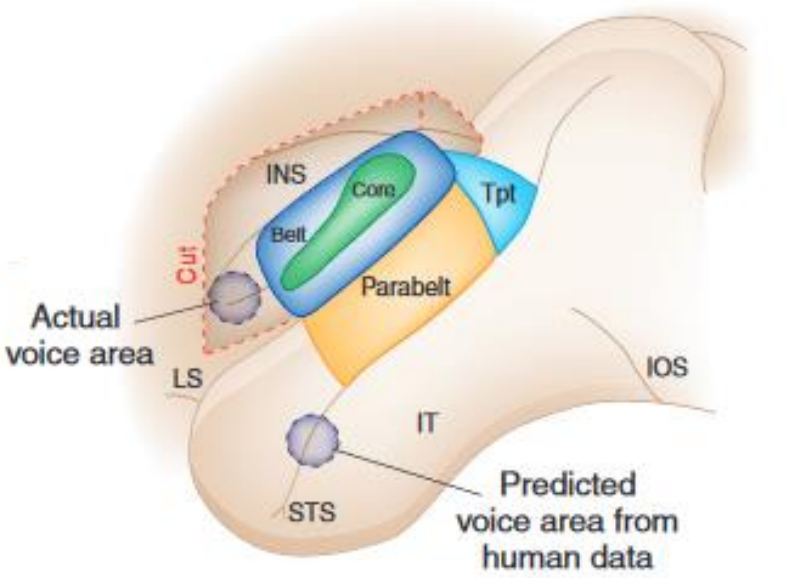


V > NV

Identity

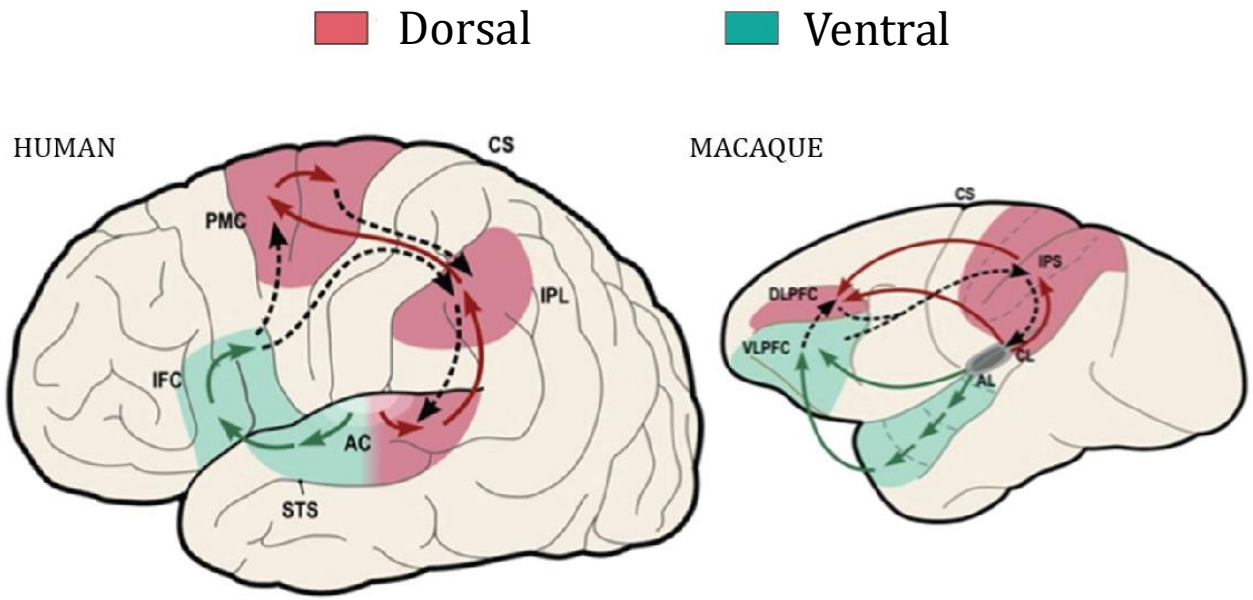
Perrodin 2015
Trends in Cognitive Sciences

Inconsistency with one voice area !



Ghazanfar 2008
Nature Neurosciences

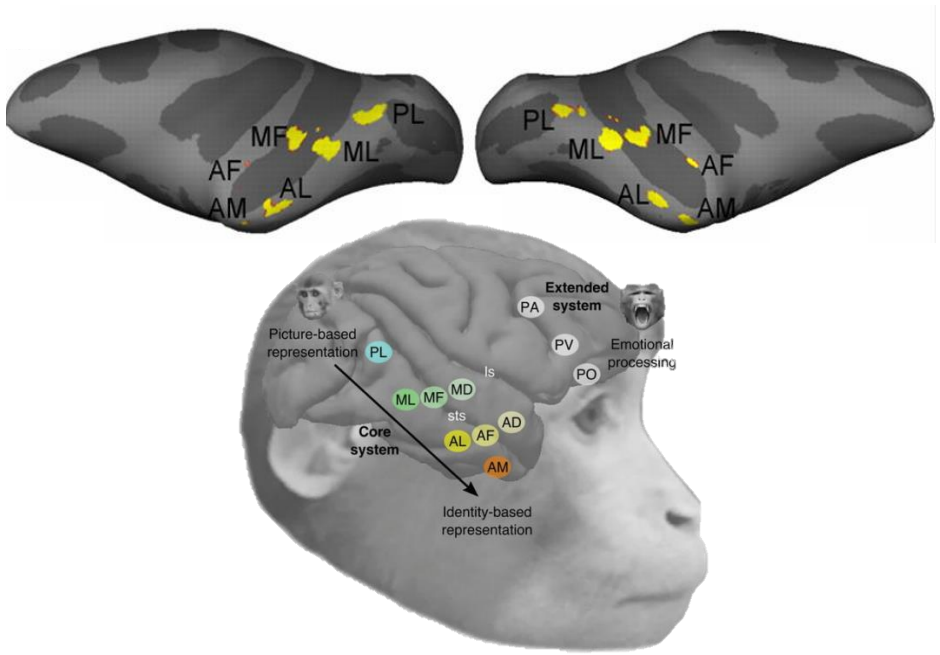
Consistency with auditory pathways in the literature :



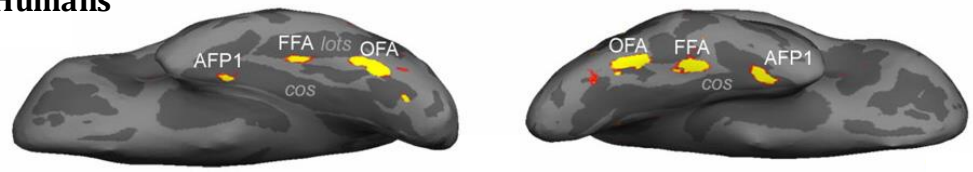
Hypothesis : a « voice patches » cortical organization

The face patch system in primates

Macaques

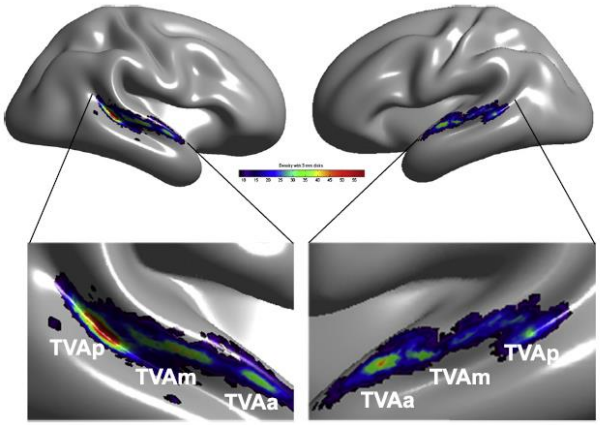


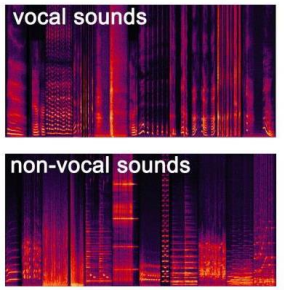
Humans



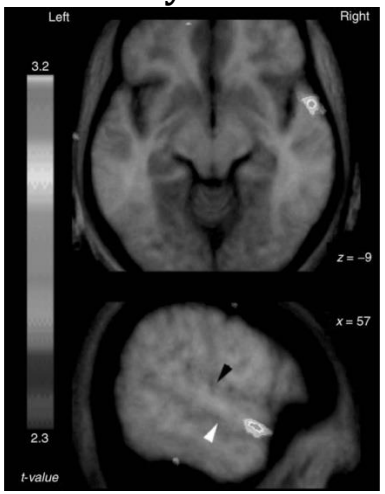
Landi et Freiwald, 2017; Tsao et al., 2008

Temporal voice areas in humans

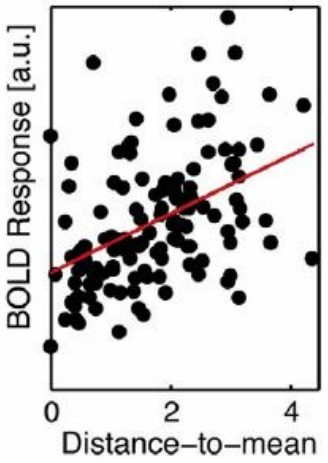




Identity cluster



Variability coding



Belin et al., 2000; Belin et Zatorre, 2003; Latinus et al., 2013 ; Pernet et al., 2015

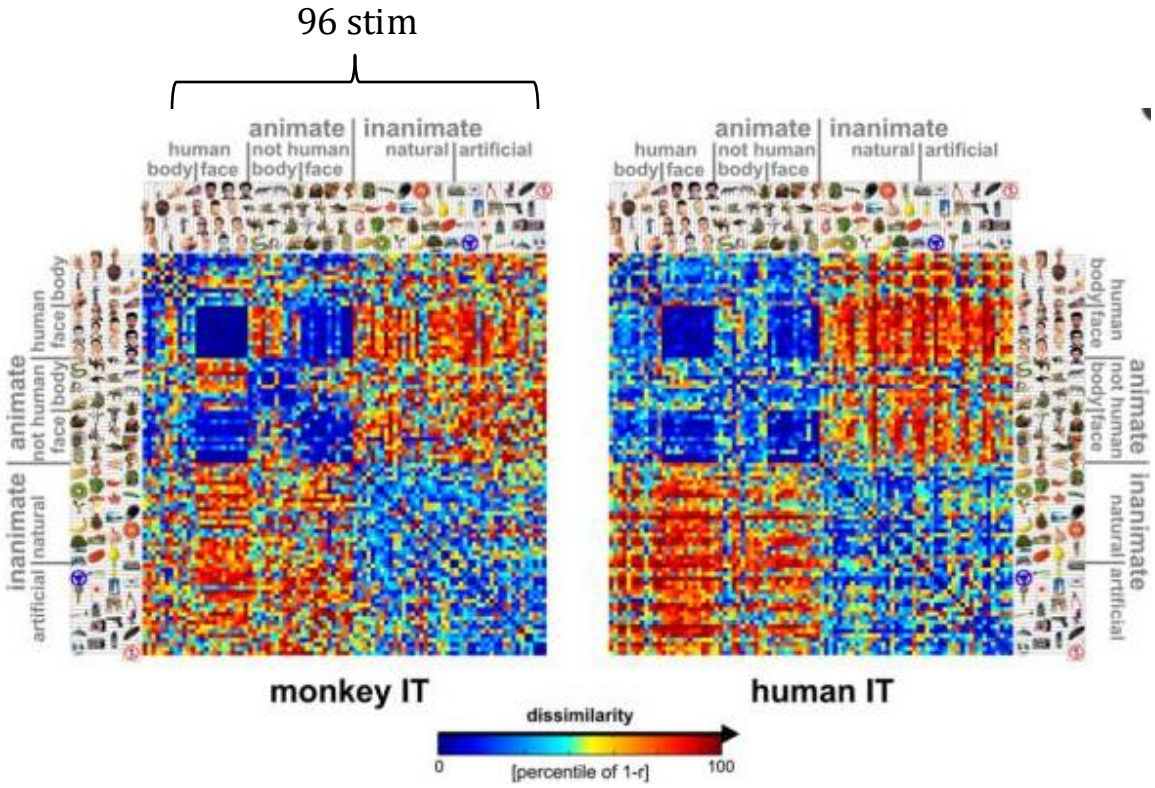
How information is processed in the voice system?

Representation similarity analysis (RSA)
(Kriegeskorte, Mur et al. 2008)

SPECIES COMPARISON

PATCHES COMPARISON

INDIVIDUAL COMPARISON



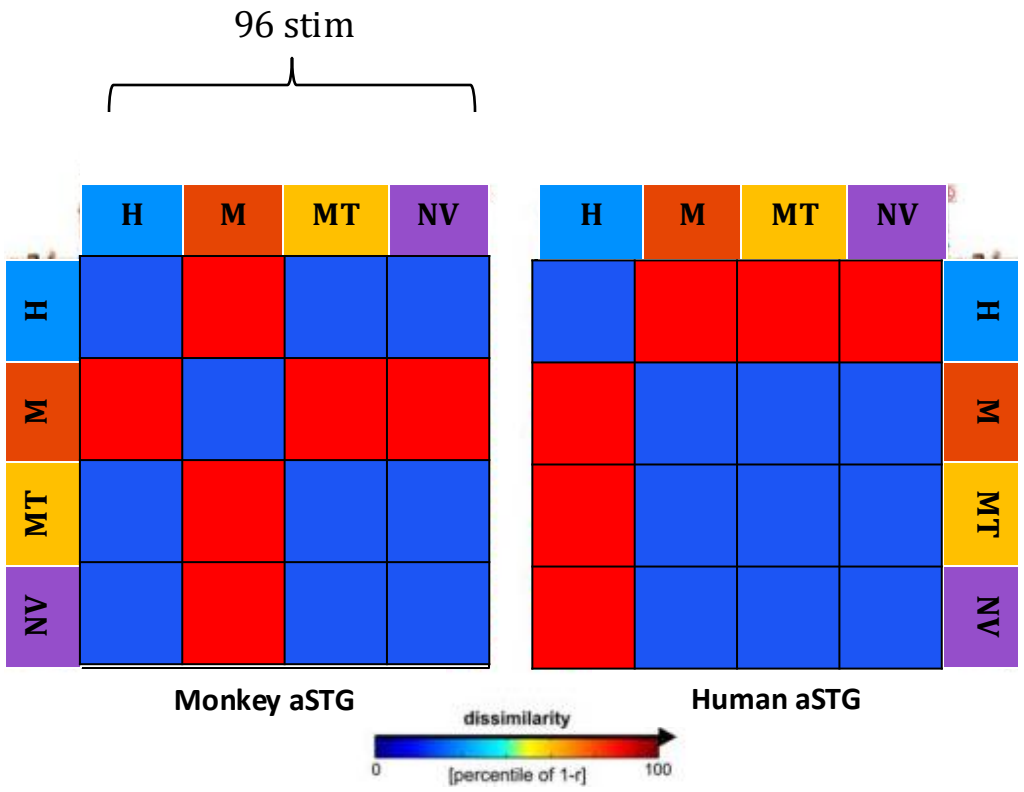
How information is processed in the voice system?

Representation similarity analysis (RSA)
(Kriegeskorte, Mur et al. 2008)

SPECIES COMPARISON

PATCHES COMPARISON

INDIVIDUAL COMPARISON

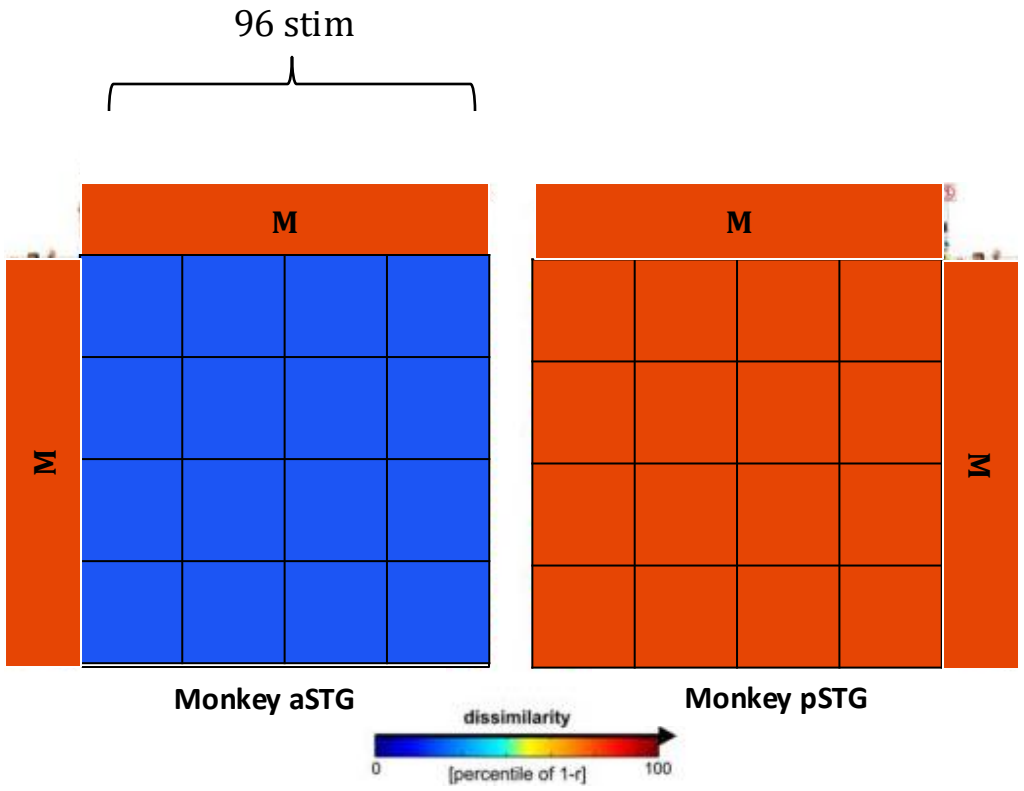


How information is processed in the voice system?

Representation similarity analysis (RSA)
(Kriegeskorte, Mur et al. 2008)

ACOUSTIC

DISTANCE

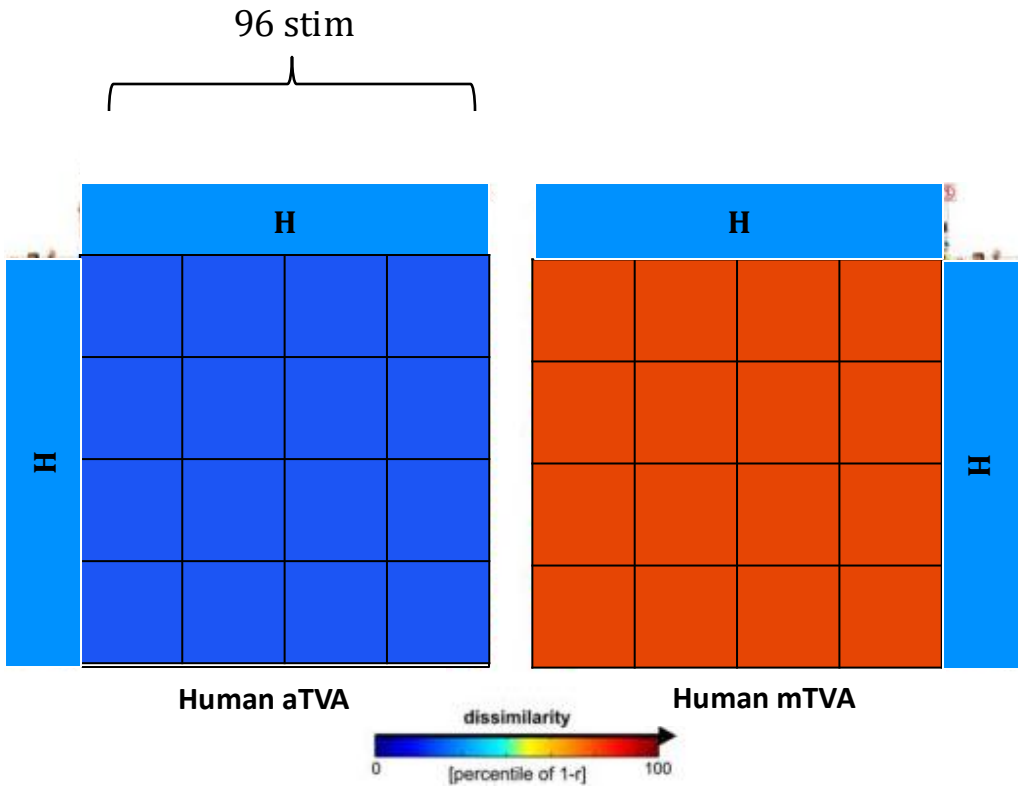


How information is processed in the voice system?

Representation similarity analysis (RSA)
(Kriegeskorte, Mur et al. 2008)

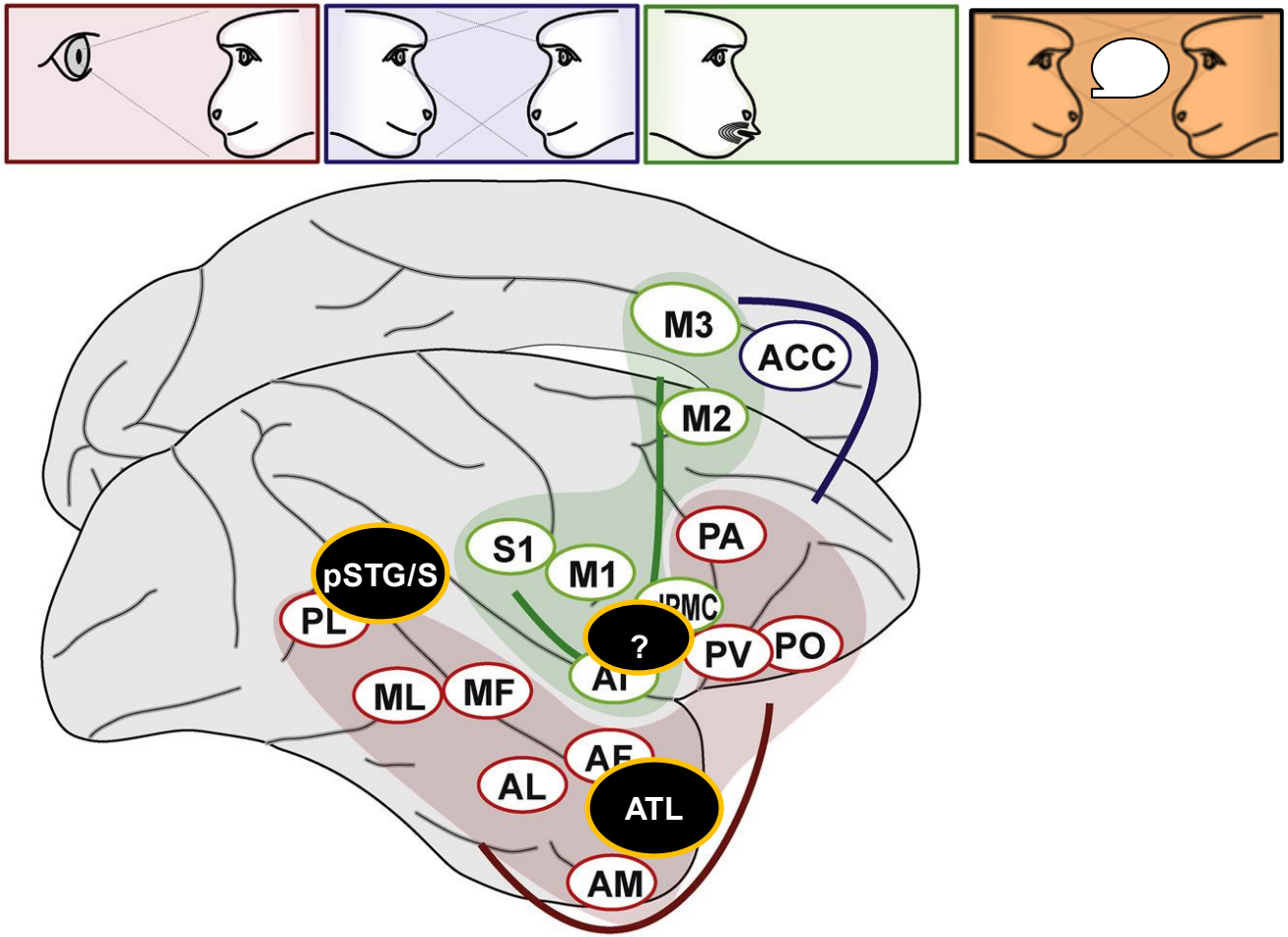
ACOUSTIC

DISTANCE

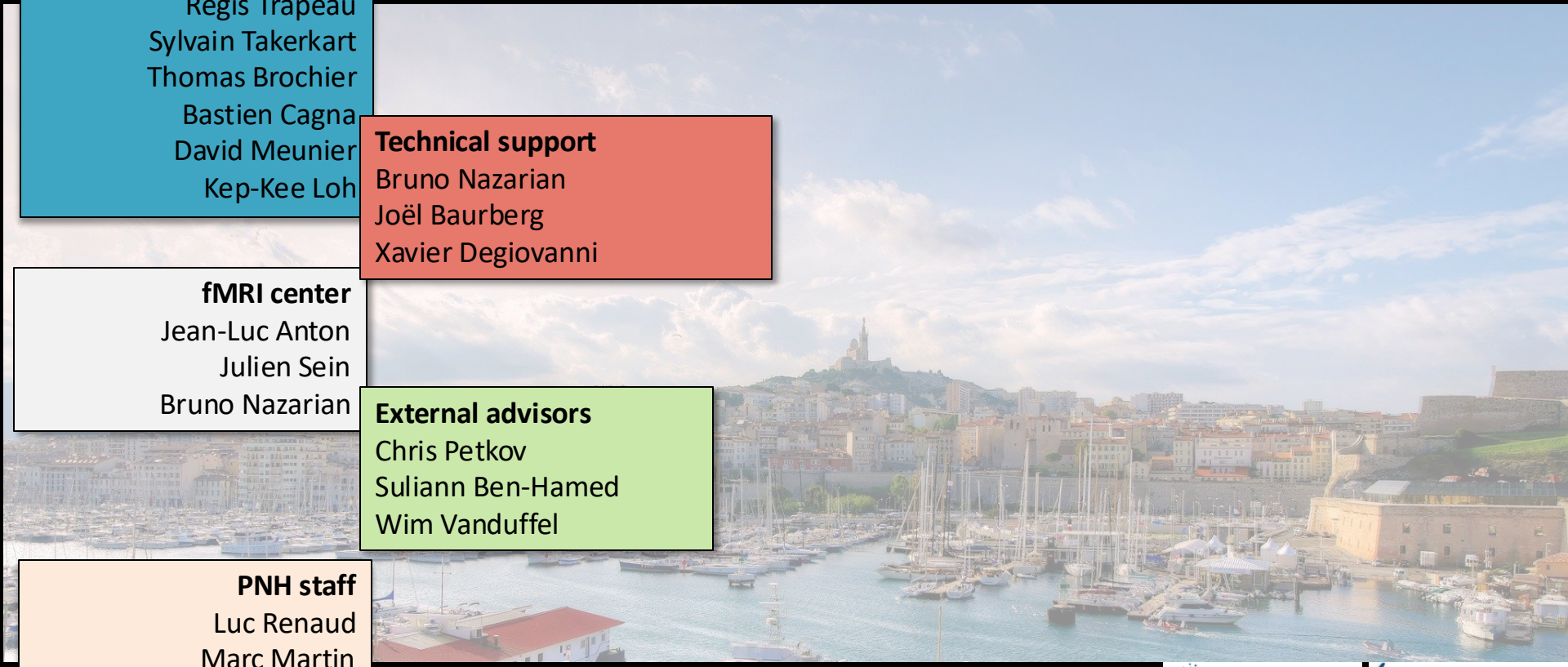


To be integrated in the communication network !

Shepherd et al. (2019)
Neuron



Thank you !



INT colleagues
Pascal Belin
Olivier Coulon
Régis Trapeau
Sylvain Takerkart
Thomas Brochier
Bastien Cagna
David Meunier
Kep-Kee Loh

Technical support
Bruno Nazarian
Joël Baurberg
Xavier Degiovanni

fMRI center
Jean-Luc Anton
Julien Sein
Bruno Nazarian

External advisors
Chris Petkov
Suliann Ben-Hamed
Wim Vanduffel

PNH staff
Luc Renaud
Marc Martin
Laurence Boes
Emilie Rapha
Frédéric Charlin

Macaques
Elouk
Apache
Maga