ICON Session S06:

Cross-modal integration and plasticity of sensory systems in the normal and peripherally deprived brain

Speakers:

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Krish Sathian- Emory University (USA)

Stephen G. Lomber- University of Western Ontario (Canada)

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Cross-modal compensation and plasticity in the blind and deaf: These two modalities do not always show similar outcomes

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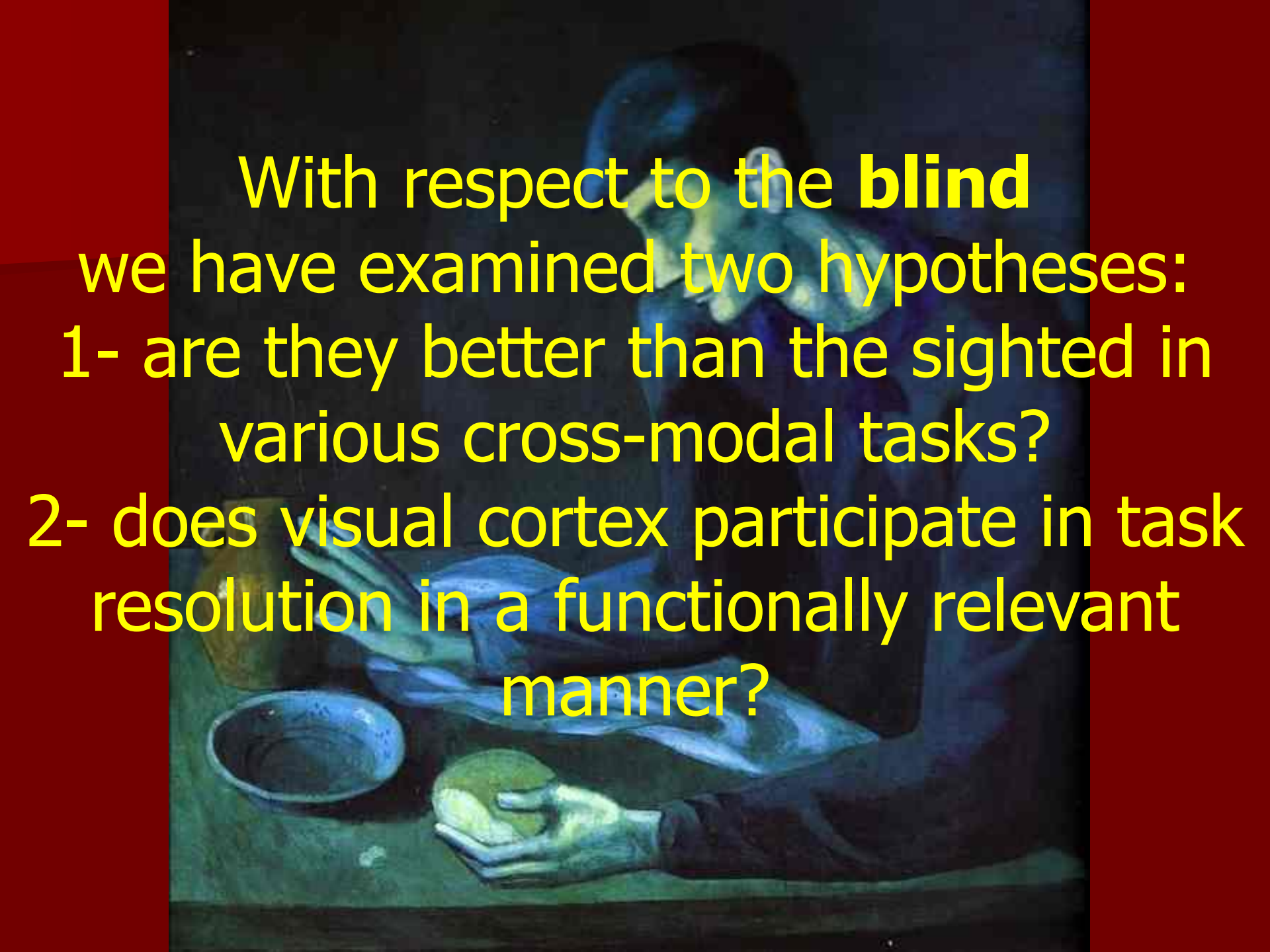
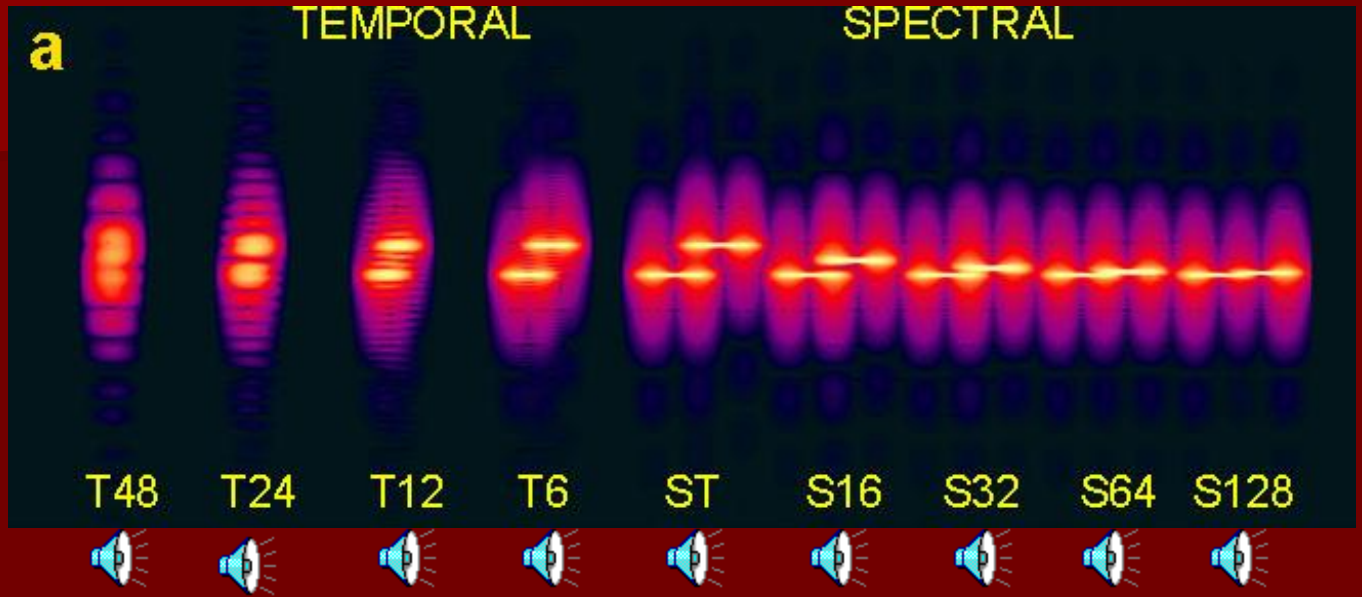


With respect to the **blind**
we have examined two hypotheses:
1- are they better than the sighted in various cross-modal tasks?
2- does visual cortex participate in task resolution in a functionally relevant manner?

Simple task: Pitch discrimination



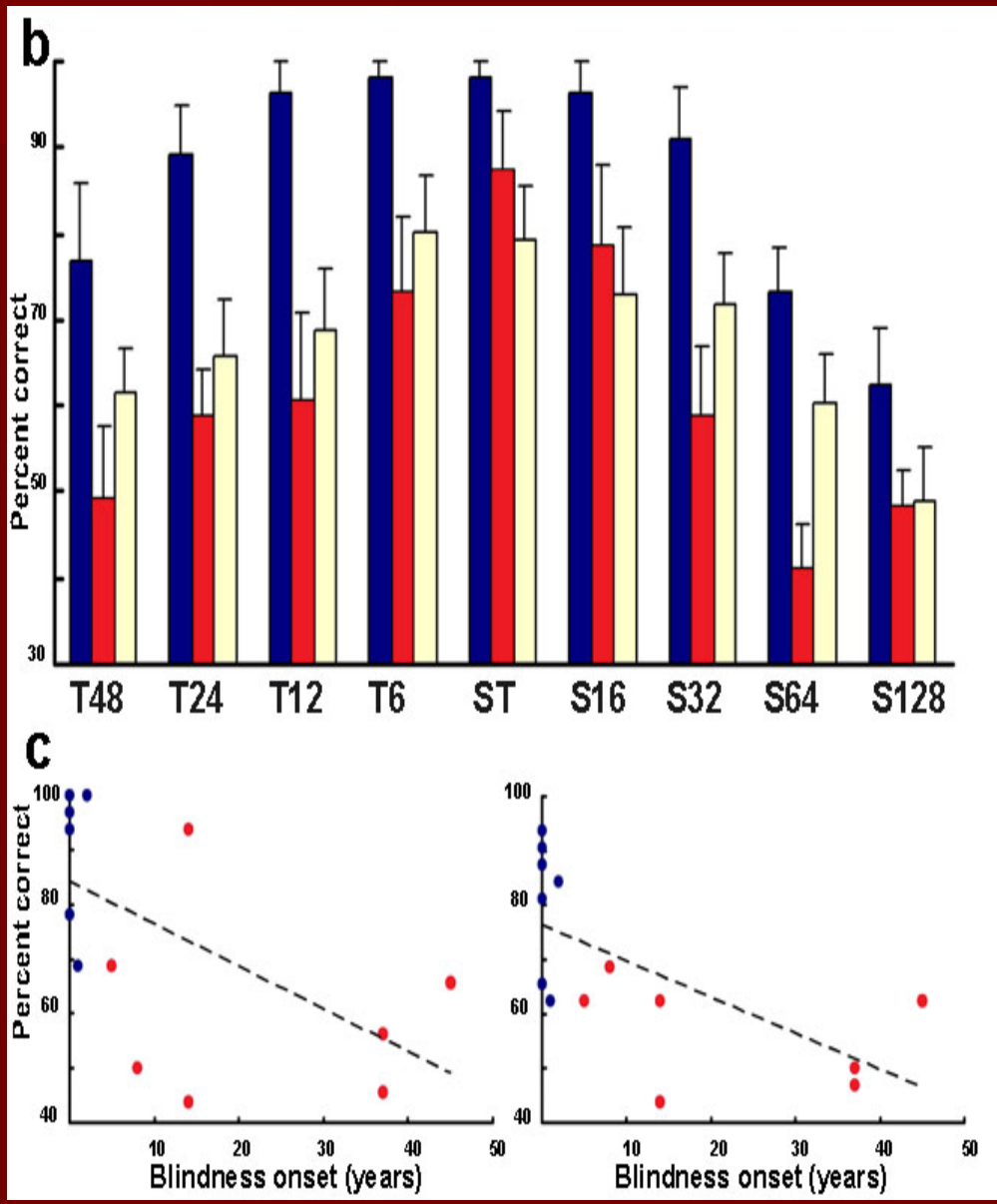
- Two tones of different frequencies or time intervals
- Is frequency decreasing or increasing?
- Standard stimulus (ST): 1.24 kHz, difference 1/8 octave, duration 333ms
- Increasing difficulty-symmetrical

Gougoux, Lepore, Lassonde, Voss, Zatorre, Belin (2004) Nature

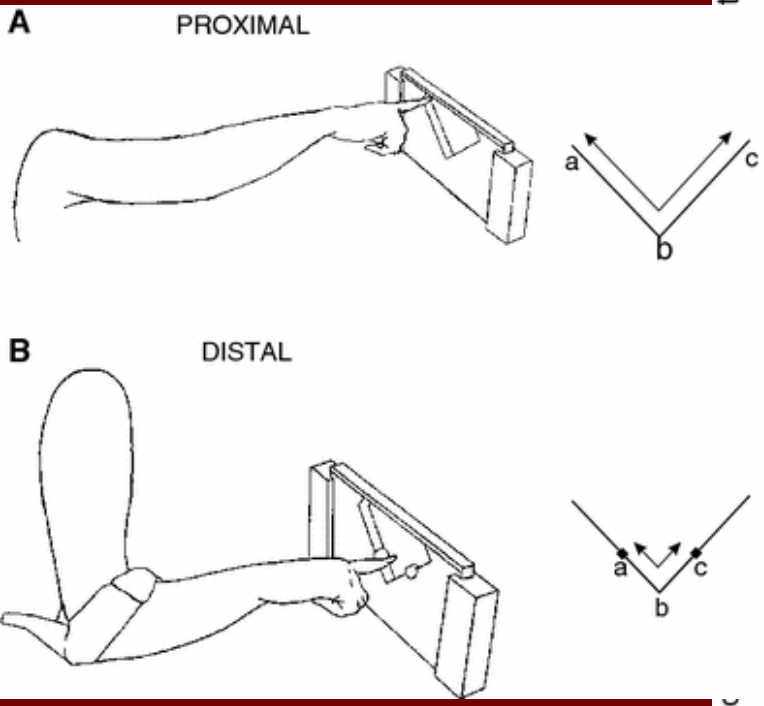
Pitch discrimination in the blind

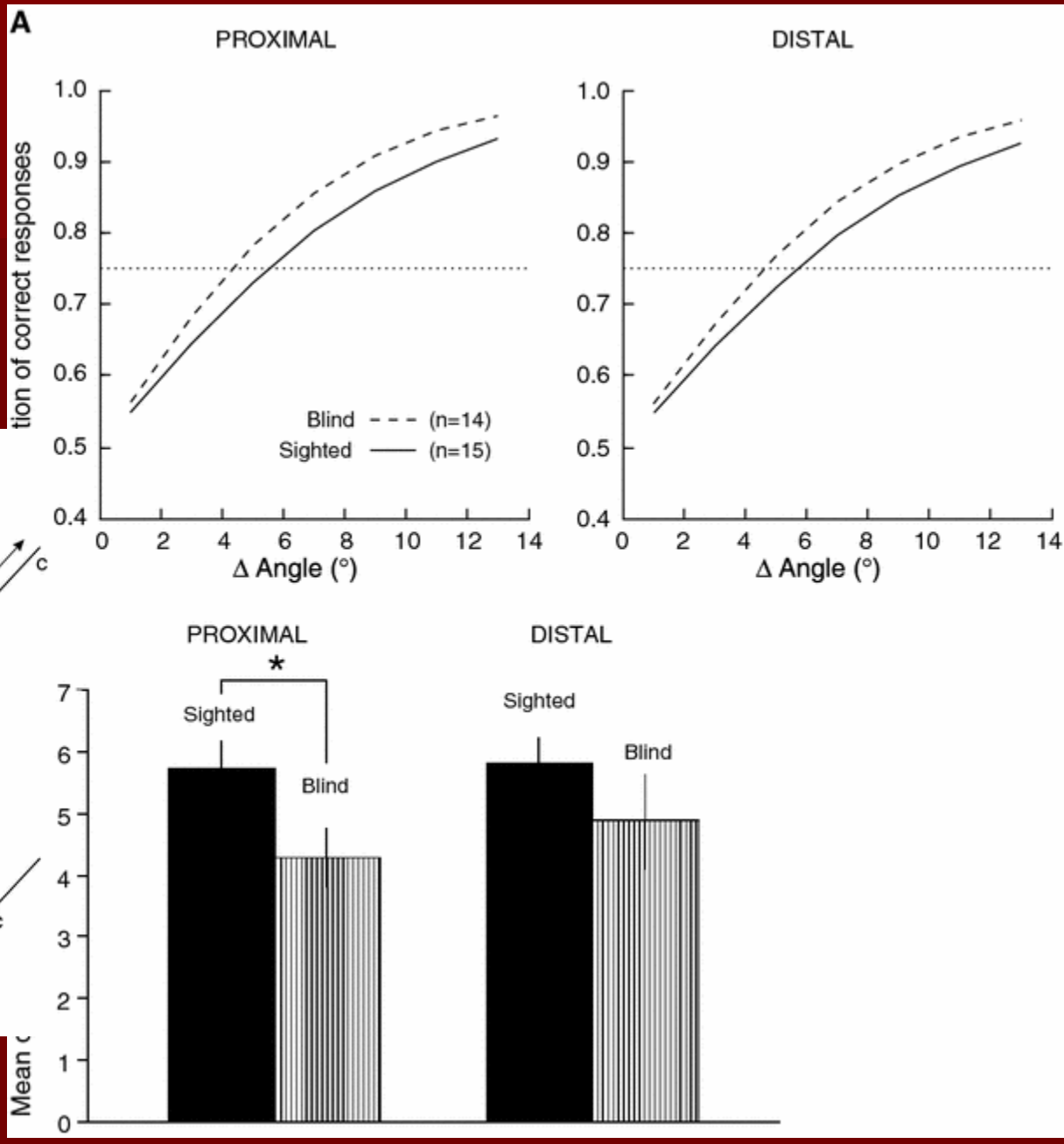
- Judgement of pitch direction and inter-tone interval
- The early-blind are superior to the sighted but, with respect to the critical period, they are also superior to the **late-blind subjects**
- Performance was negatively correlated with age of blindness onset

- Gougoux, Lepore, Lassonde, Voss, Zatorre, Belin (2004) Nature

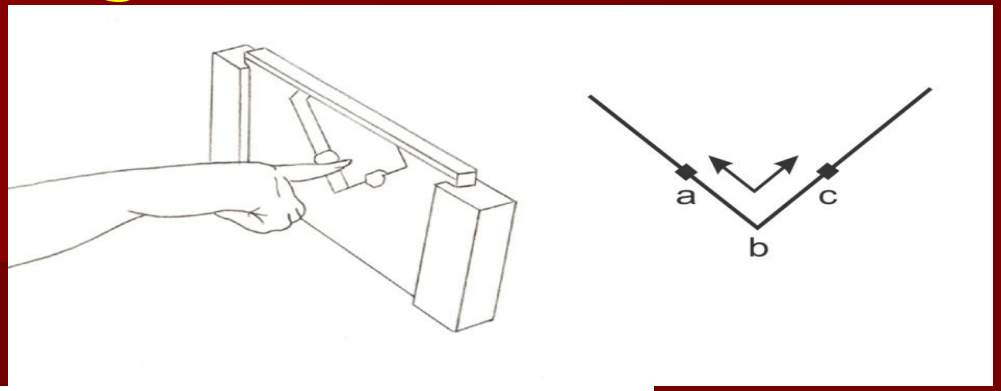


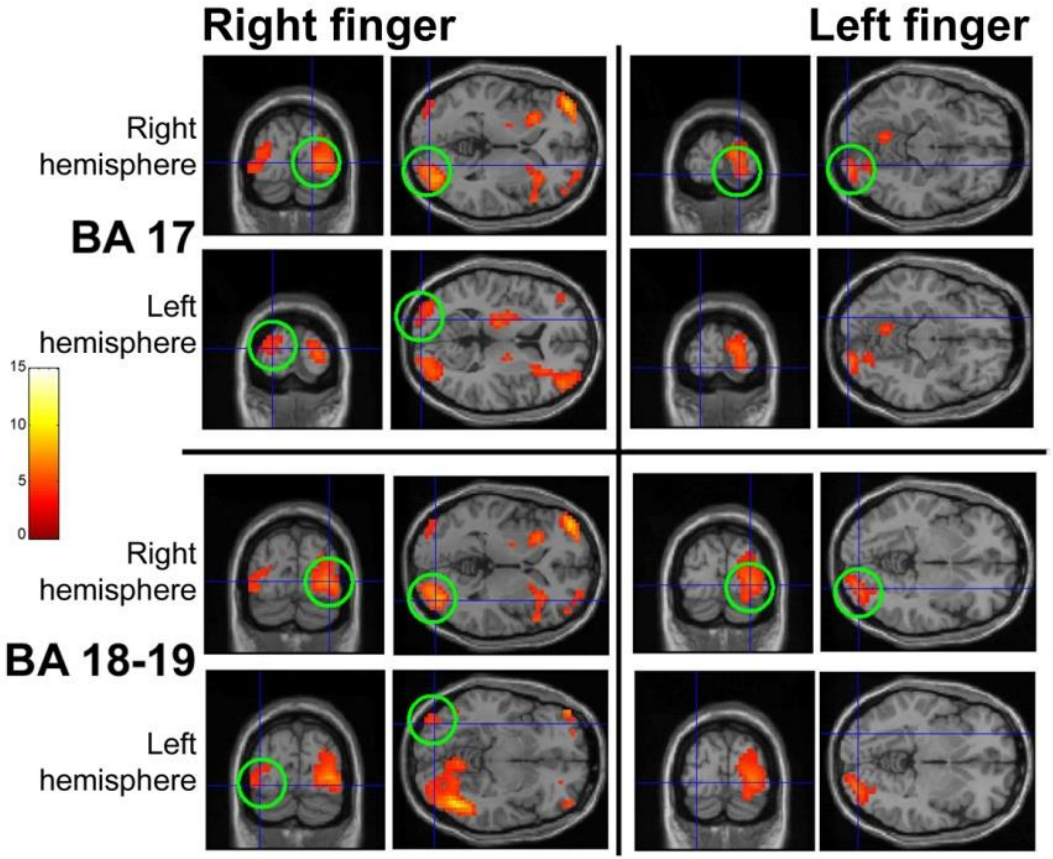
Tactile angle discrimination: the blind are better

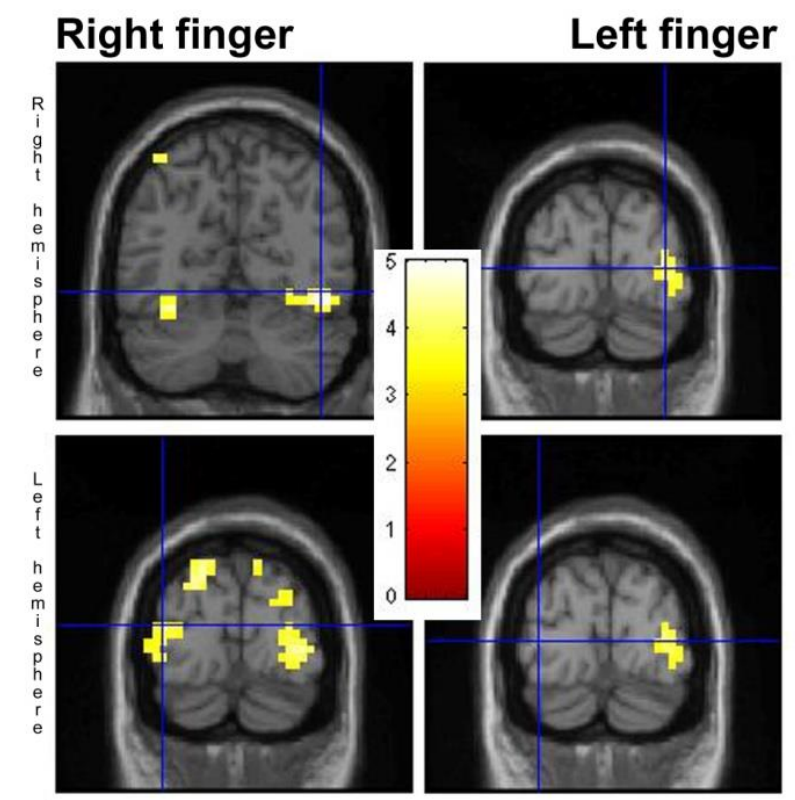




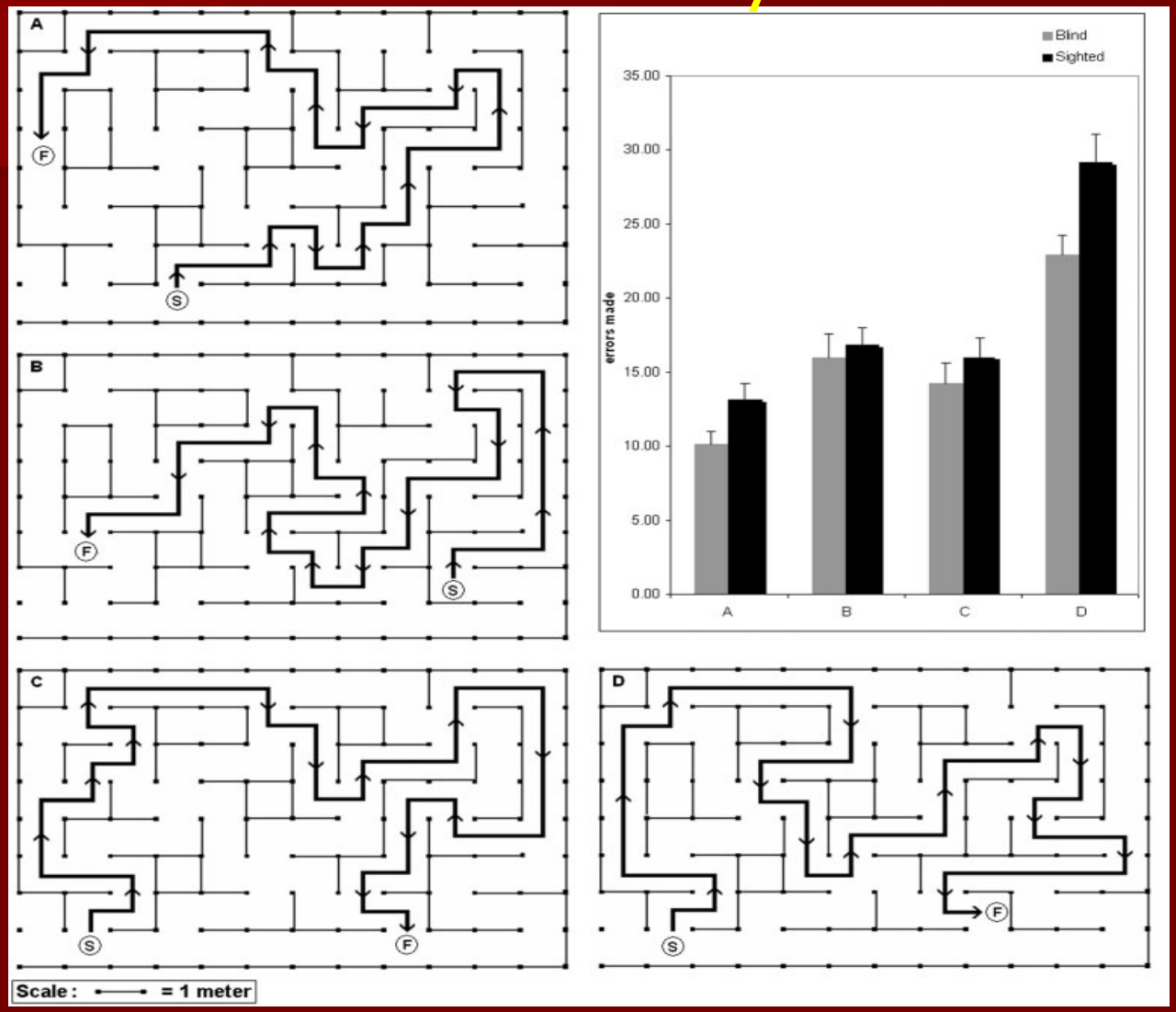
Tactile : angle discrimination in the blind



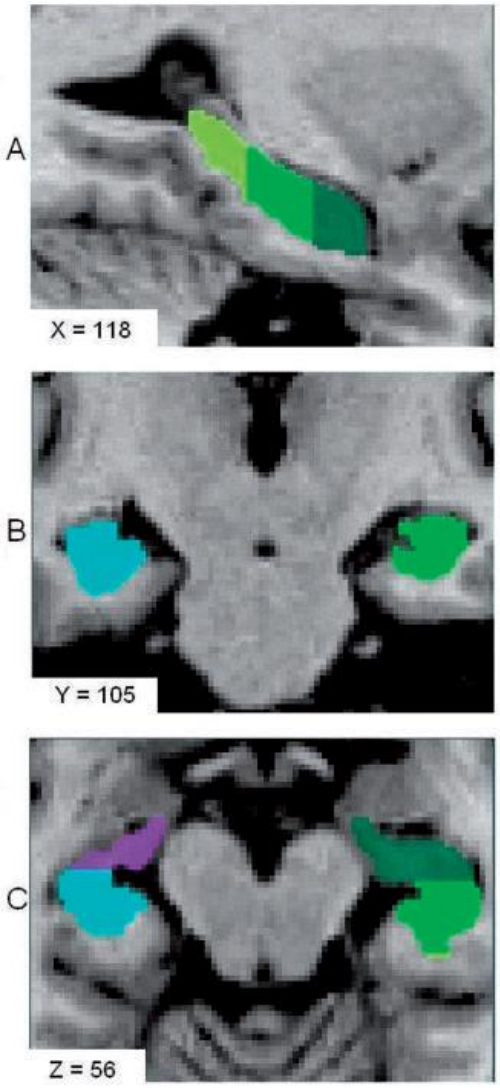


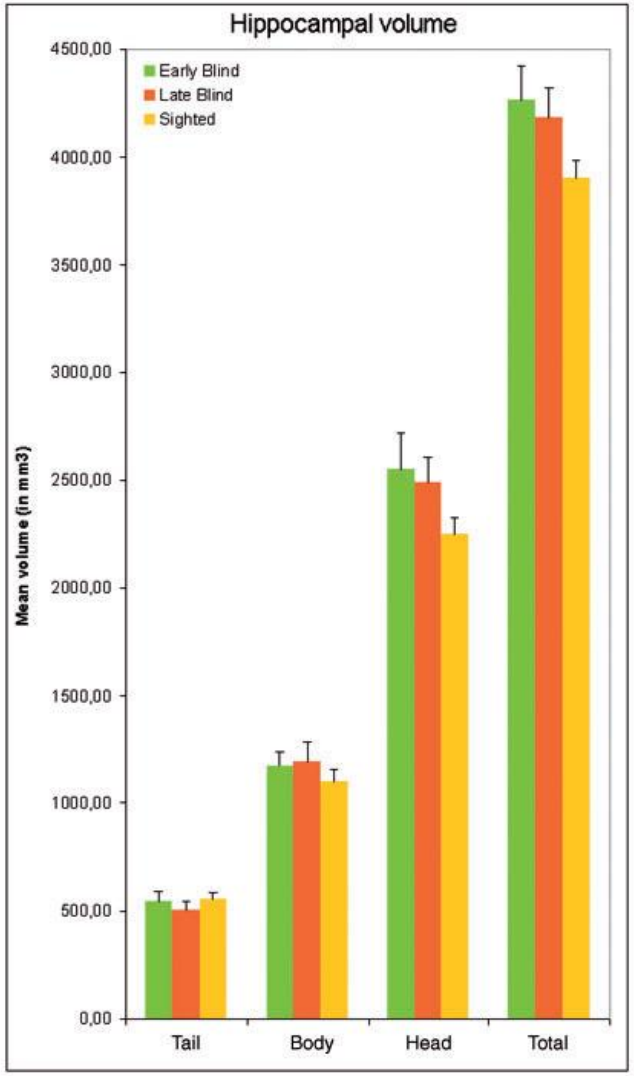


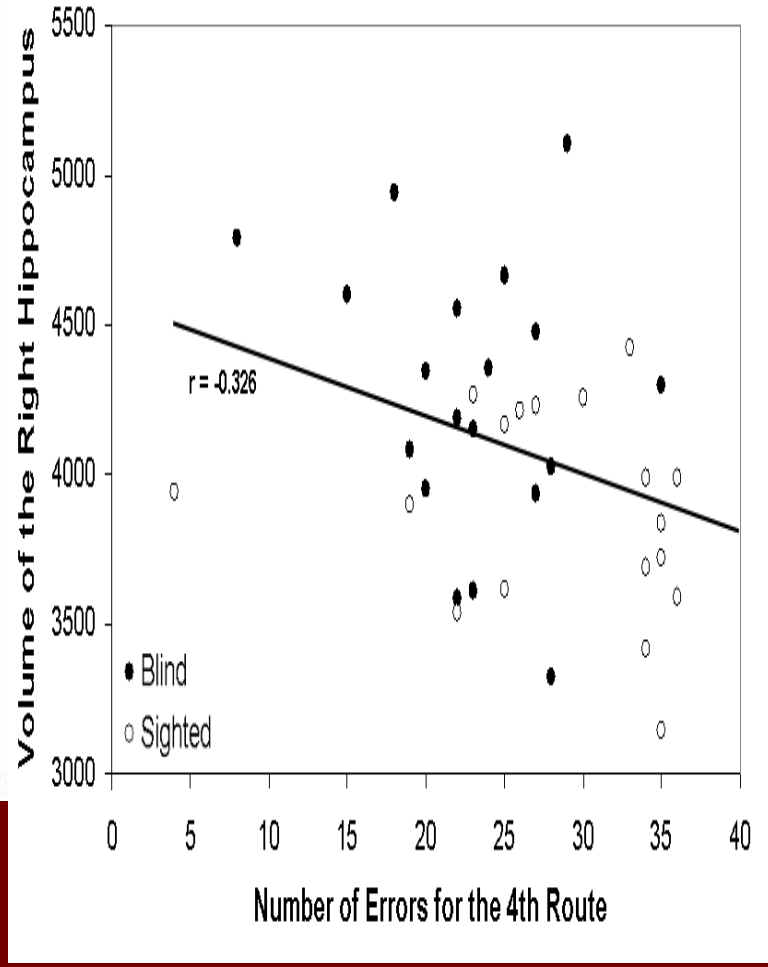
The blind are better at **navigating** in a human size labyrinth



Fortin, Voss, Lassonde, Belin, Zato rre, Lepore, 2008, Brain





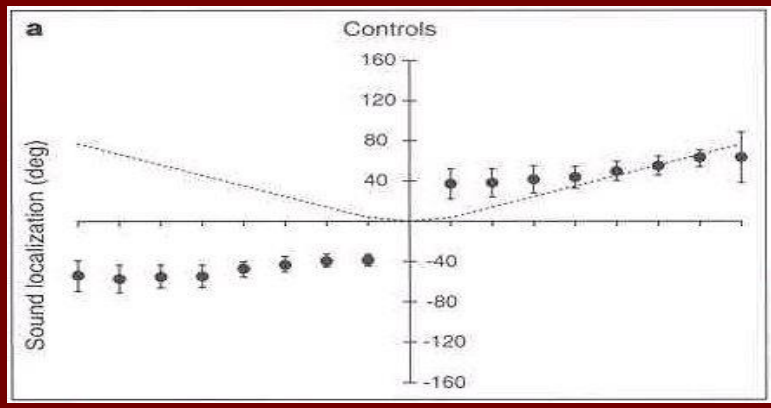


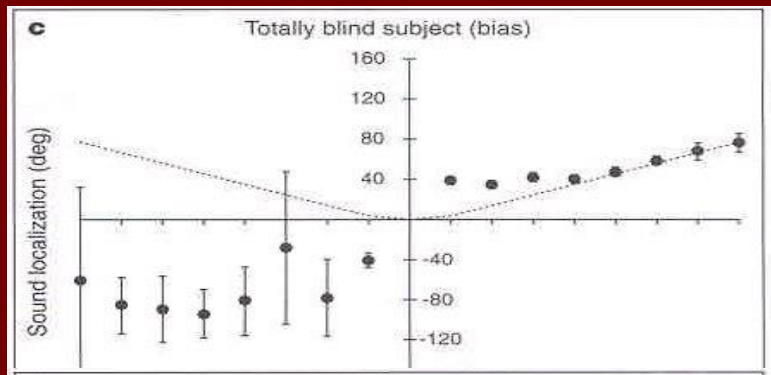
Fortin, Voss, Lassonde, Belin, Zatorre, Lepore, 2008, Brain

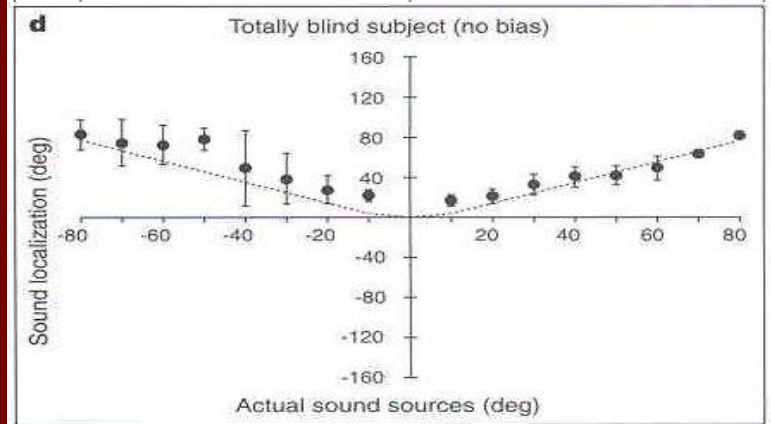
Monaural sound localization

Sighted

Blind





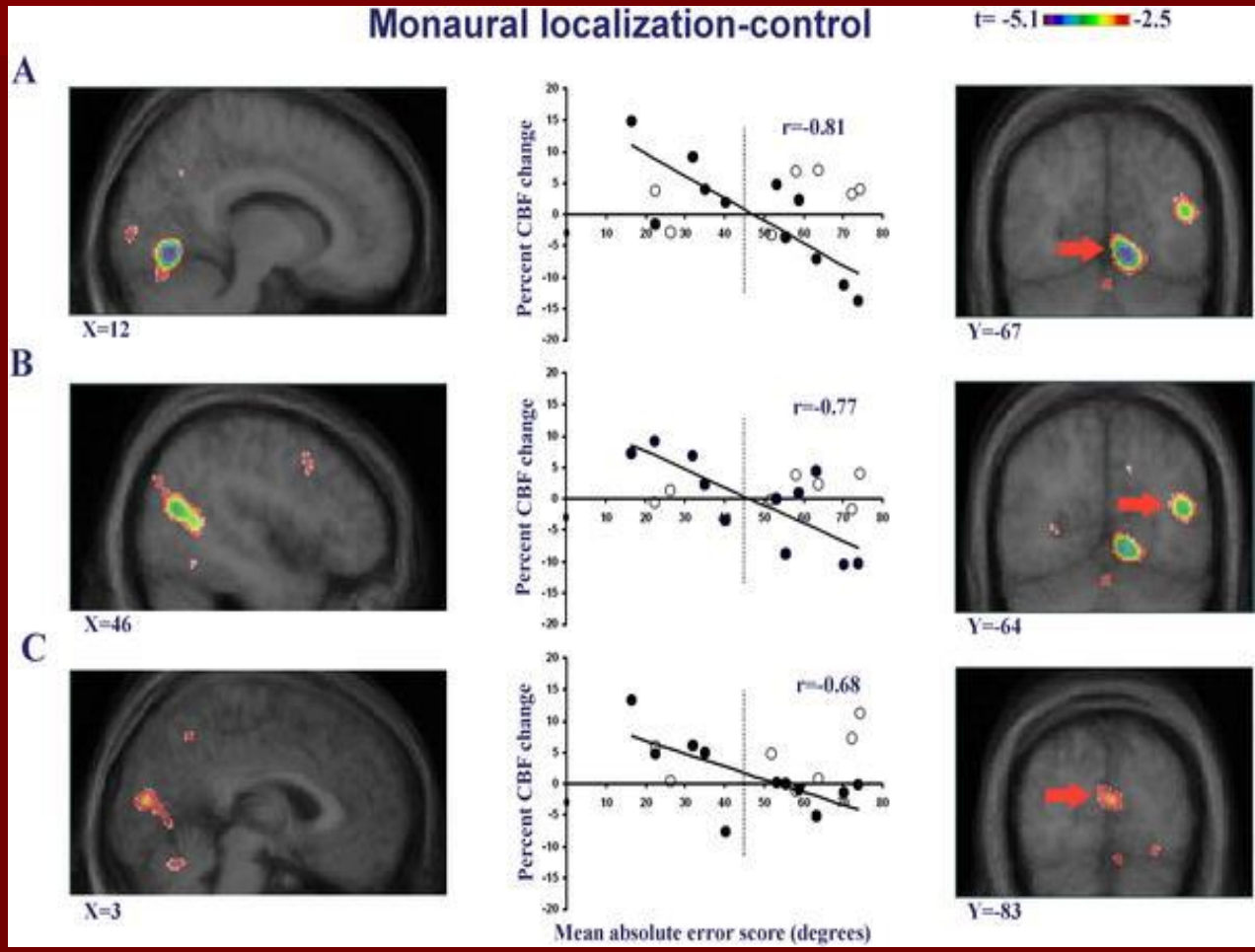


Lessard, Paré, Lepore, Lassonde (1998) Nature

Monaural localization and PET

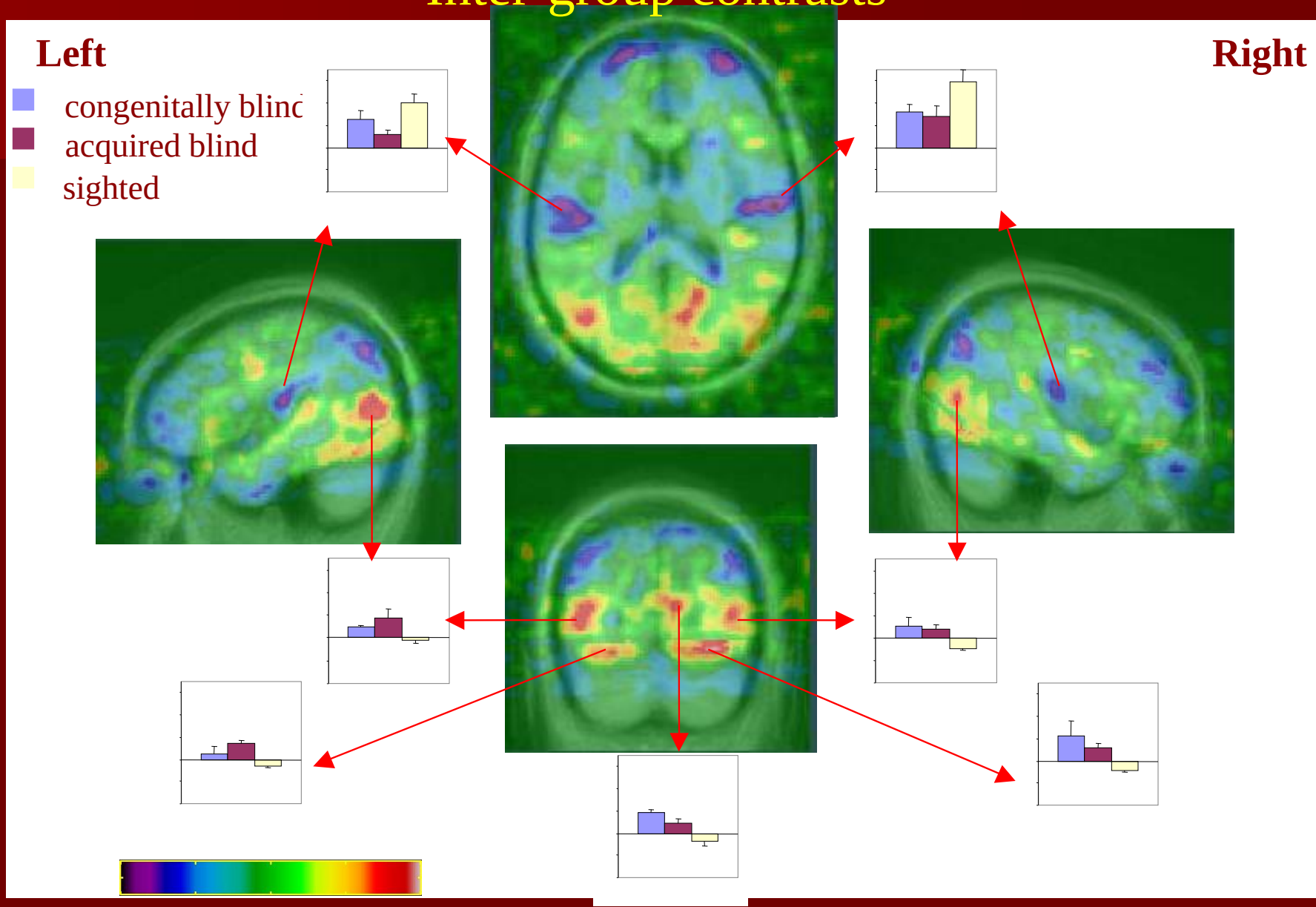
A strong activation was observed in different regions of visual cortex in the blind individuals

But more importantly, there was a correlation between degree of activation and localization performance



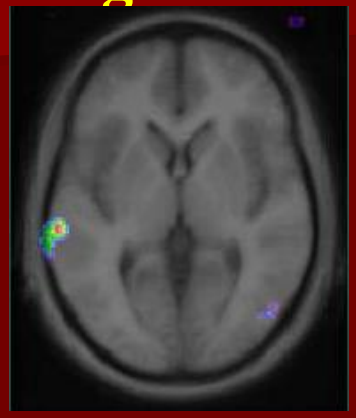
Gougoux, Zatorre, Lassonde, Voss, Lepore, (2005) PLoS Biology

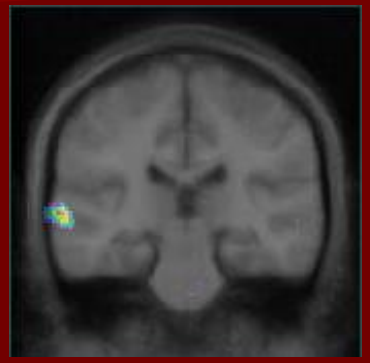
Voice discrimination: All stimuli - silence
Inter-group contrasts



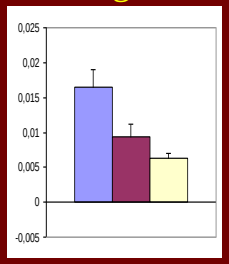
Vocal versus non-vocal
Inter-group contrasts

congenital vs acquired



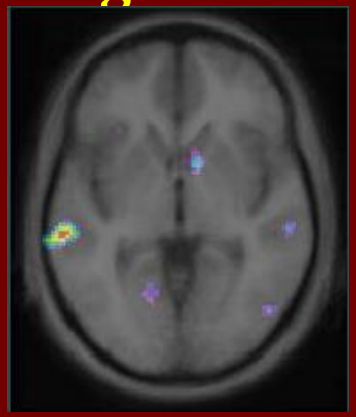


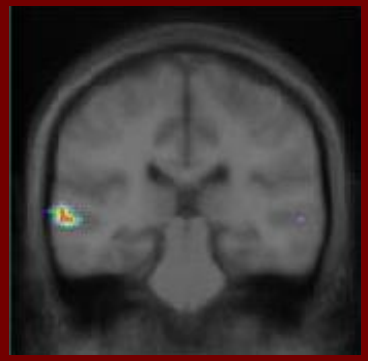
congenitally blind
acquired blind
sighted

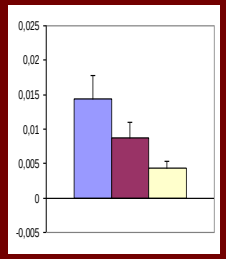


y=-28

congenital vs sighted

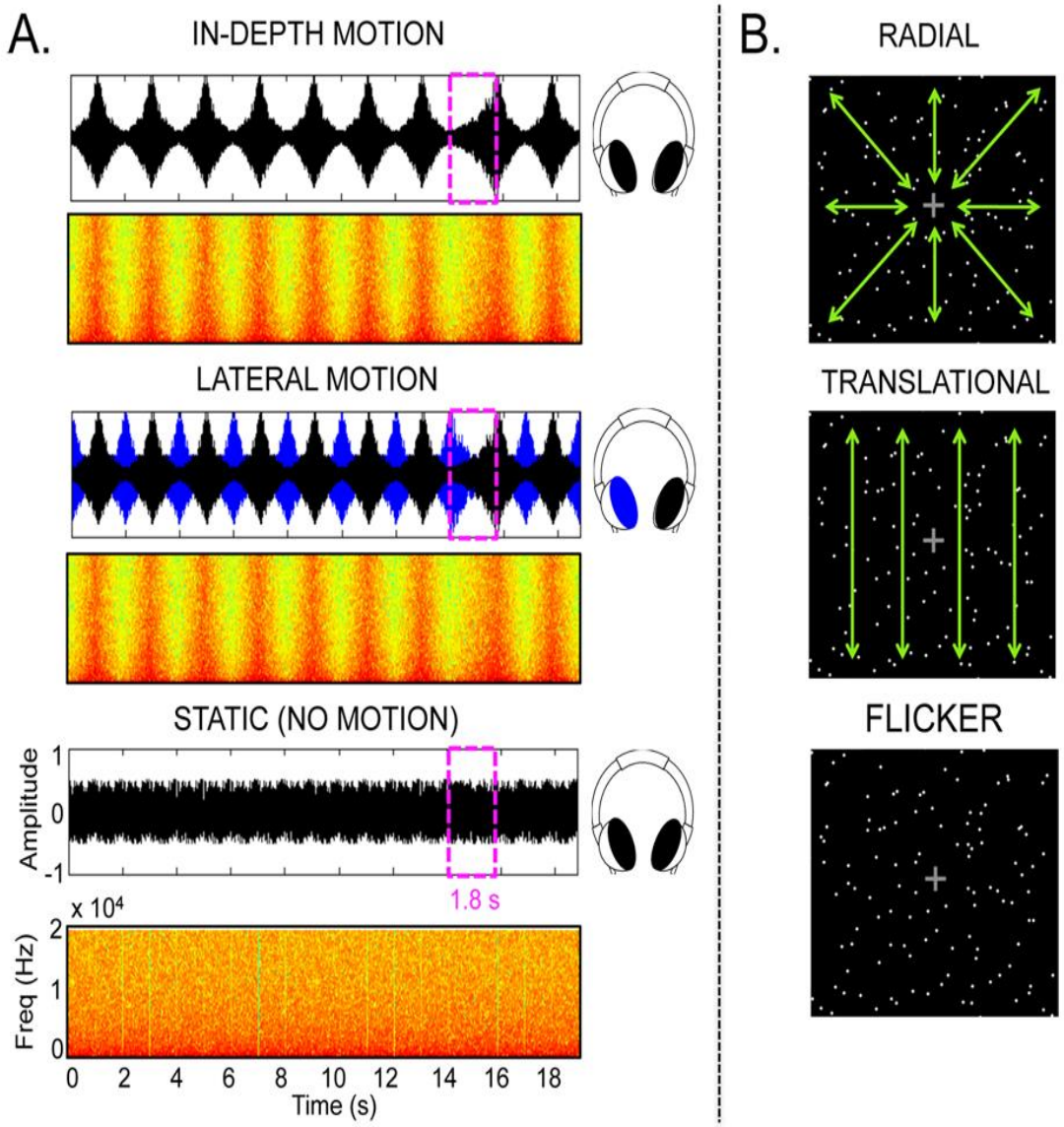


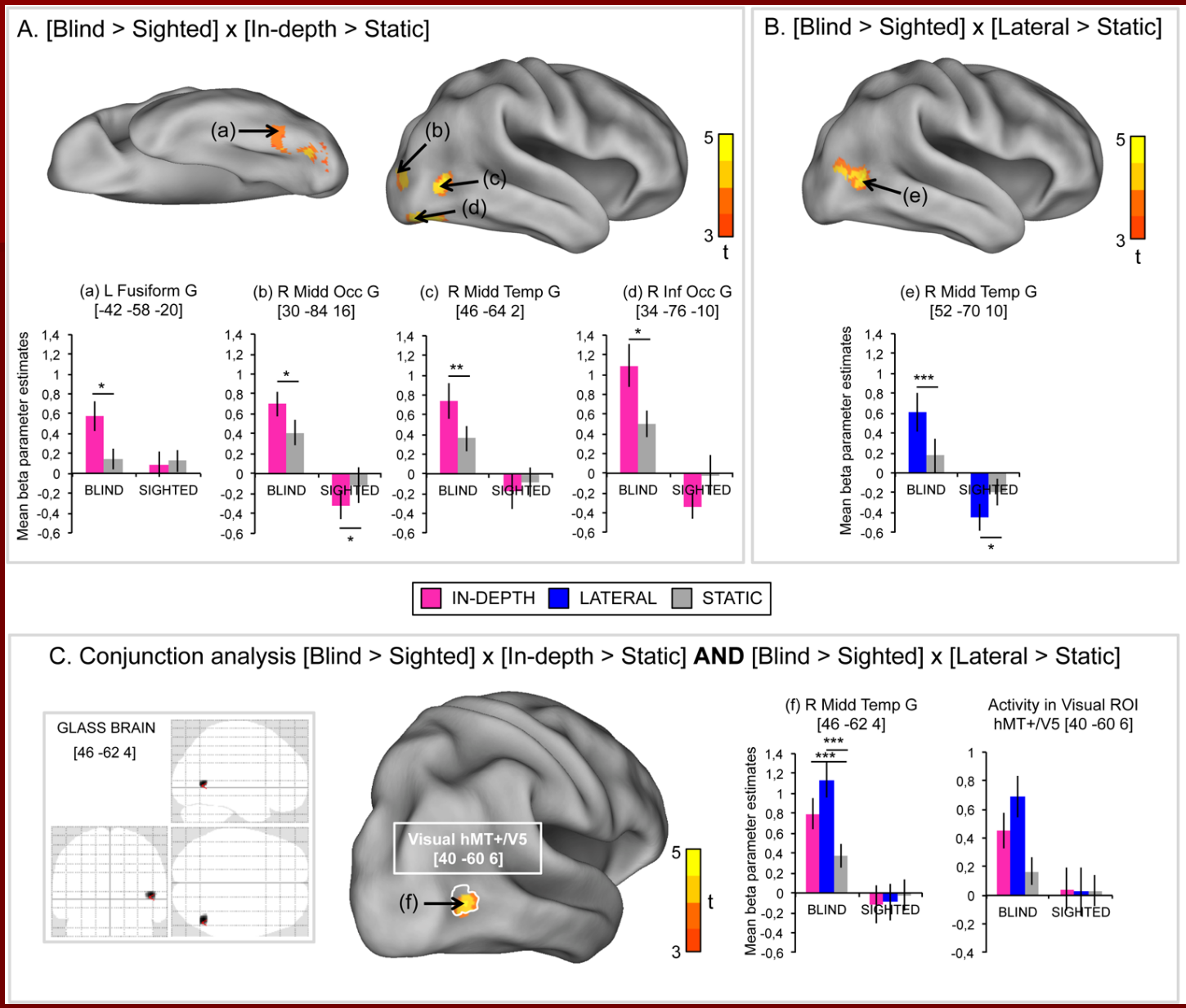




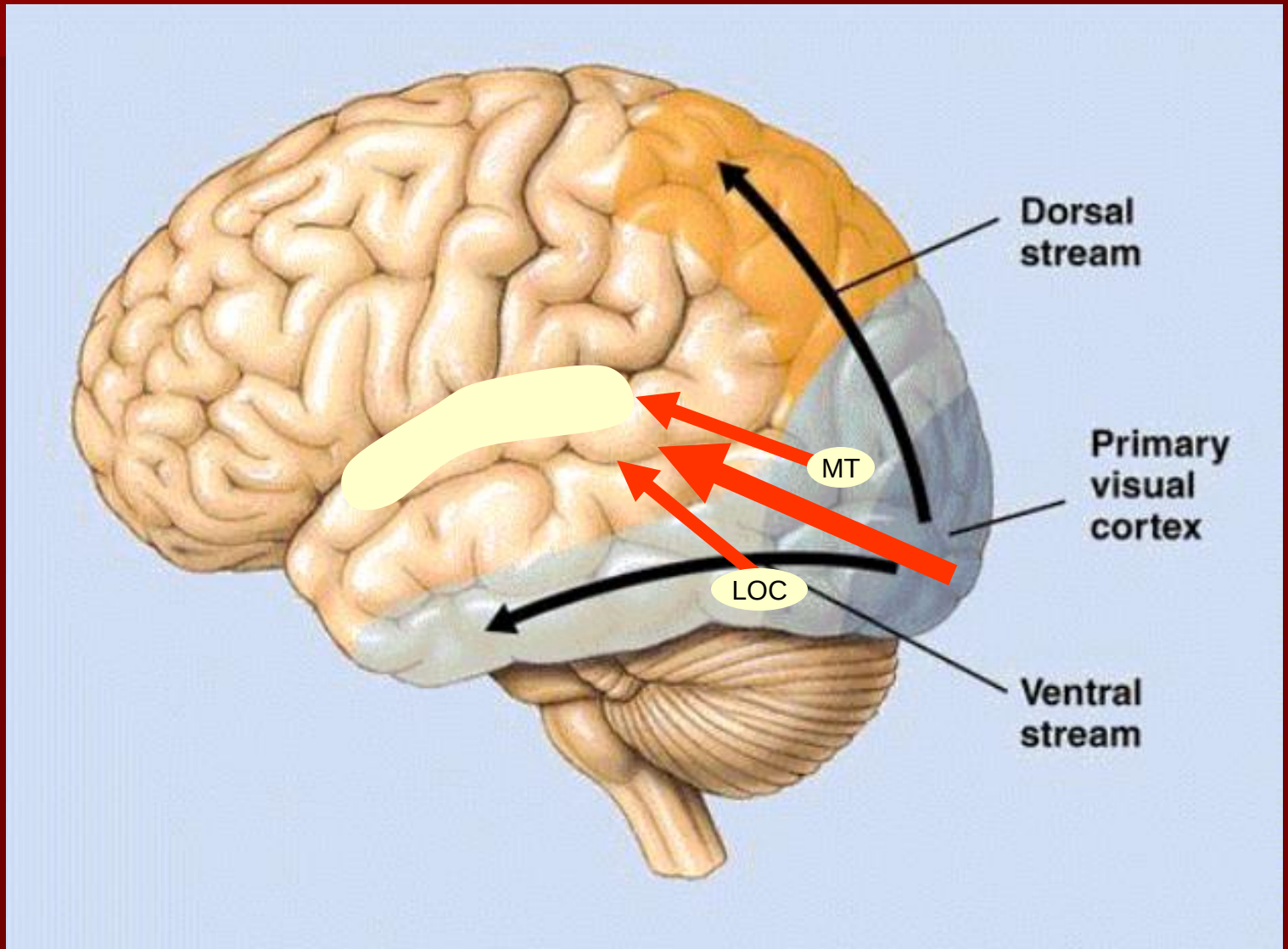
y=-30

Gougoux, Lassonde, Zatorre, Voss, Belin, Lepore (Neuropsychologia, 2009)


A.
IN-DEPTH MOTION
LATERAL MOTION
STATIC (NO MOTION)
Amplitude
1
0
-1
1.8 s
x 10^4
Freq (Hz)
2
1
0
0 2 4 6 8 10 12 14 16 18
Time (s)
B.
RADIAL
TRANSLATIONAL
FLICKER

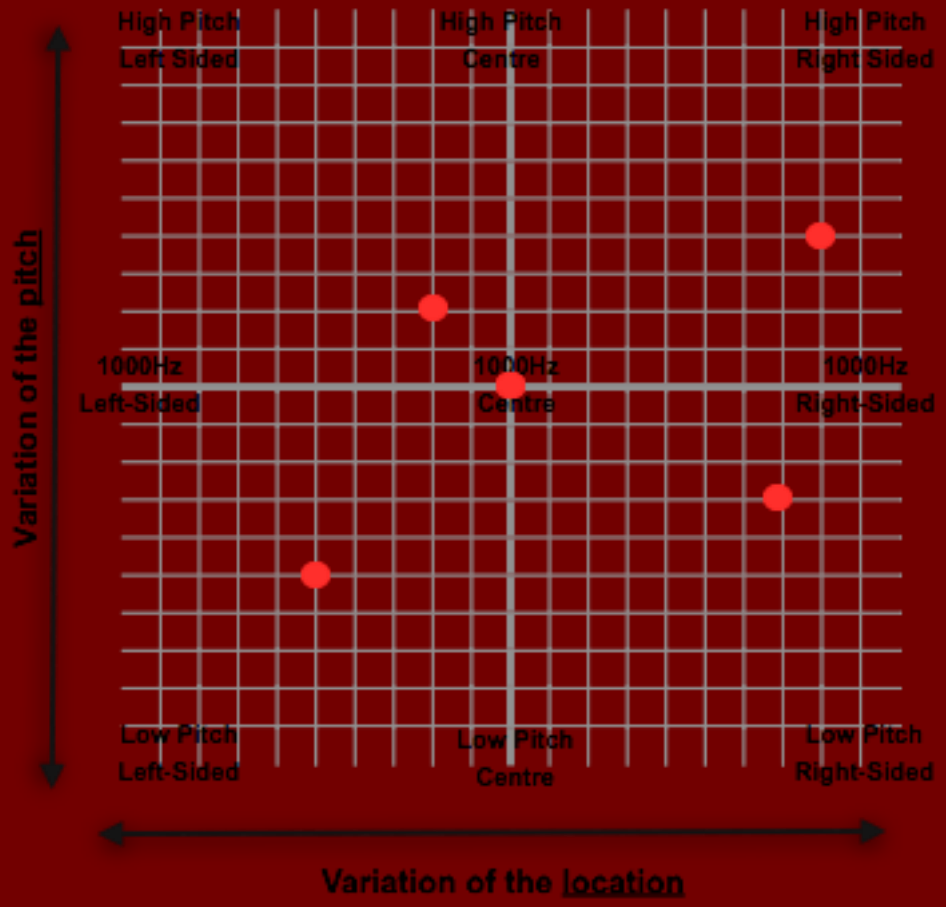

A. [Blind > Sighted] x [In-depth > Static]
(a)
(b)
(c)
(d)
5
3
t
(a) L Fusiform G
[-42 -58 -20]
(b) R Midd Occ G
[30 -84 16]
(c) R Midd Temp G
[46 -64 2]
(d) R Inf Occ G
[34 -76 -10]
Mean beta parameter estimates
1,4
1,2
1
0,8
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
BLIND
SIGHTED
*
**
B. [Blind > Sighted] x [Lateral > Static]
(e)
(e) R Midd Temp G
[52 -70 10]
***
IN-DEPTH
LATERAL
STATIC
C. Conjunction analysis [Blind > Sighted] x [In-depth > Static] AND [Blind > Sighted] x [Lateral > Static]
GLASS BRAIN
[46 -62 4]
Visual hMT+/V5
[40 -60 6]
(f)
(f) R Midd Temp G
[46 -62 4]
Activity in Visual ROI
hMT+/V5 [40 -60 6]

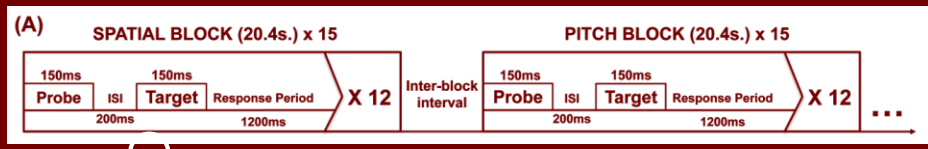
Does reorganisation in blind individuals also respect another critical function : ventral and dorsal streams



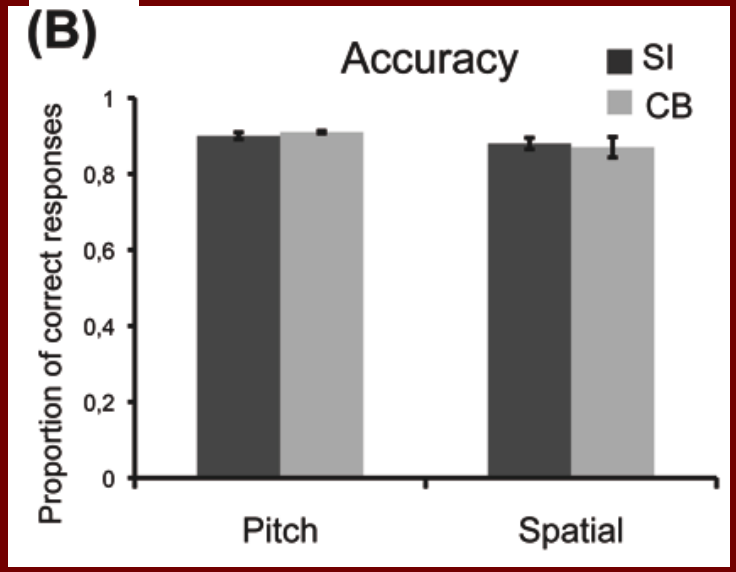
Design:

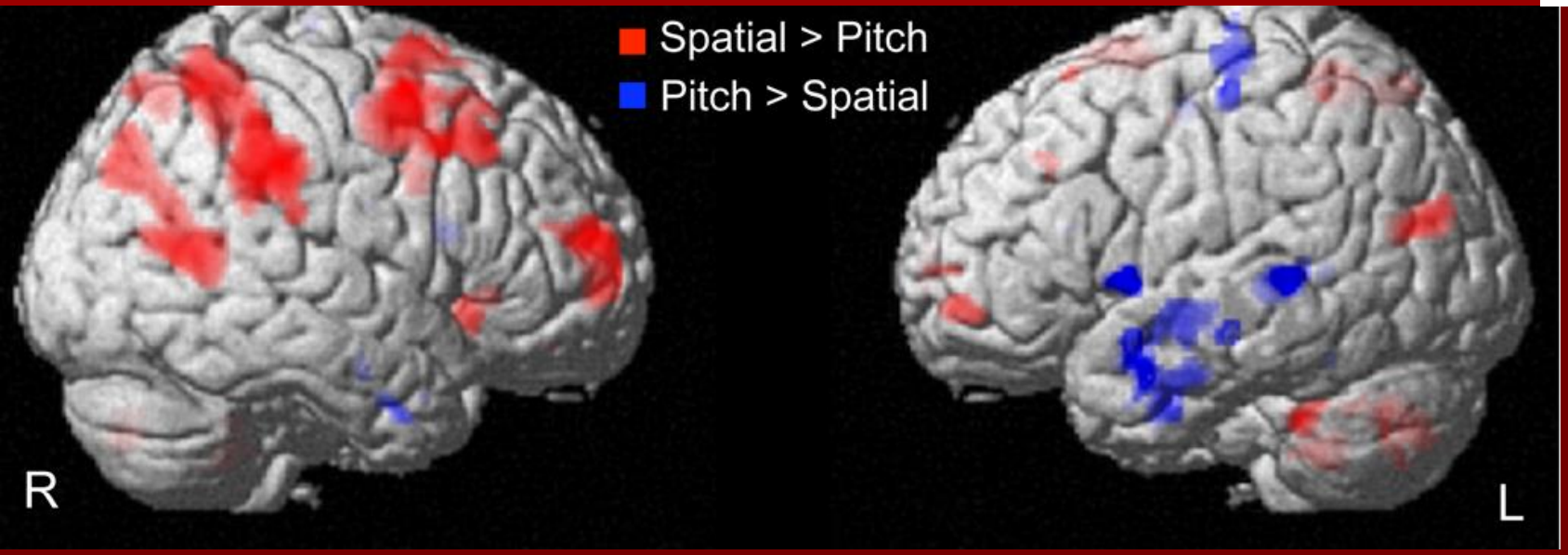
6400 sounds matrix

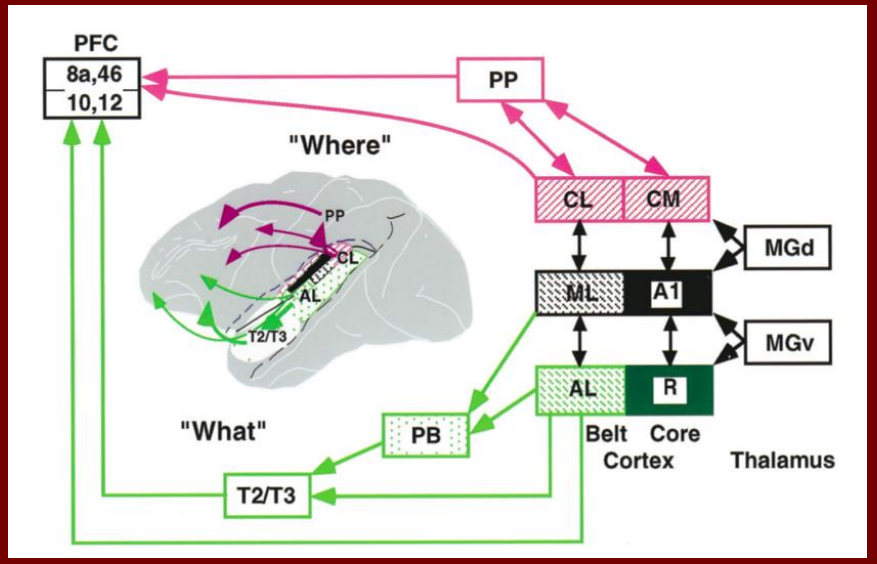




- Same sounds in each condition
- Staircase [~ 1 down - 6 up]




Spatial > Pitch
Pitch > Spatial
R
L


PFC
8a,46
10,12
PP
"Where"
CL
CM
MGd
ML
A1
MGv
AL
R
"What"
PB
Belt
Core
Cortex
Thalamus
T2/T3

As seen with respect to the **blind** two comments can be made:

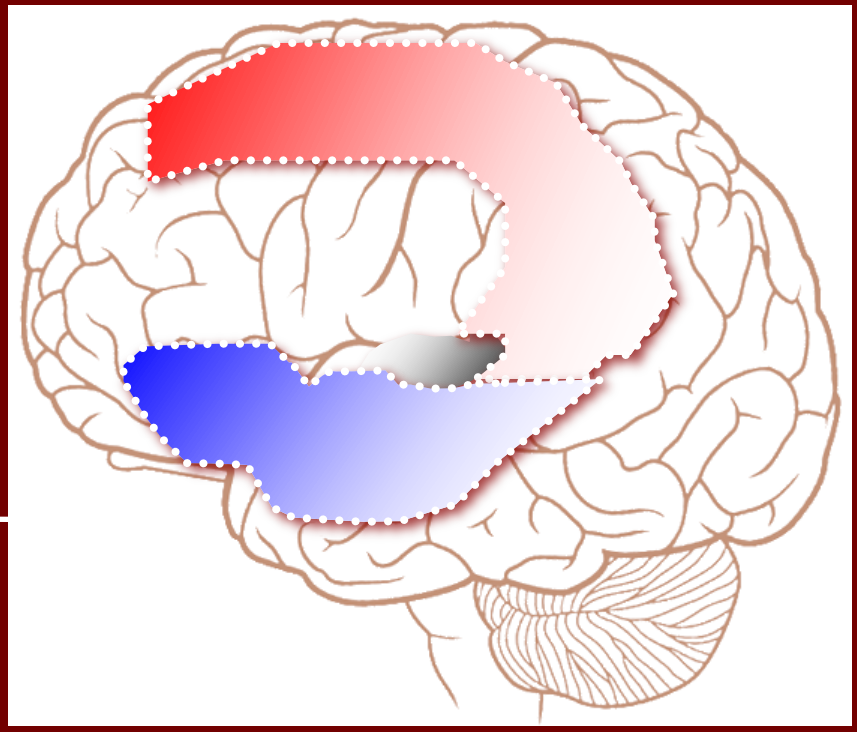
1- They are better than the sighted in various cross-modal tasks

2-The visual cortex participates in task resolution in a functionally significant manner

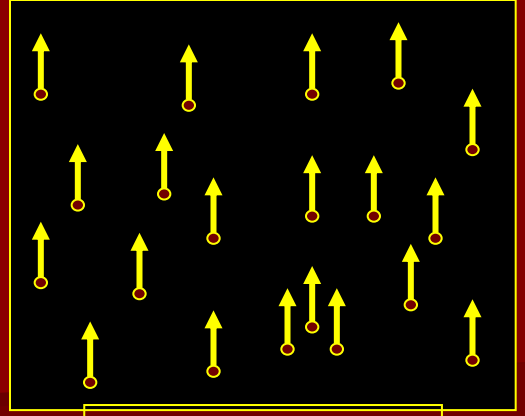
Does this hold for the **deaf** with respect to other functions?

Auditory Domain

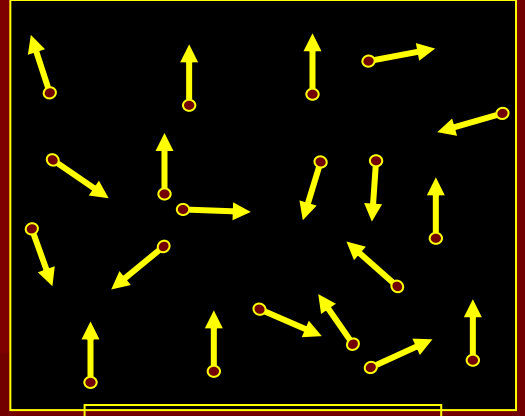
Dorsal Stream - Localization



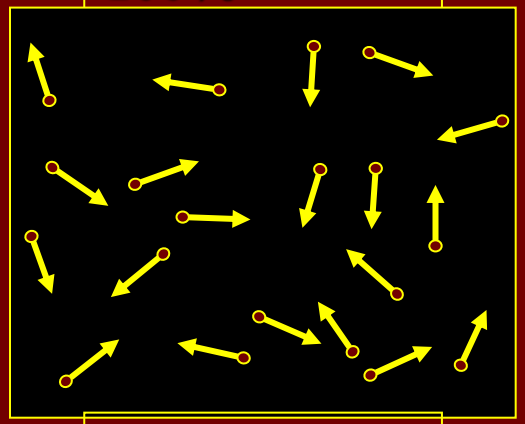
Ventral Stream - Identification



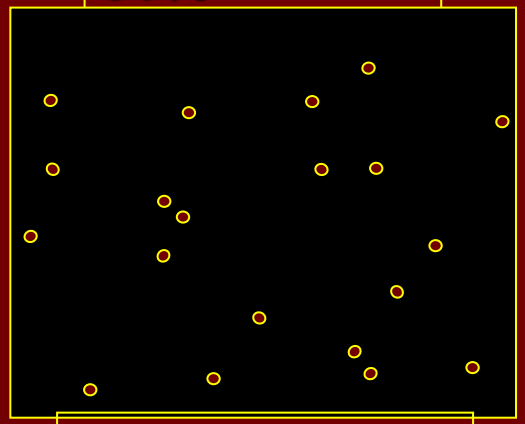
100%



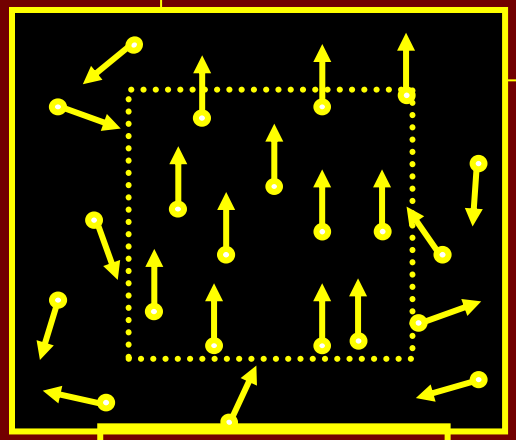
30%



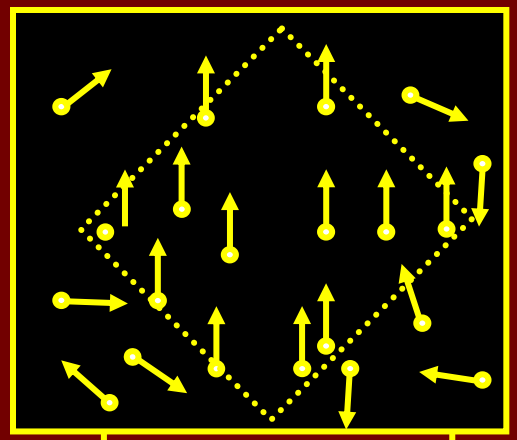
0%
cohérence



Static

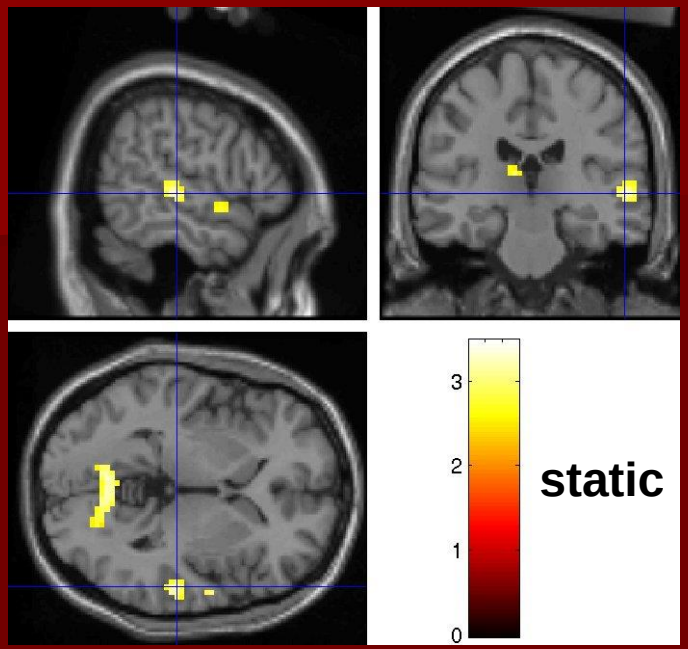


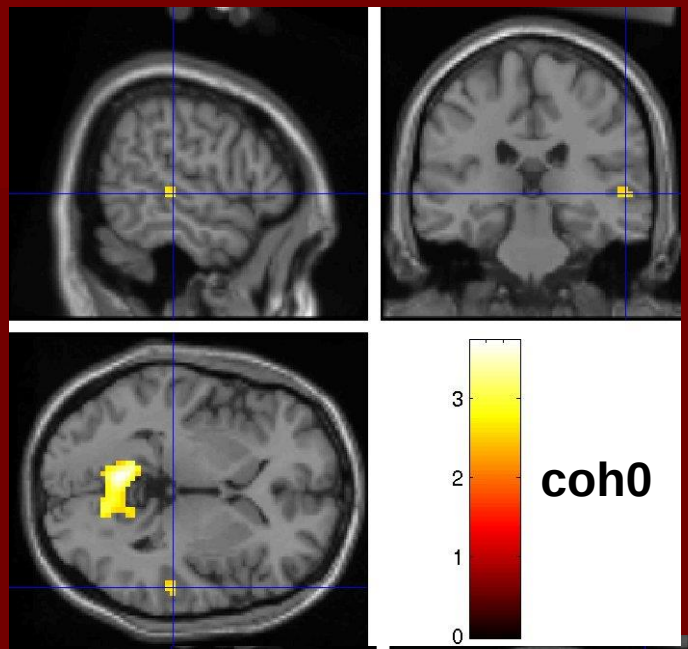
square

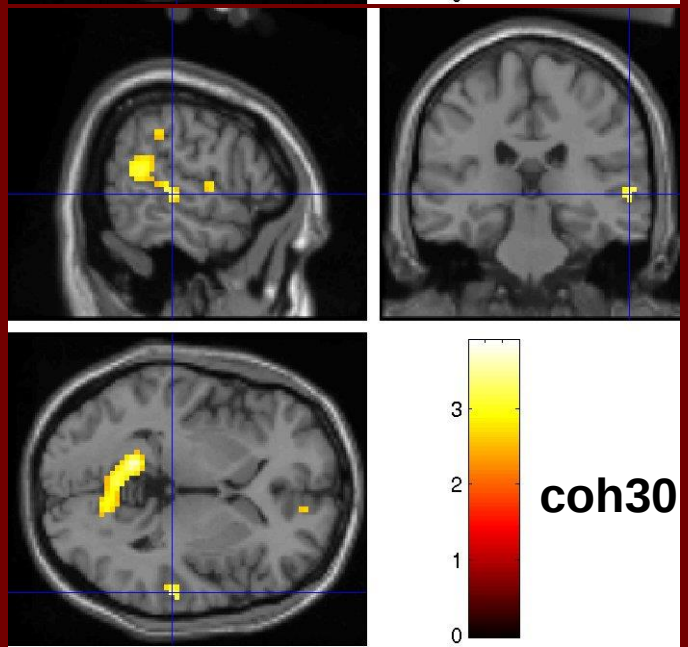


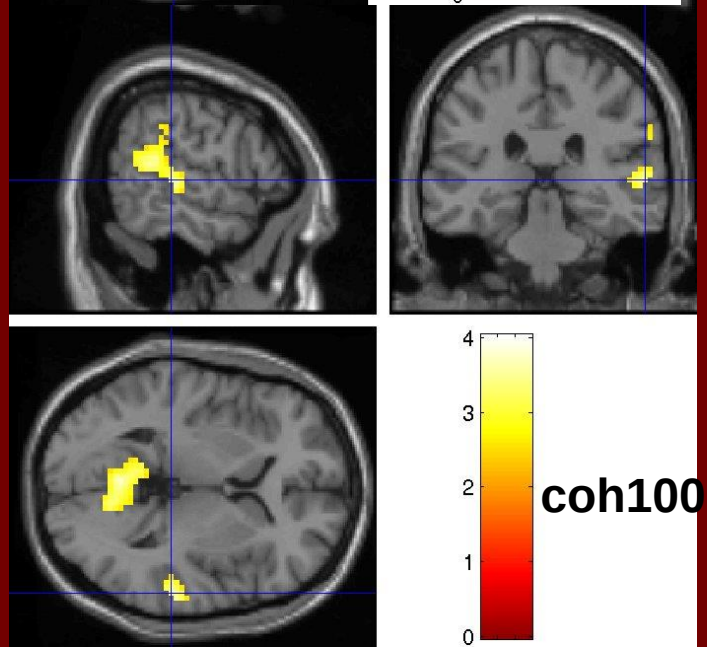
diamond

Activations under différent conditions between deaf participants and hearing controls: mouvement

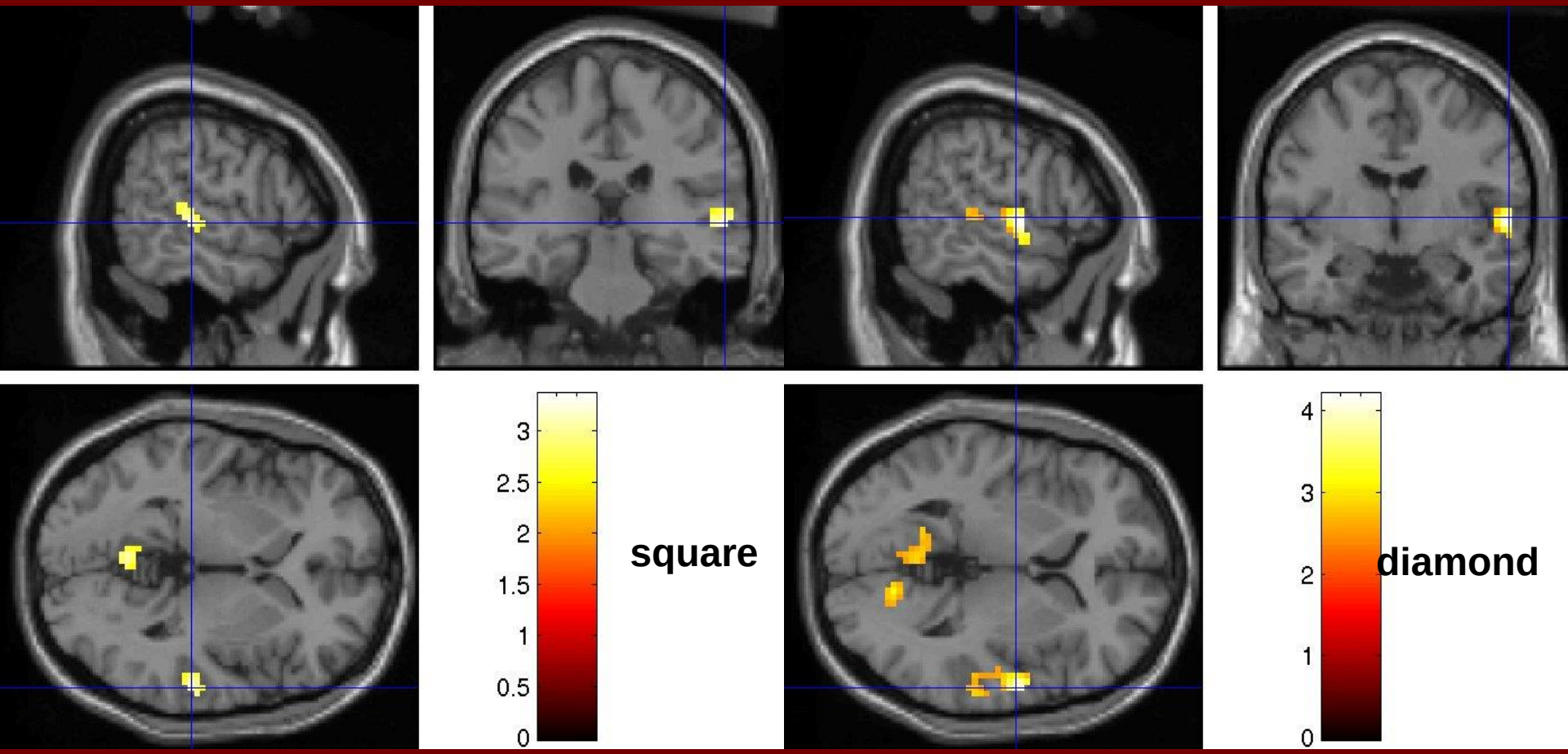




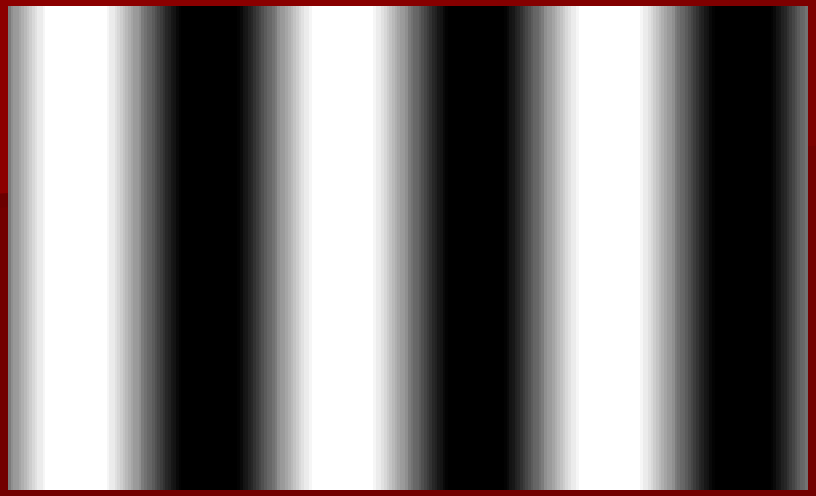


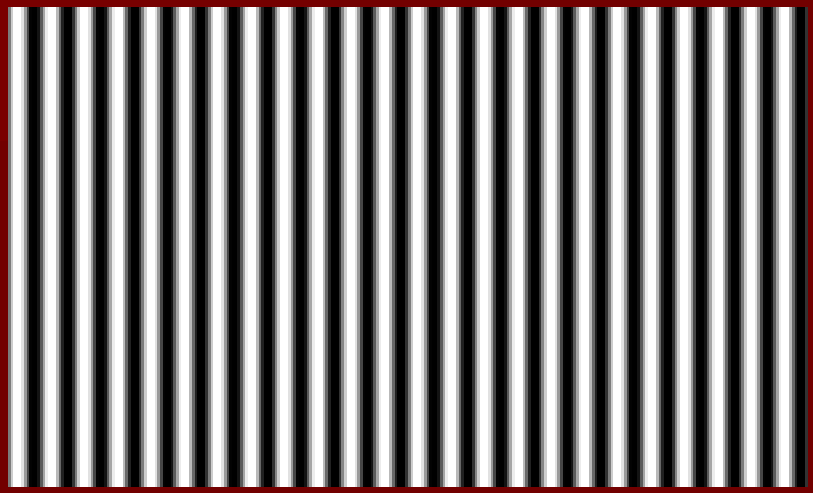


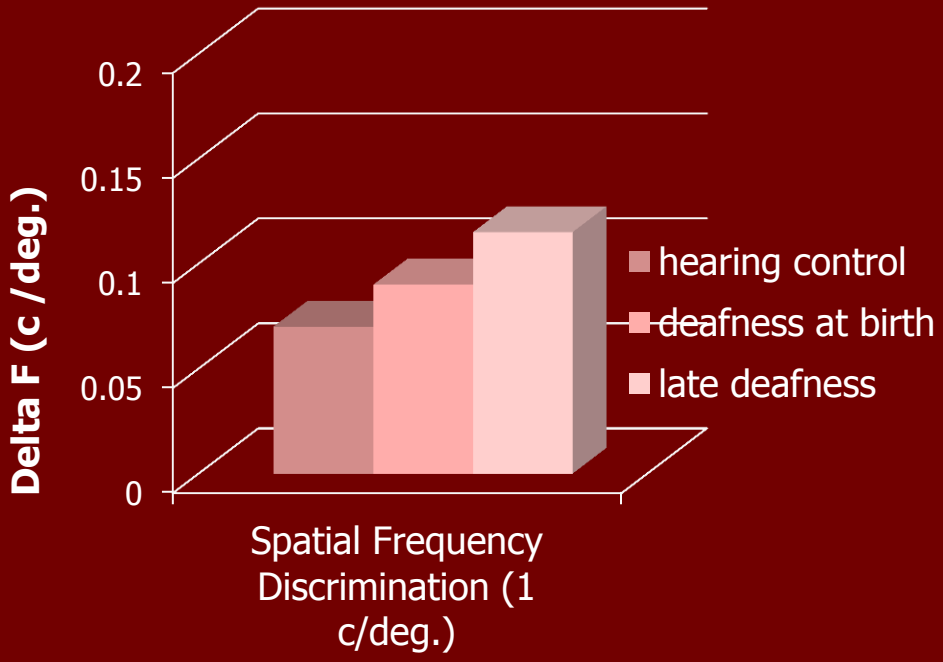
Activations under différent conditions between deaf participants and hearing controls: form

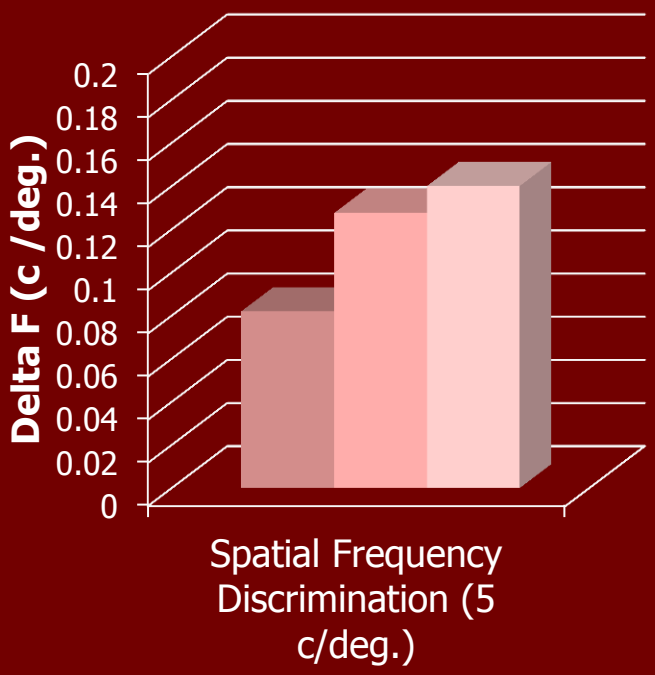


Visual Discrimination

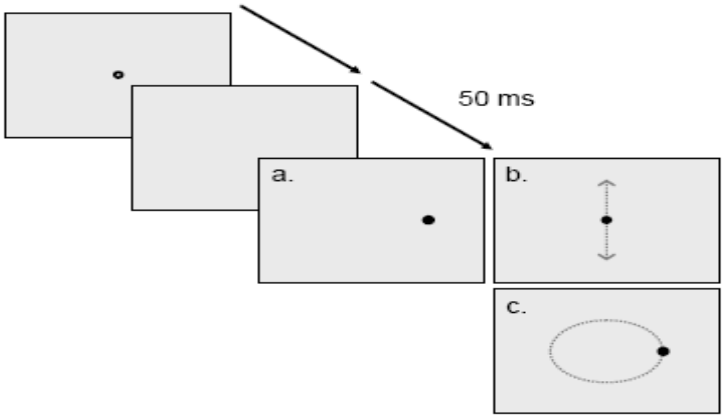


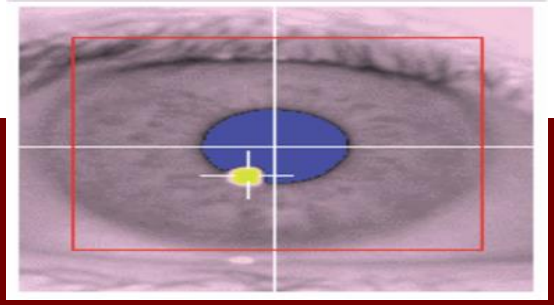






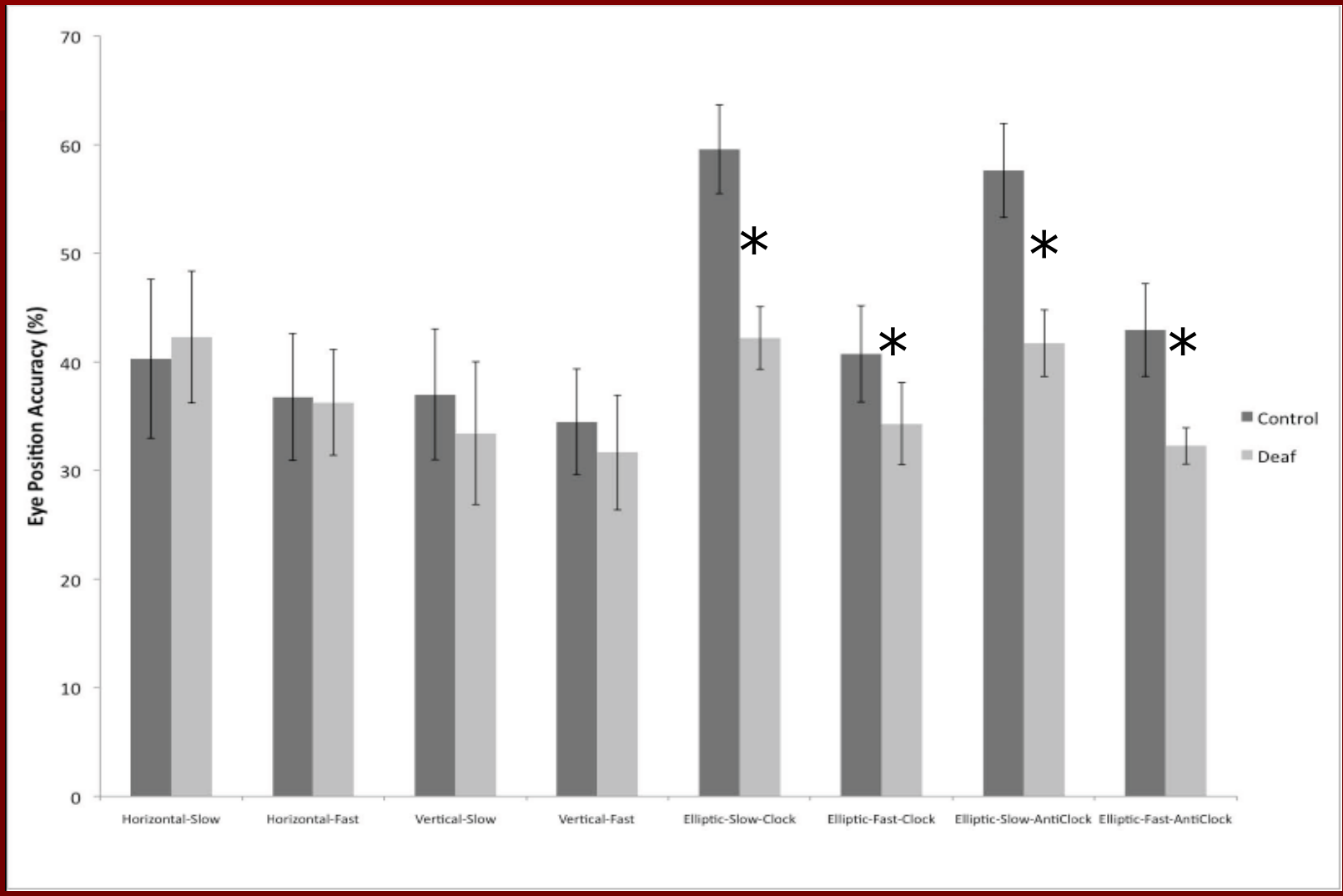
Auditory deprivation during infancy affects eye movement scanning function



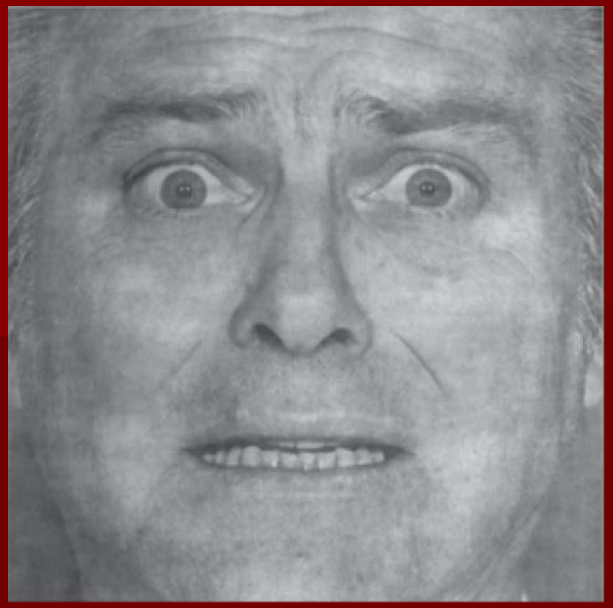


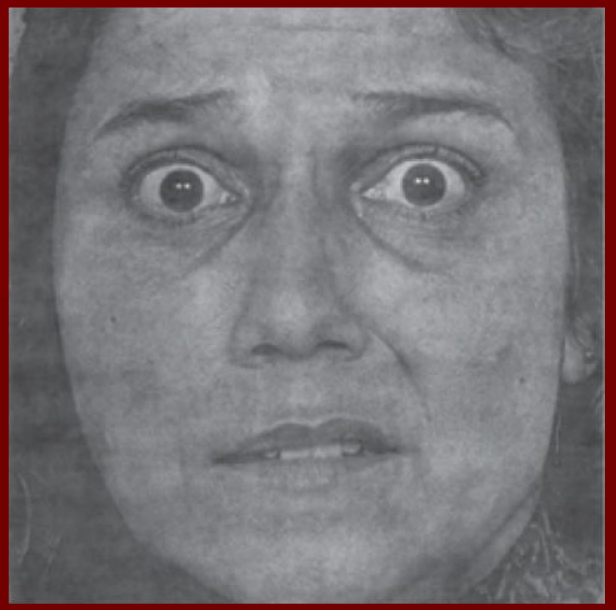
Turgeon, Johnson, Lepore, & Ellemberg (CAA 2009)

Pursuit task



fearful

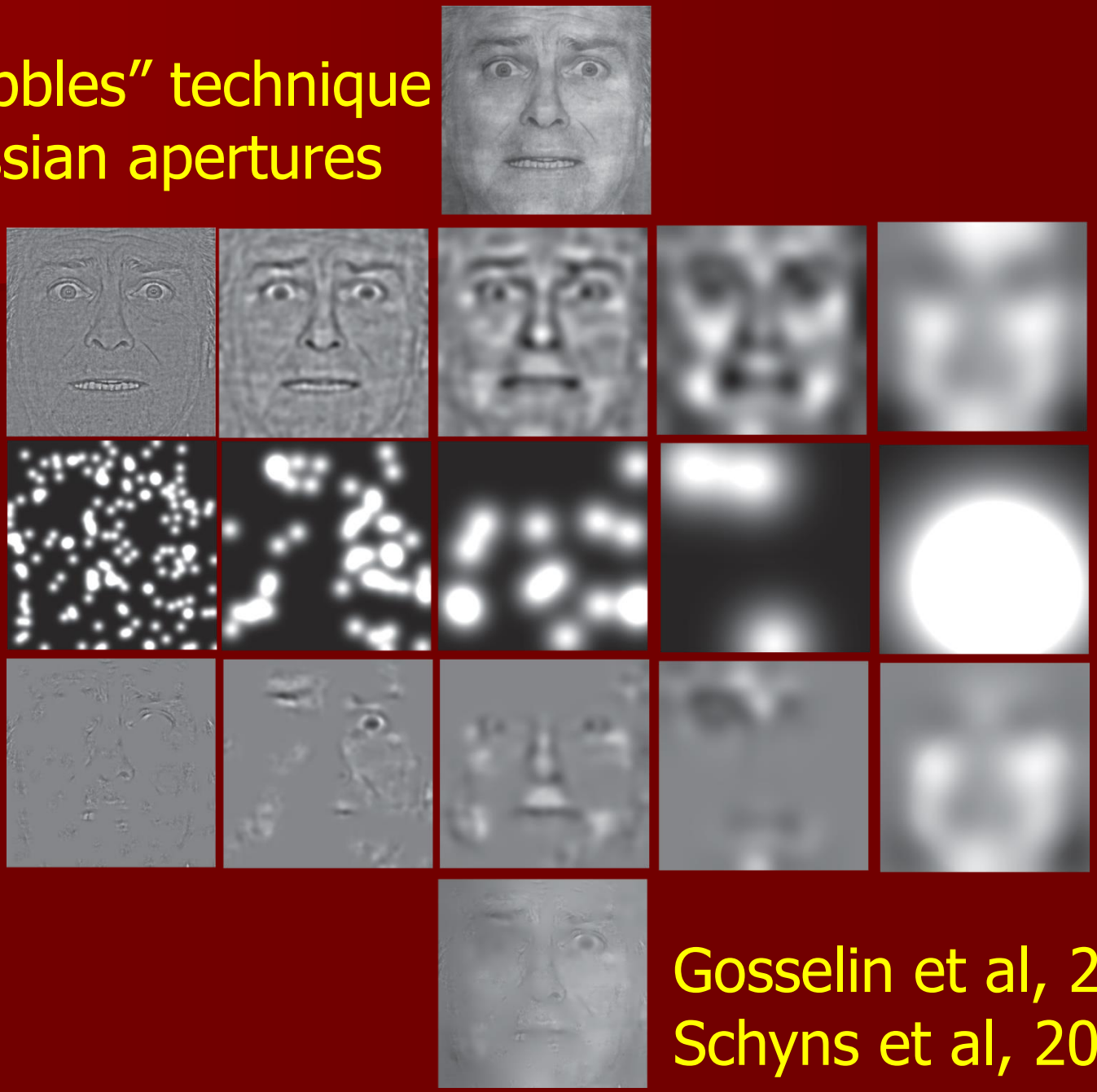




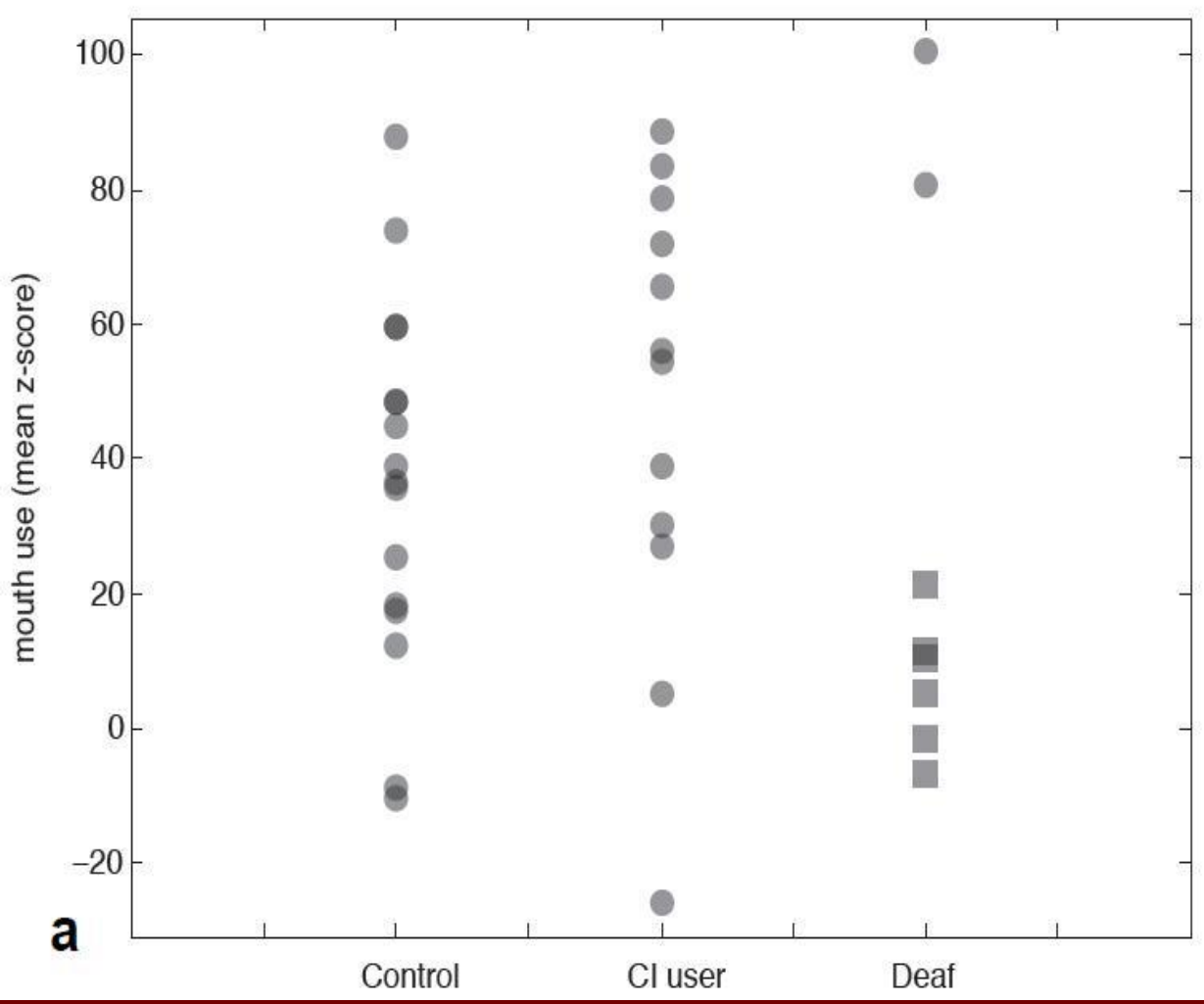
happy

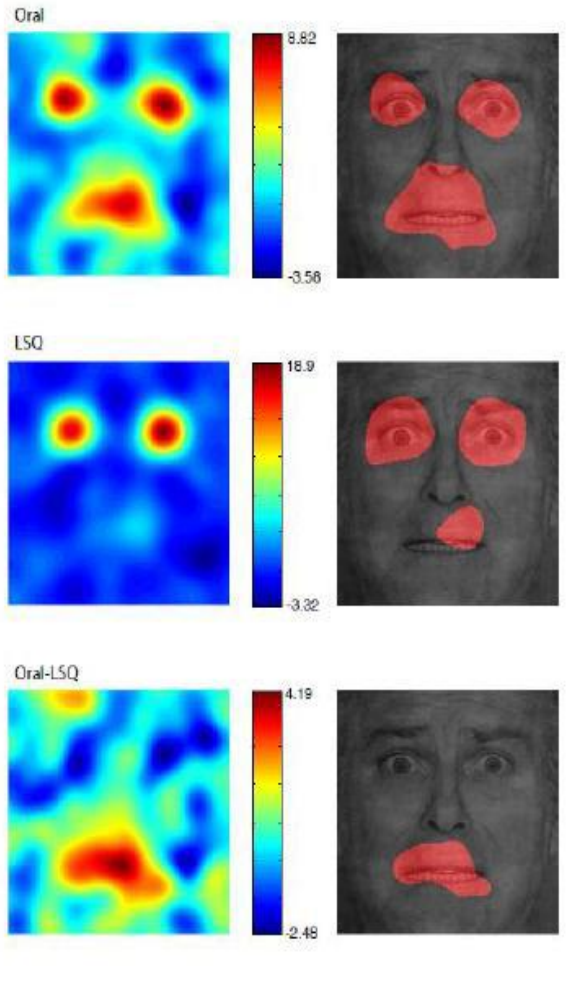
Doucet, Gosselin, Lepore, et al

The “bubbles” technique
i.e. gaussian apertures



Gosselin et al, 2005;
Schyns et al, 2004


mouth use (mean z-score)
100
80
60
40
20
0
−20
Control
CI user
Deaf
a

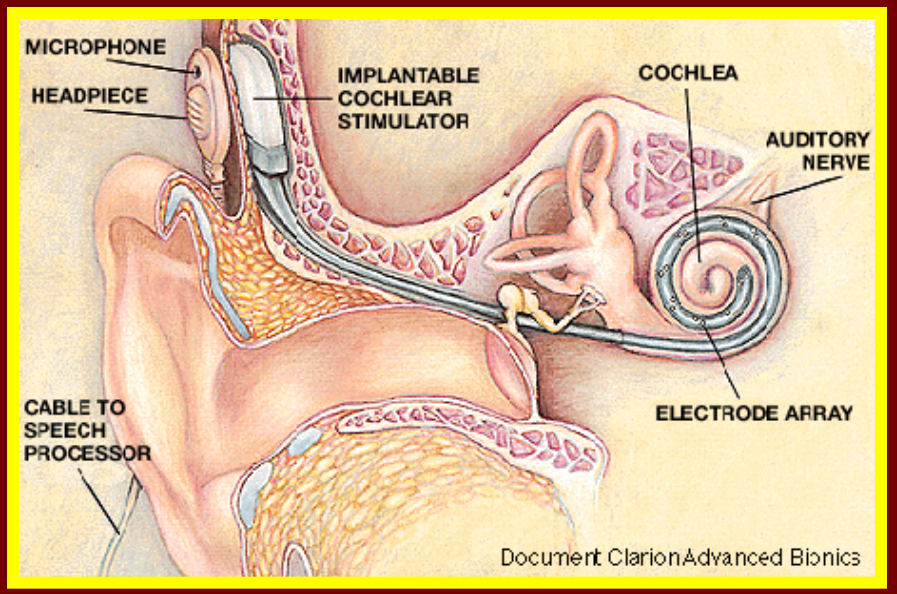

Oral
8.82
-3.56
LSQ
18.9
-3.32
Oral-LSQ
4.19
-2.48
b

The conclusions with respect to the **deaf** are:

-**Yes** vision recruits in a cross-modal fashion auditory areas

-**No**, in both simple and higher level tasks we found no supra-performance and in fact there is under-performance

Reactivation of a sensory system



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« And the Blind shall hear »

Results show that cochlear implants are efficient in re-establishing oral language comprehension

However, they are not always equally efficient for all deaf subjects to recognize language. Why?:

We examined the conditions that affect performance using four modes of presentations of **40 bi-syllabic words**:

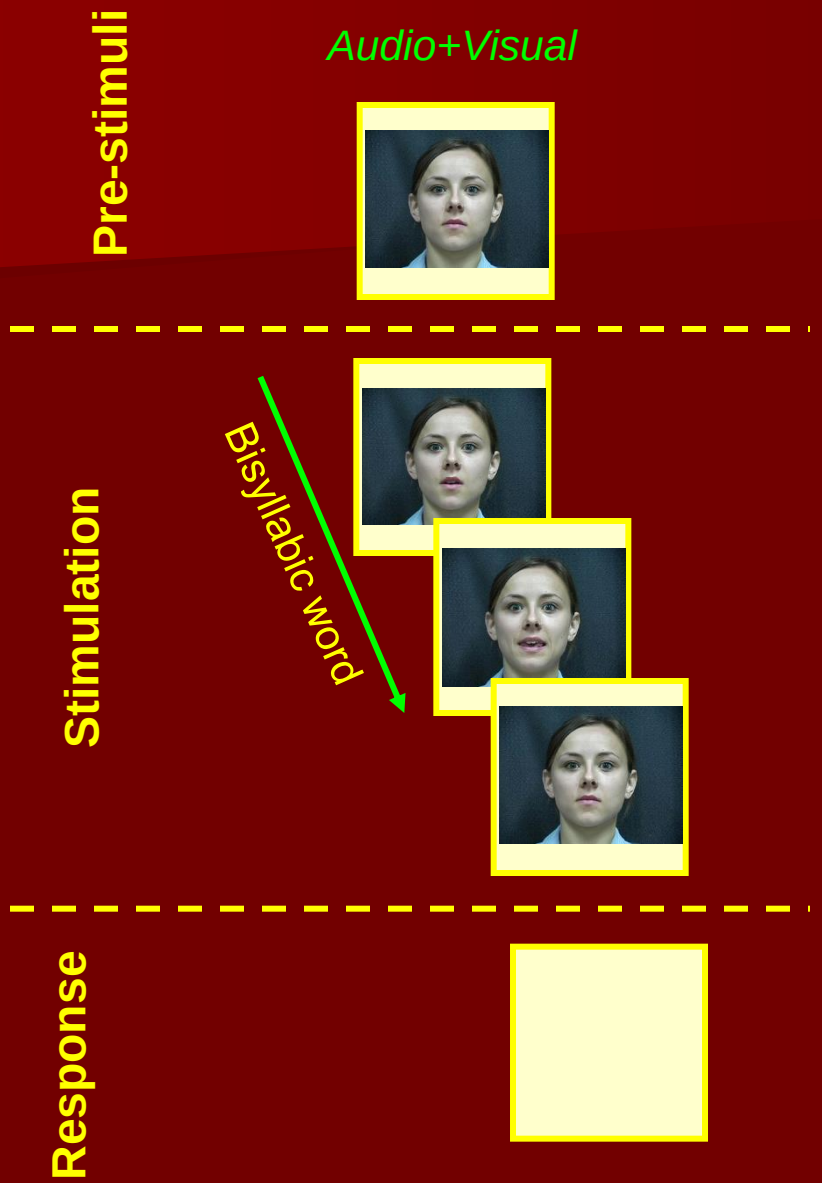
-presented alone

-presented simultaneously with a color

-presented with coherently moving dots

-presented with facial expressions saying a different bi-syllabic word

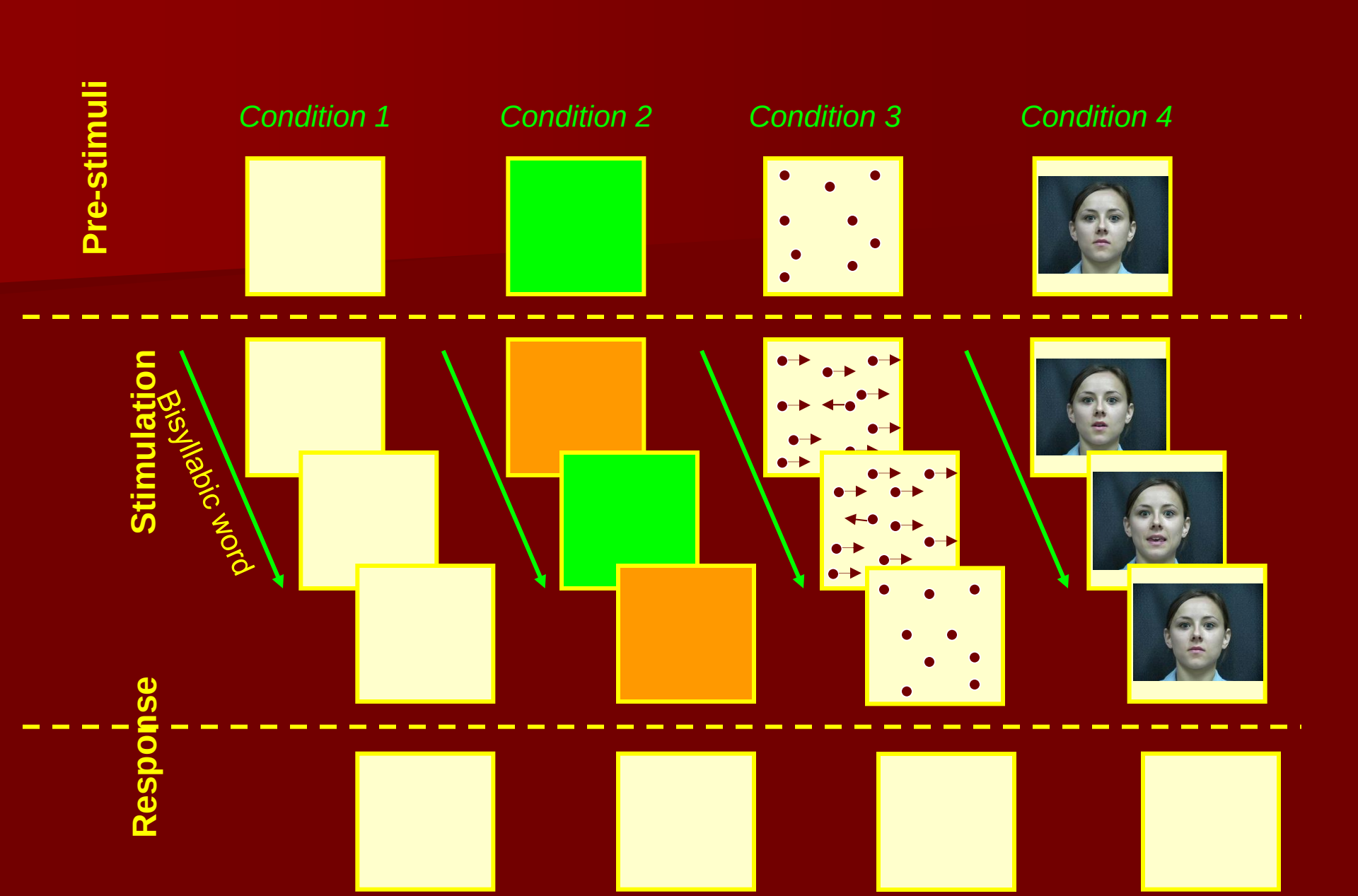
What happens in language comprehension?



Task:

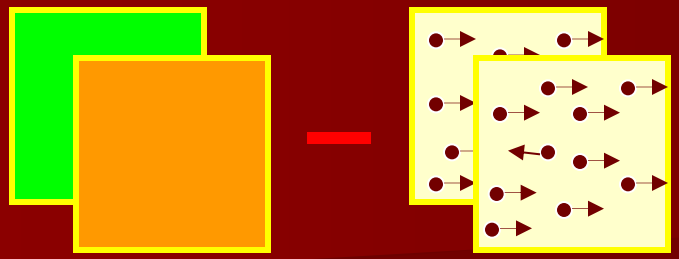
Repeat mono- or bi-syllabic words

Some deaf subjects who have received a cochlear implant perform well on this task while others do not

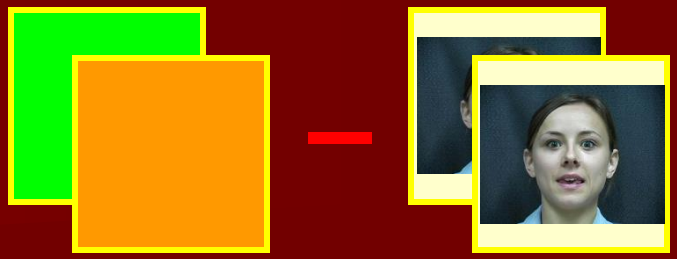


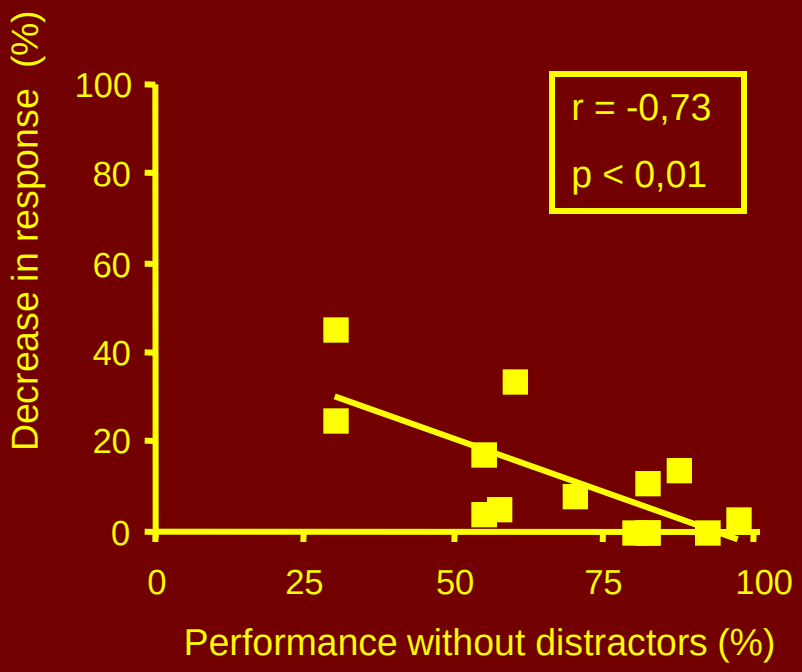
Champoux,F, Tremblay, C, Lepore, F, Theoret,H, Neuropsychologia, 2008

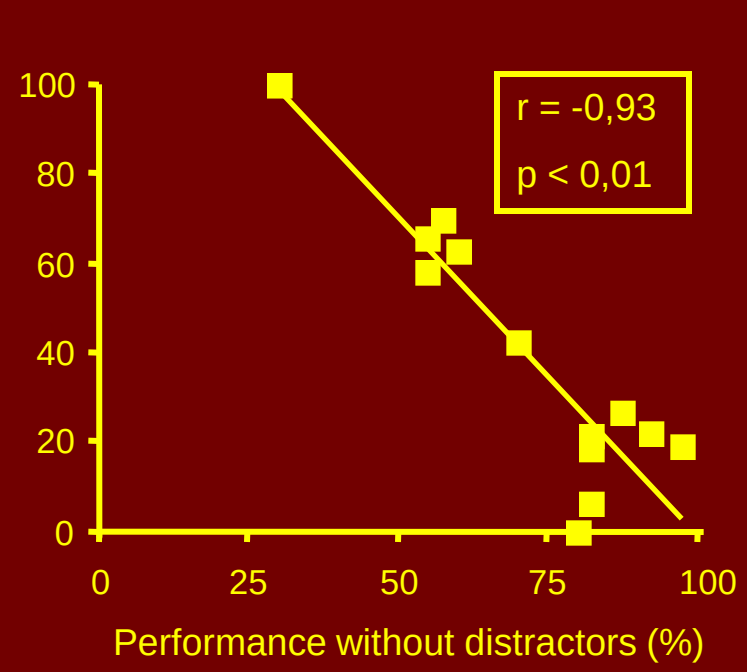
A)



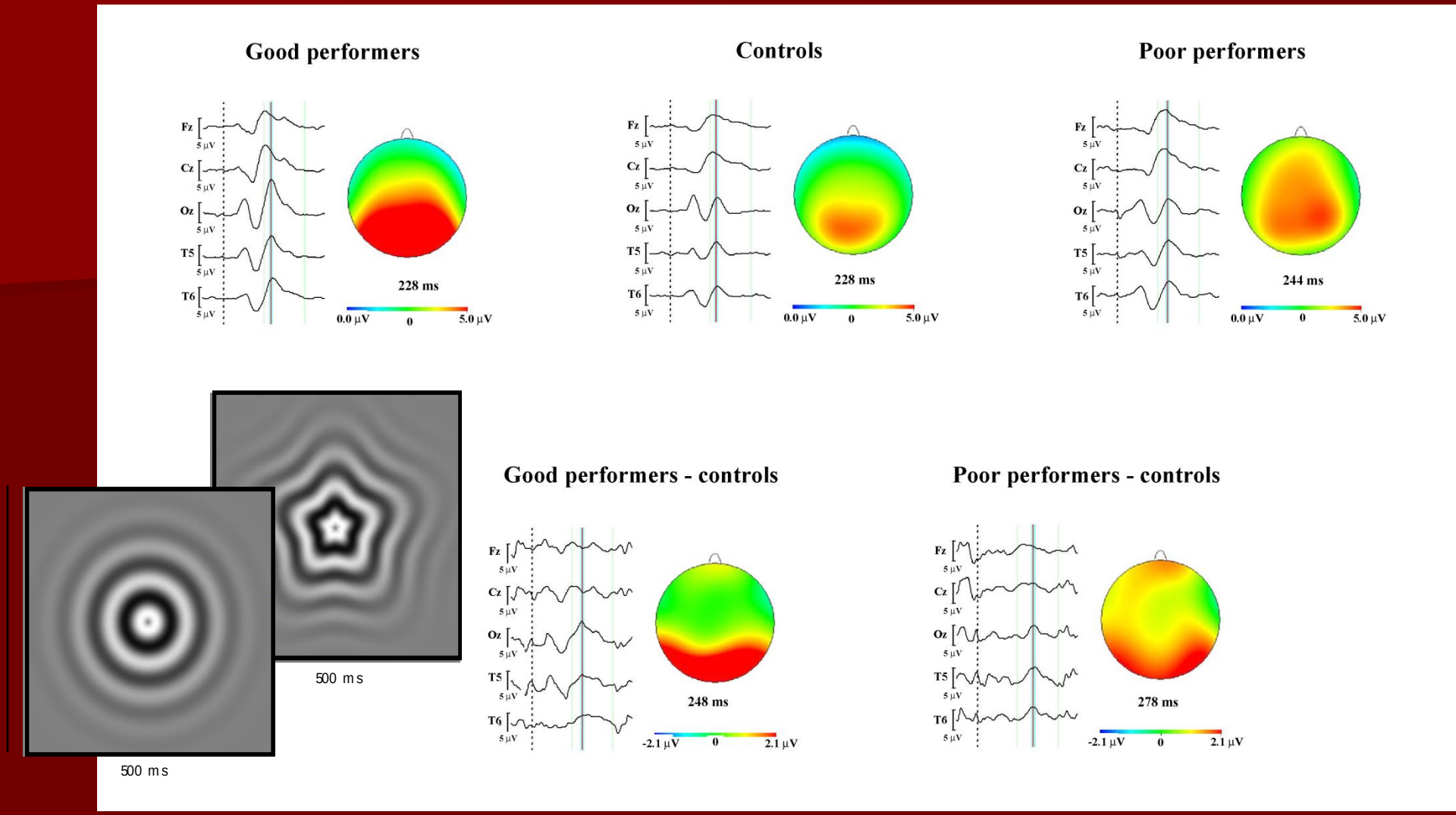
B)







Champoux,F, Tremblay, C, Lepore, F, Theoret,H, Neuropsychologia, 2008



Visual evoked potentials to the presentation of the transformational apparent motion stimulus for good performing and badly performing subjects

Doucet, Lassonde, Lepore et al, Brain, 2006

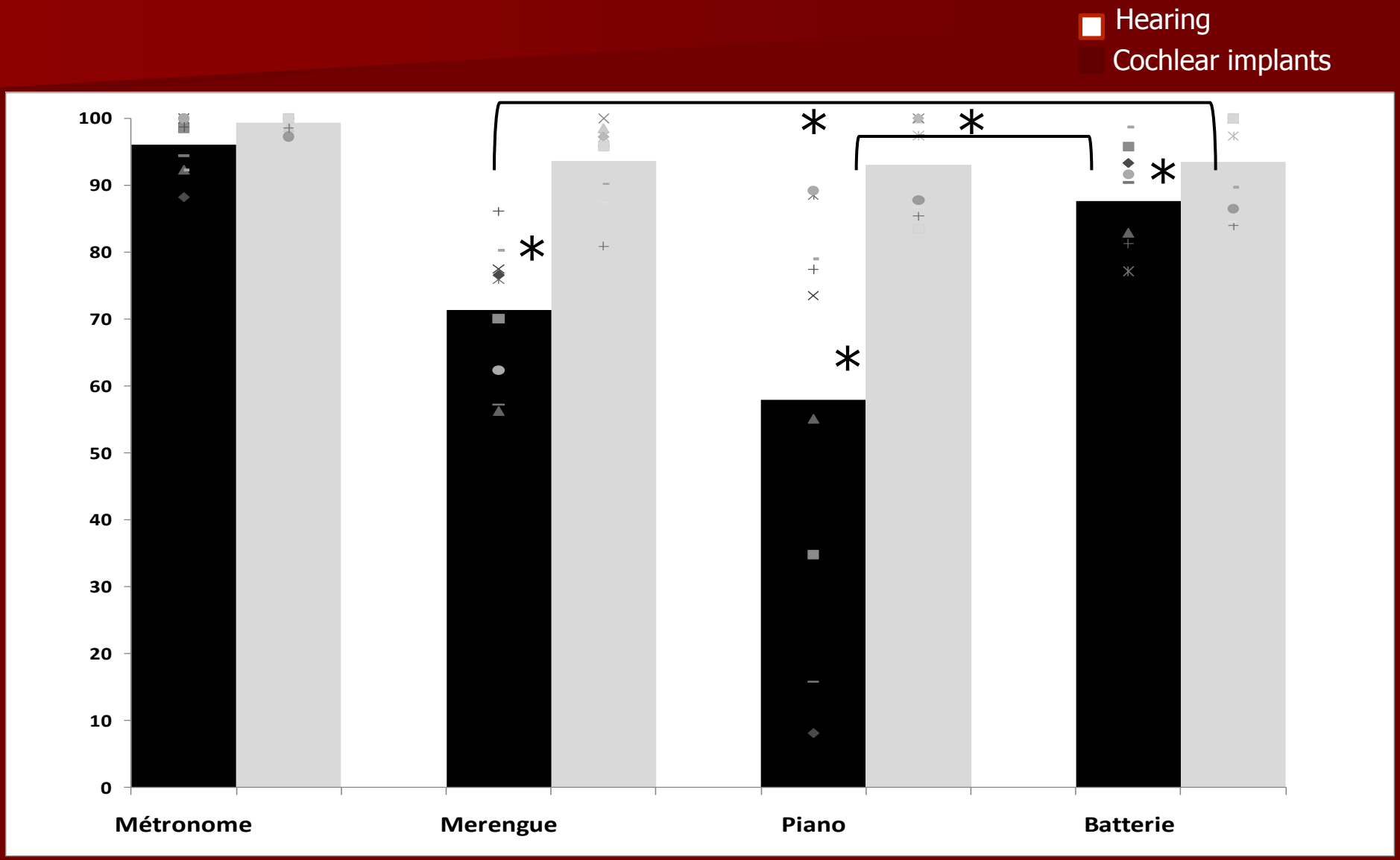
Measure used to study dancing in cochlear implanted subjects:

Perception and time reproduction of music using a synchronization and music capture apparatus

It gives:

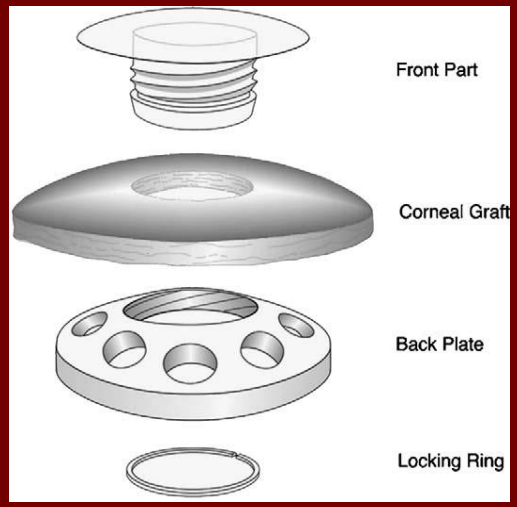
1. Periodicity of body mouvements
2. The constancy of this mouvement
3. The ability to compare performance with norms

Music perception and dance with cochlear implant



These results with hearing restauration using cochlear implants with the deaf raise an interesting question: what happens with sight restauration in the blind- the **Boston Keratoprosthesis (Kpro)**

We have seen that there appears to be a « sensitive period » for plasticity to manifest itself. But is this an absolute rule? The Boston Keratoprosthesis study seems to indicate that this is not true!



Adlave, 2009; Dagher & Dohlman, 2008; Dohlman, 2007; Khan et al., 2008

Sight restoration following lens implant

- Patient: 41 years, Rieger Syndrome
- Keratoprosthesis of the right eye

	OD	OS	OU
PRE	MM	20/400 -	20/400
POST +J3	20/100	20/400	20/100 - 20/125

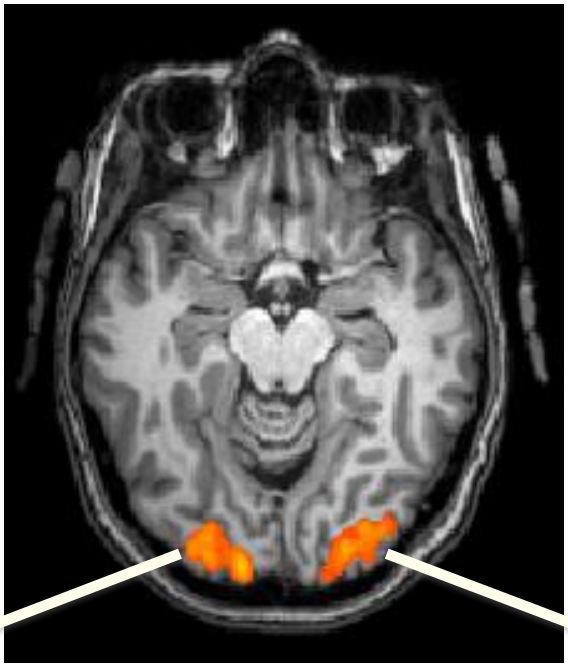
Examined with fMRI

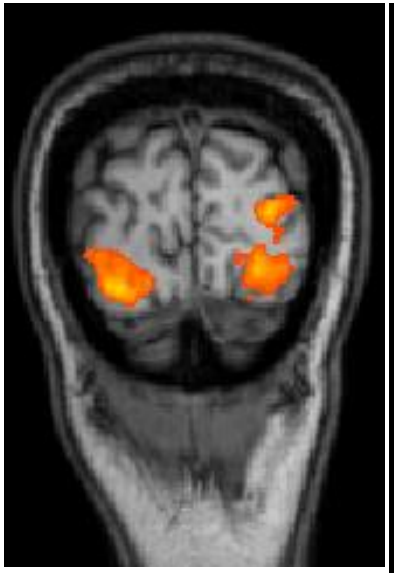
1) Just before implant
2) 3 days after

Auditory and visual tasks

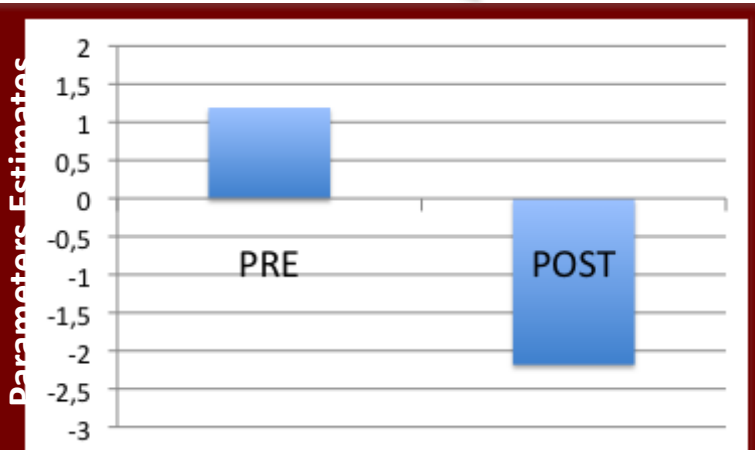
Cross-modal plasticity before Kpro

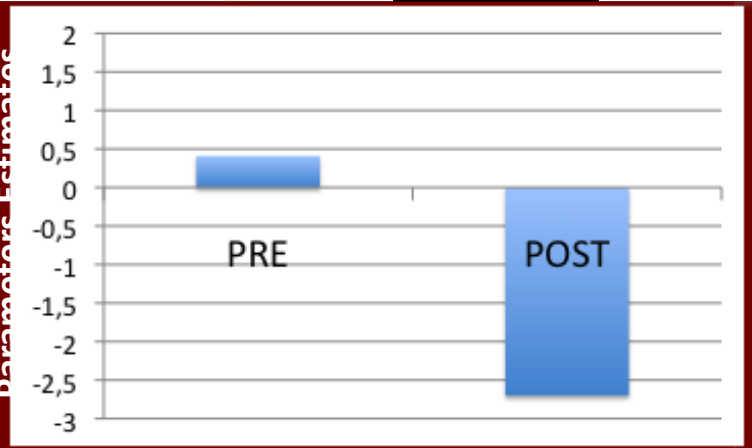
AUDITION Before KPro > After KPro



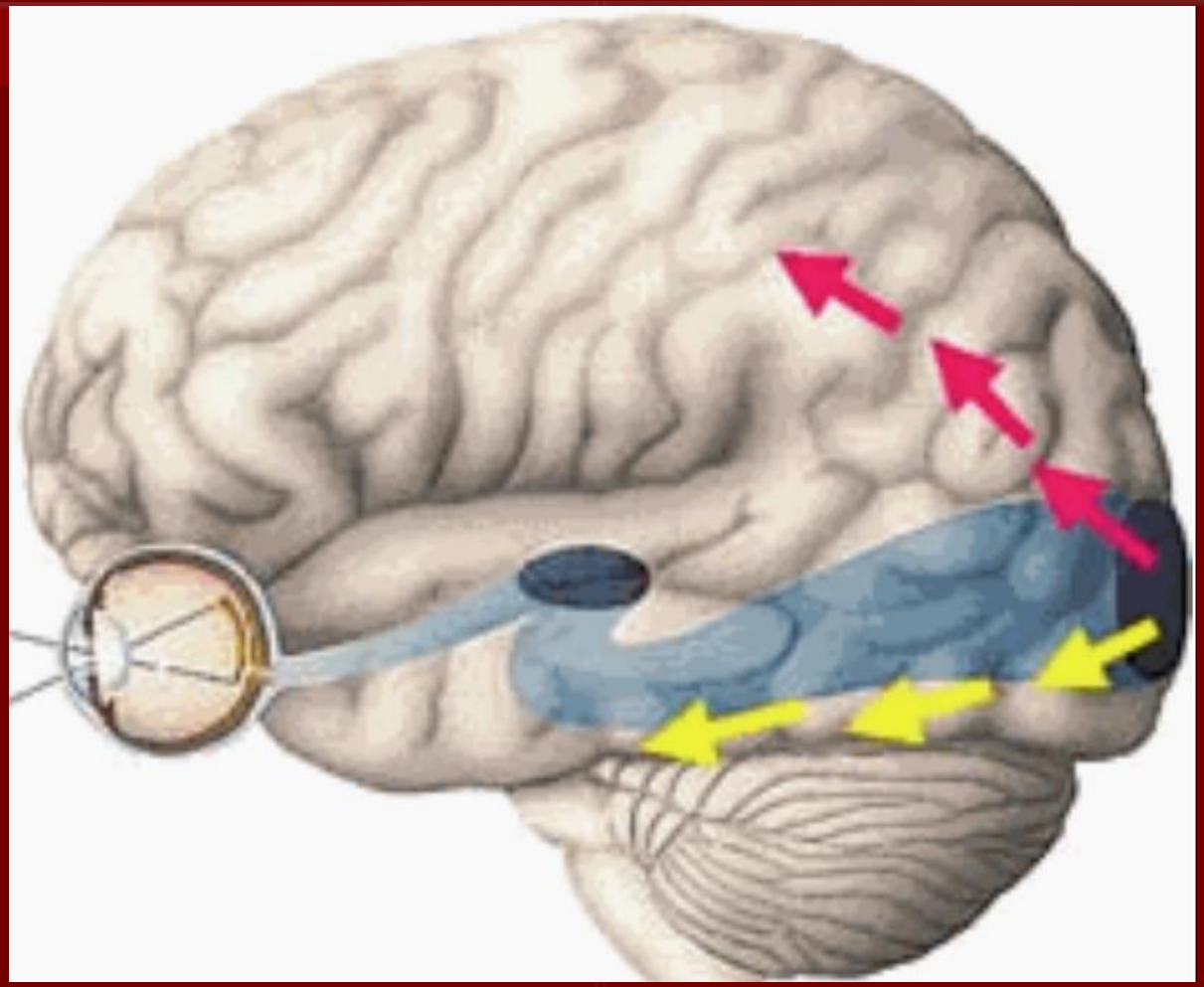


p(Bonf) < 1.000





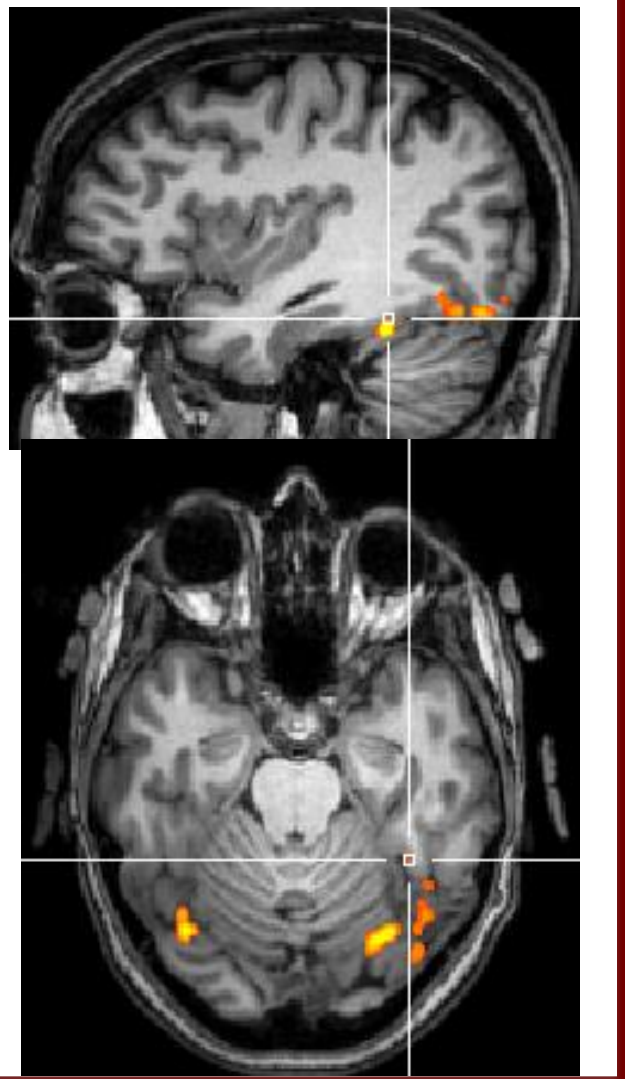
Face specific ventral visual areas

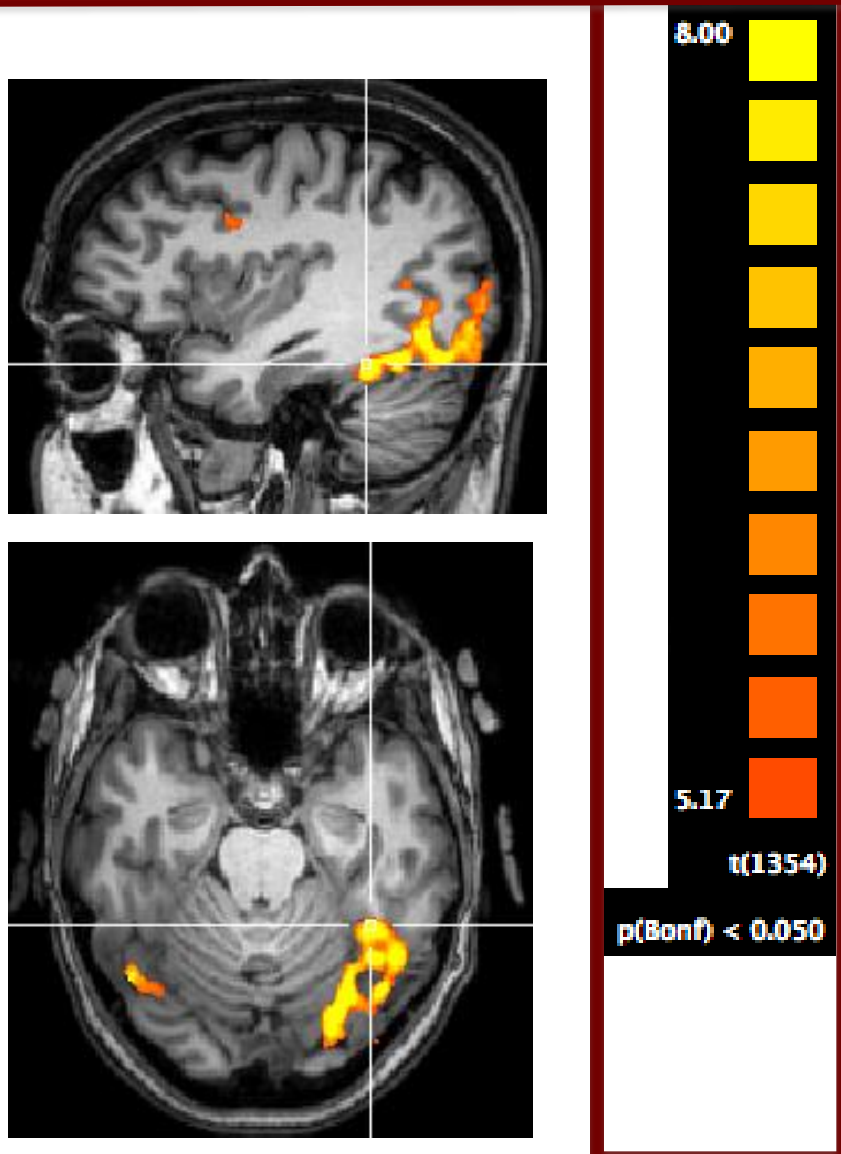


Haxby et al., *PNAS*, 1991; Kanwisher et al., *The Journal of Neuroscience*, 1997

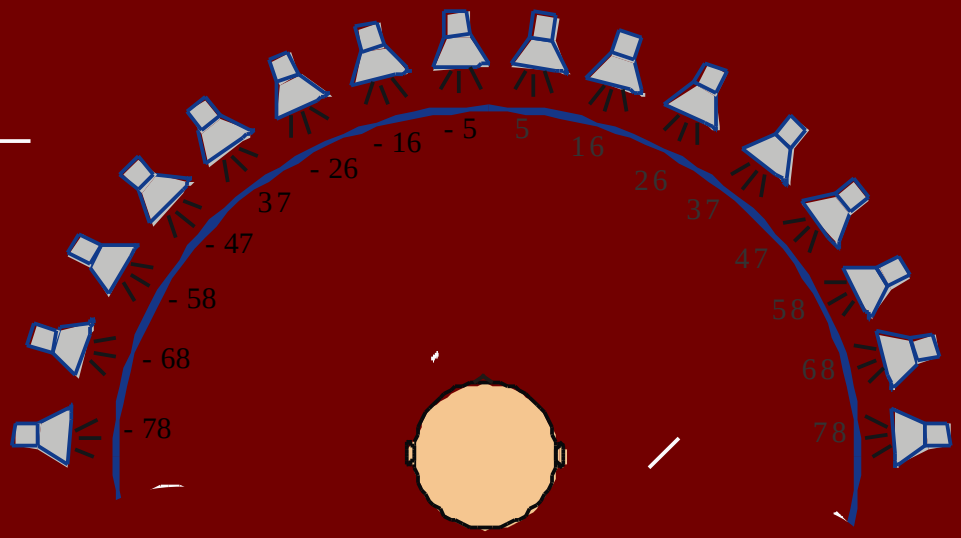
Before KPro

3 days after Kpro

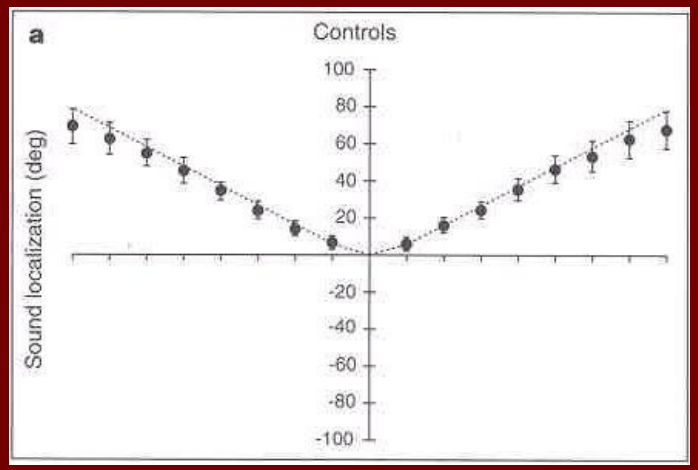




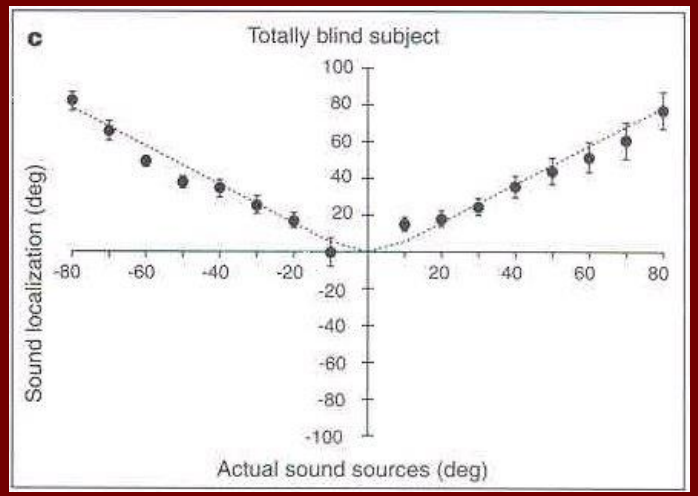
Binaural sound localization



Sighted

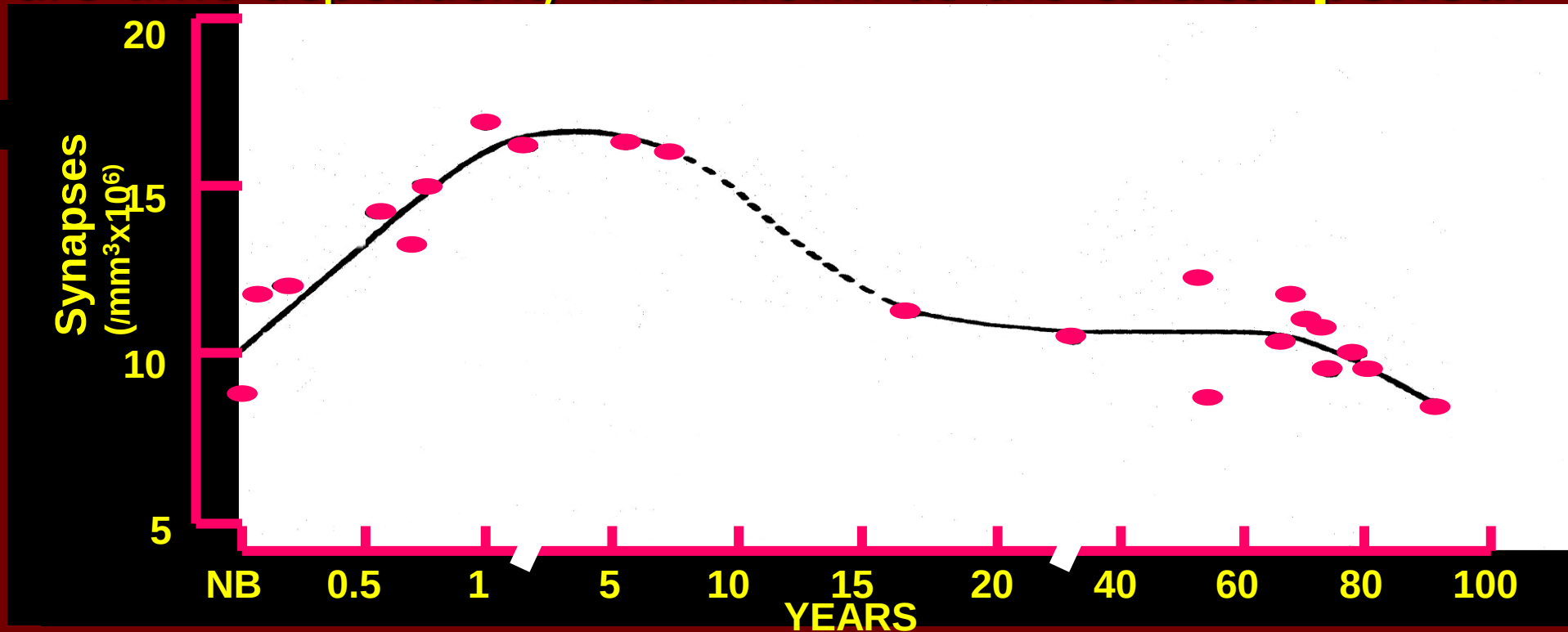


Blind

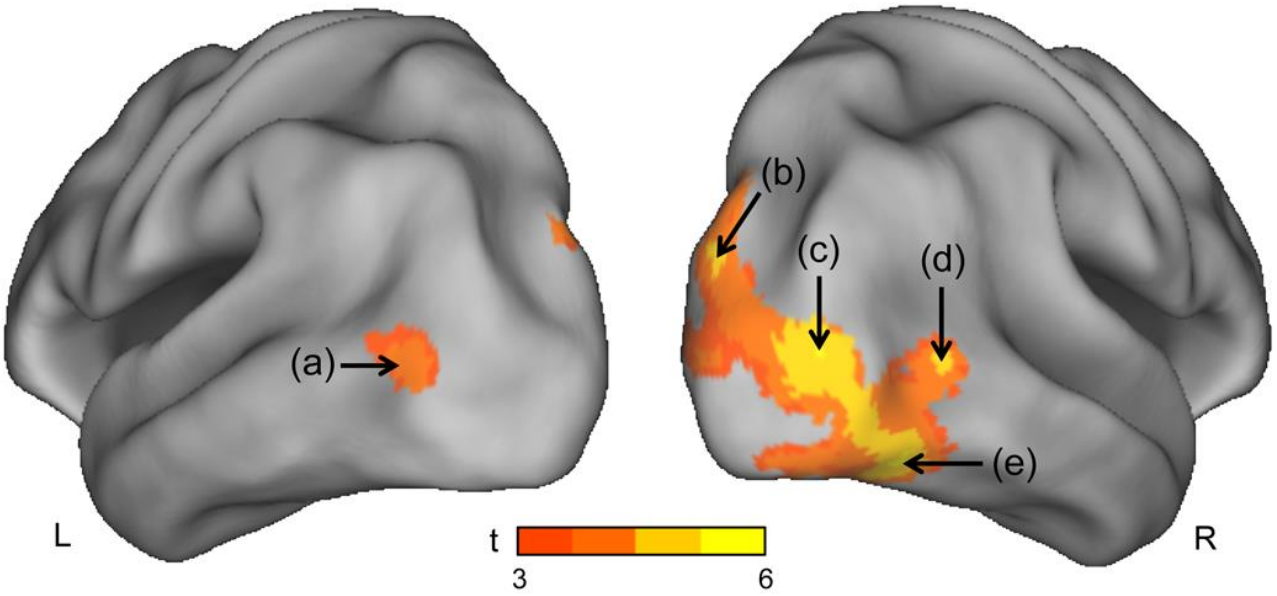


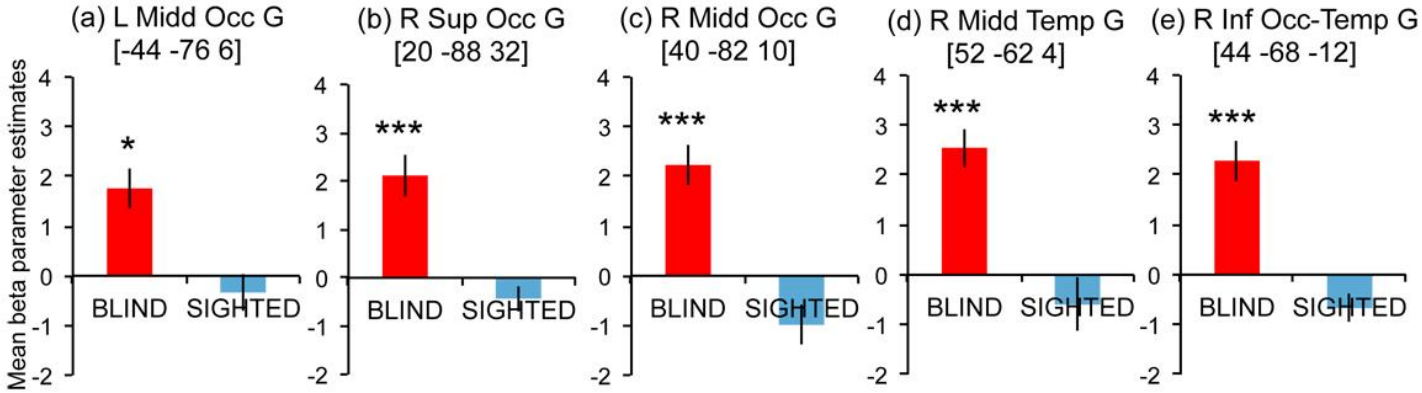
Lessard, Paré, Lepore, Lassonde (1998) Nature

The human brain is hard-wired at birth. However, following development and learning, a number of phenomena take place, such as **synaptic pruning**, which modify substantially its structure. These modifications are normal and allow us to act, feel and adapt to the environment as well as to others. These are time dependent, well known as the **critical period**.



[Blind > Sighted] x [In-depth + Lateral + Static]



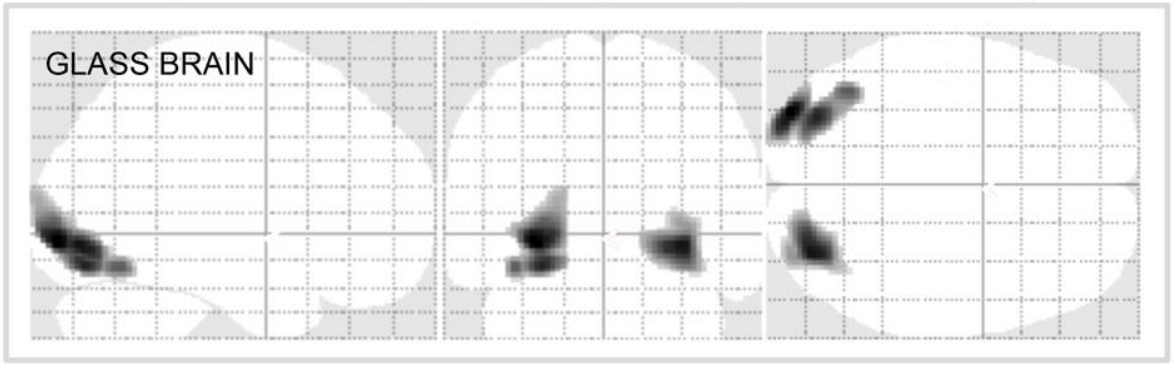


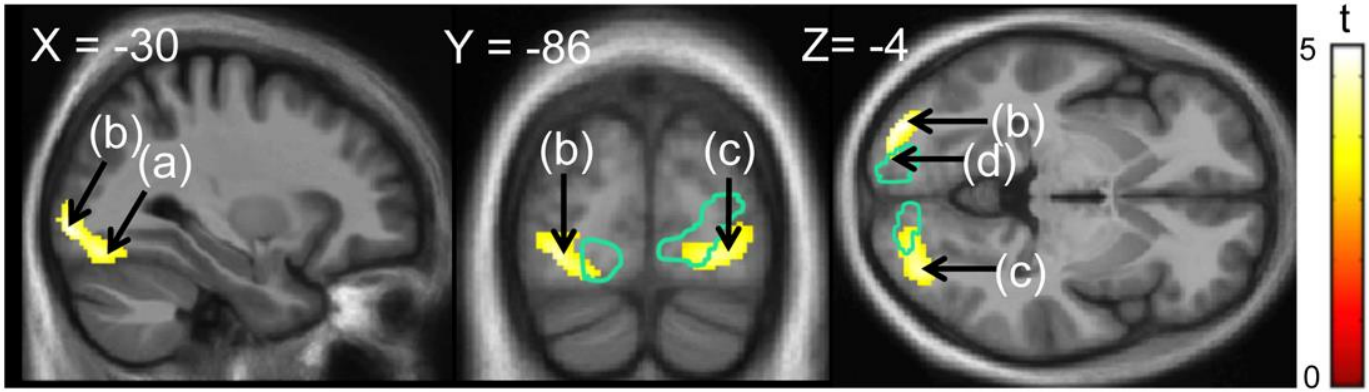
We have in the context of the studies to be presented today two subject populations who had significant sensory impairements: visual loss or deafness

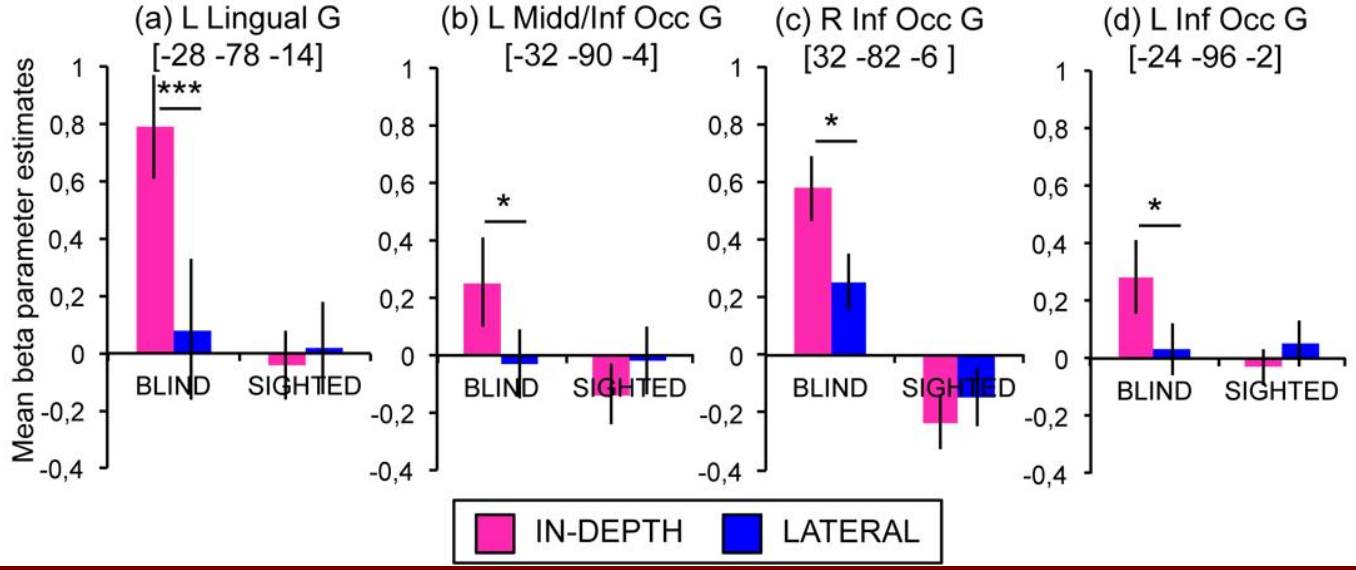
-with respect to vision loss, we shall examine two sub-populations:
-blind subjects and individuals with lens restauration

-with respect to the deaf, we shall also look at two sub-populations: deaf subjects and individuals whose auditory functions were re-established with a cochlear implant

[Blind > Sighted] x [In-depth > Lateral]



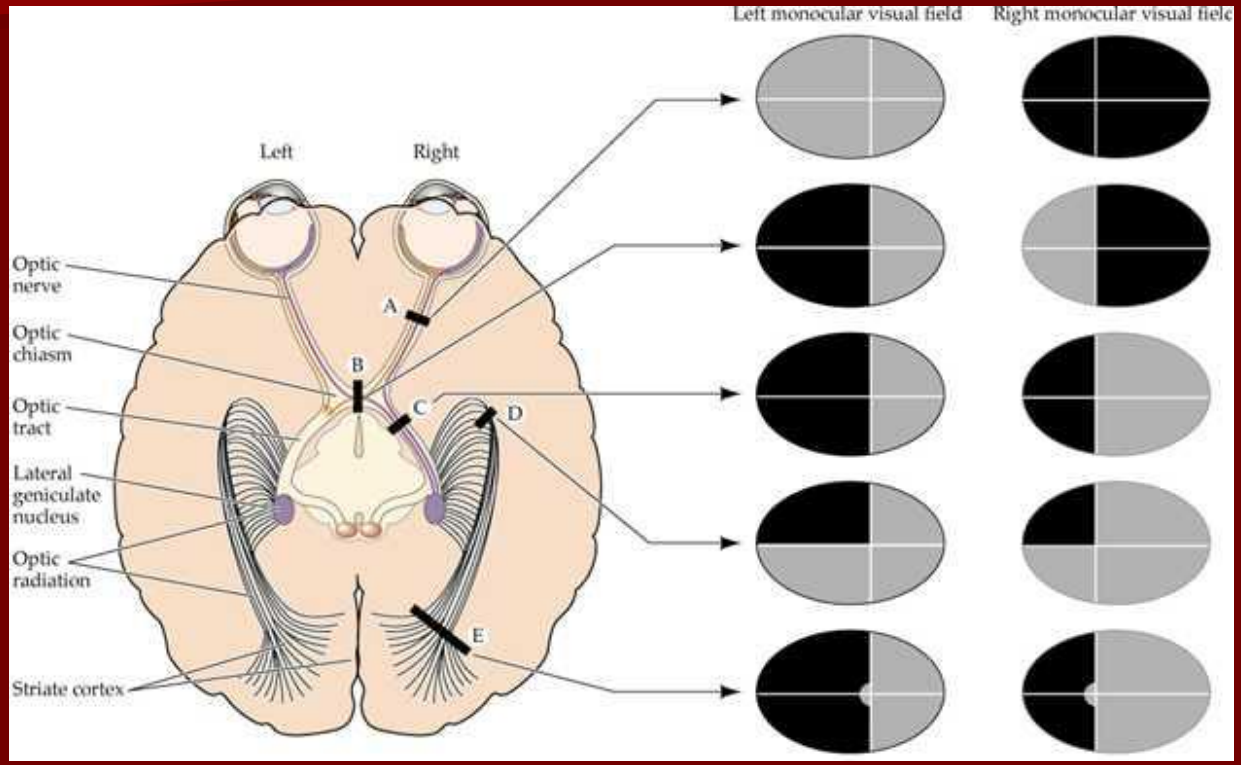




We have shown important plasticity and reorganization in individuals who loose sight through peripheral receptor loss. How do persons adapt to vision loss due to cerebral cortical loss: the case of hemianopic subjects

I would like to specify that this is a new project and we only have preliminary data. The reason for presenting it is to show another field in which we are working and where biomedical imaging can furnish an excellent tool to study spared function and the effect of rehabilitation

Hemianopia and blindsight: why is it interesting?

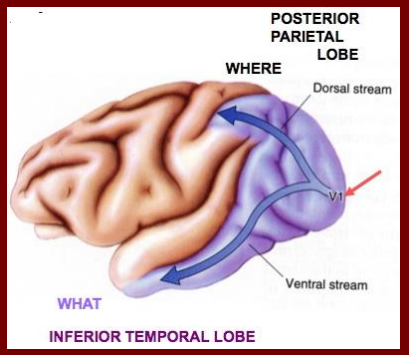


Unilateral loss of posterior visual cortex due to surgery or stroke leads to blindness in contralateral field.

- *Sign of a residual cortical or sub-cortical visual pathway remaining.*
- *Residual visual capacities in the blind field.*
- Develop a rehabilitation technique to improve the visual abilities in the blind field.

Our plan…

- Compare the results obtained in **two populations.**
  - Cortical infarct
  - Delimited lesion of the visual cortex



- Evaluate the **residual visual capacities** of our participants.
- **fMRI and Diffusion Tensor Imaging (DTI**) to try to define the **functional activations and connectivity between areas**.
- **Training using coupled visual/auditory stimulations and stimuli which are treated by subcortical structures, such as moving dots (to come in the future!)**

Our hypothesis …

*Implication of the **subcortical pathways** passing by the superior colliculus and pulvinar and by the **"where" or parietal dorsal stream pathway**.*

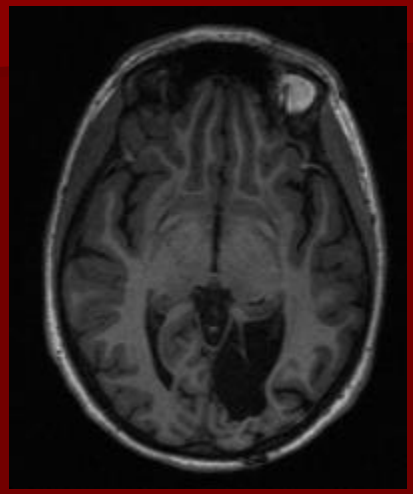
Preliminary behavioural study on two hemianopic participants

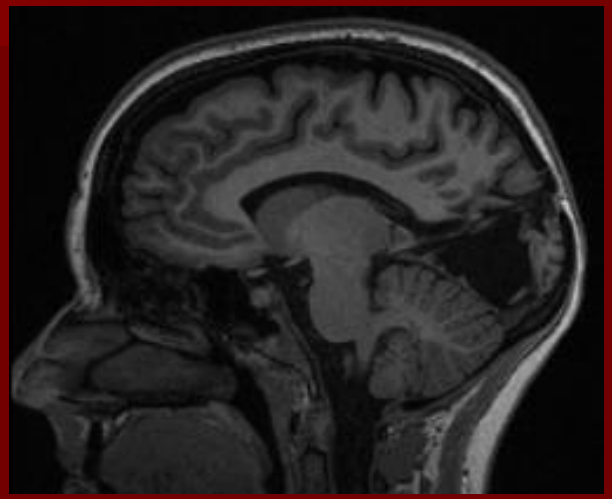
- Two participants :
  - Participant 1 : right homonymous hemianopia.
  - Participant 2 : left homonymous hemianopia

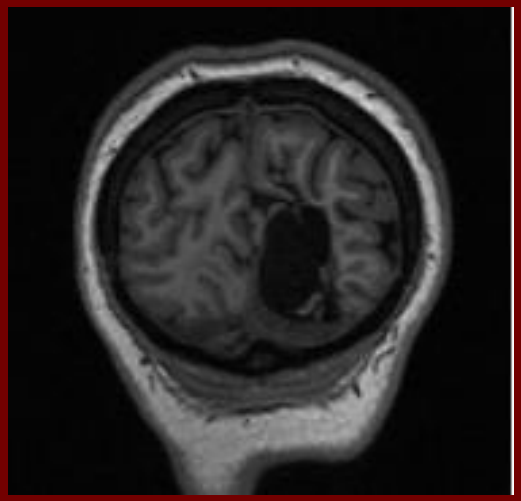
- Use the functional specificity of the superior colliculus and of the parietal pathway to evaluate the quality of the residual visual capacities and to determine the implication of these regions.
  - (low frequency, motion, multisensory stimulation and integration).

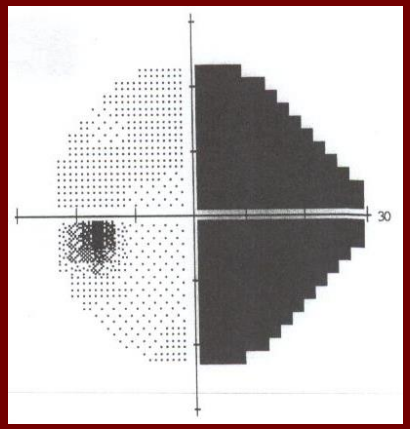
All potential saccadic movements were controlled with an EOG system.

Participant 1

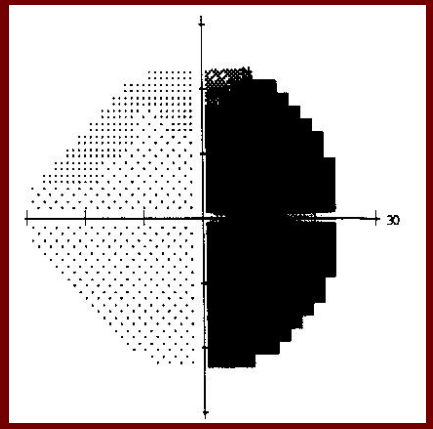






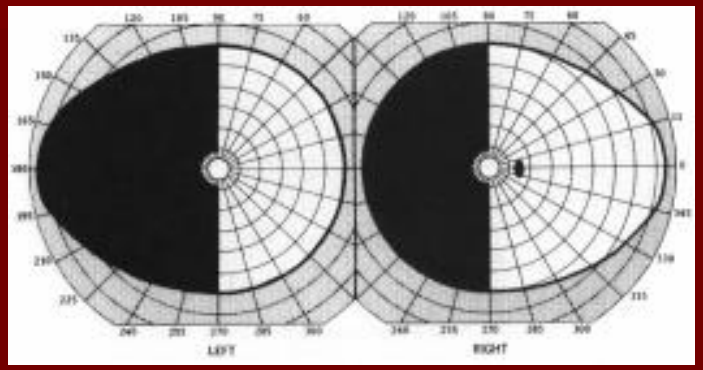


Retinotopy left eye

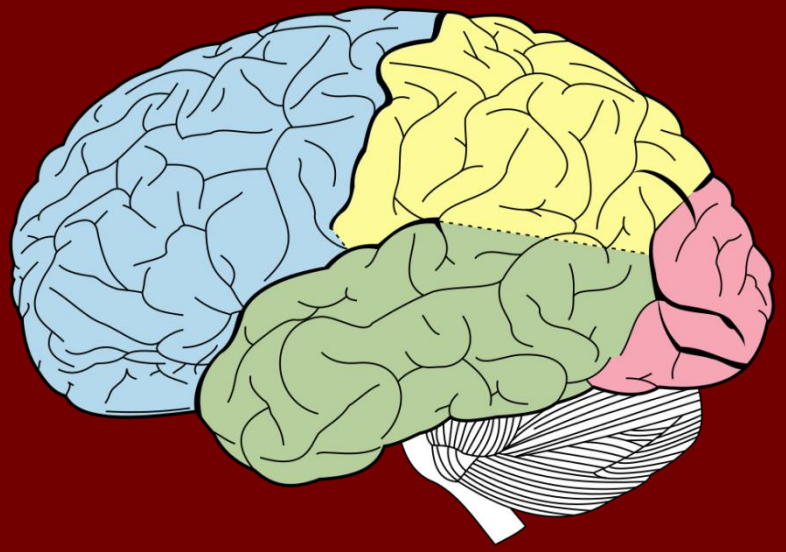


Retinotopy right eye

Participant 2

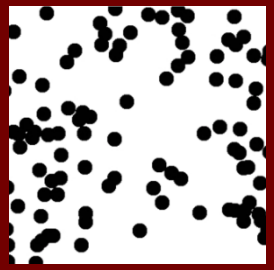


- Had epilepsy in her right hemisphere.
- Had the removal of the visual cortex the 24 of September 2013.
- Doesn't have any sensation of visual stimulation, including motion in her natural environment.
- Has developed a sweeping oculomotor technique, when concentrated.



Patch of moving dots paradigm

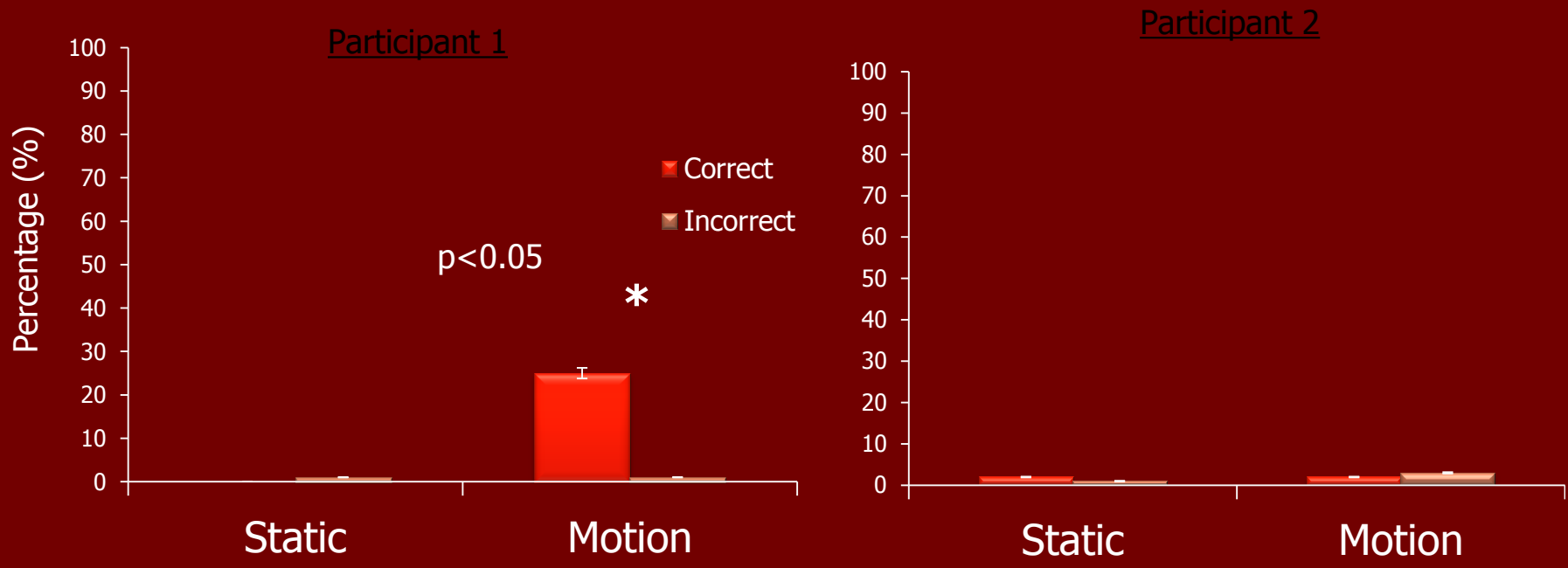
(*All the tasks where carried out in the blind field)*



- First part : Presentation of moving dots versus static dots.
  - 12 degree patch
  - White background
  - 150 dots of 0.5 degree each with a 12°/sec for the vertically moving dots.
  - Presented at 12 degrees.

- Second part : Discrimination of the direction of the motion.
  - Same parameters as in the first part.
  - Upward and downward discrimination.
  - White noise auditory stimulus to initiate the answer presented at the same position.

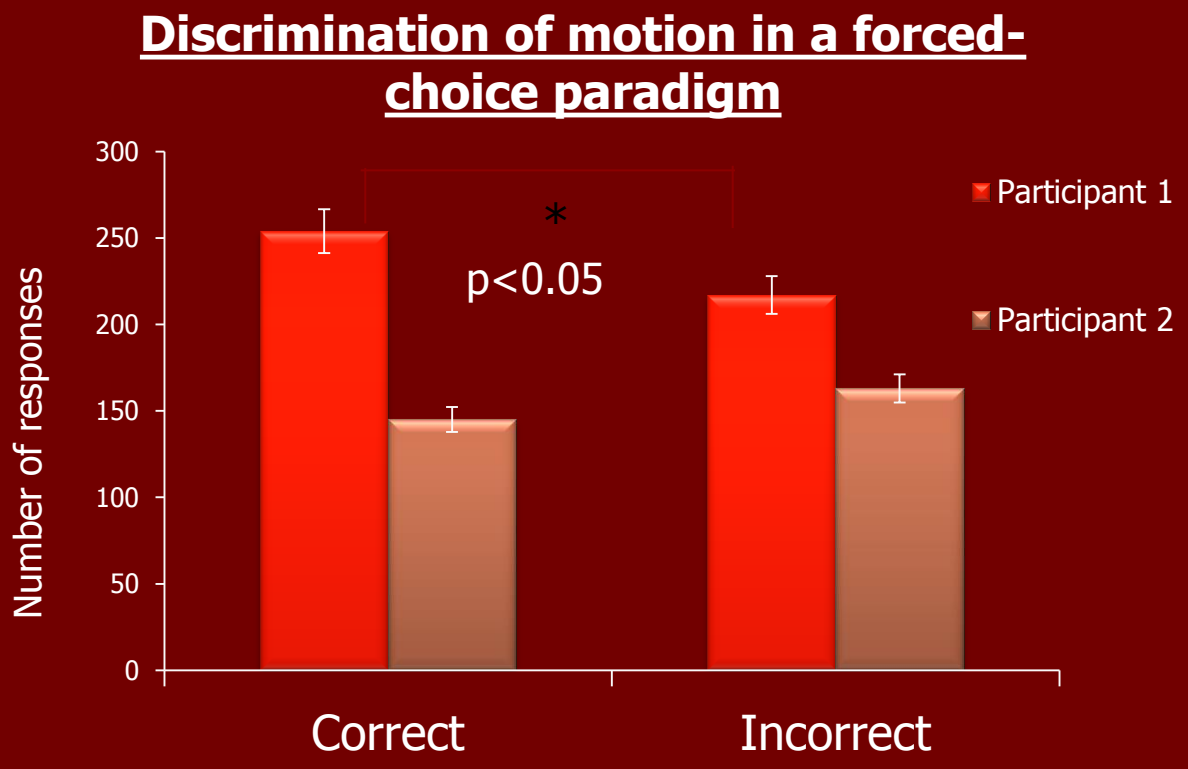
Is there any reported perception in the blind field when presented with moving dots or static dots?



** Participant 1 reported correctly a sensation of motion when moving dots were presented compared to the presentation of static dots.*

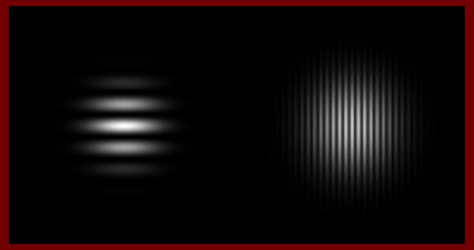
No false positives.

Is this awareness reflected in the detection of the motion direction?



** Significant results only in participant 1 who had better performance when discriminating between downward and upward motion.*

- Gabor patch (12°) of low and high spatial frequency



  - Low frequency = 1 Hz. High frequency = 5 Hz.
  - Two directions = vertical and horizontal.
  - Two positions : 20° on the y axis in the upper field and in the lower field, with a 24° on the abscissa.

- Motion detection of a moving single gray bar

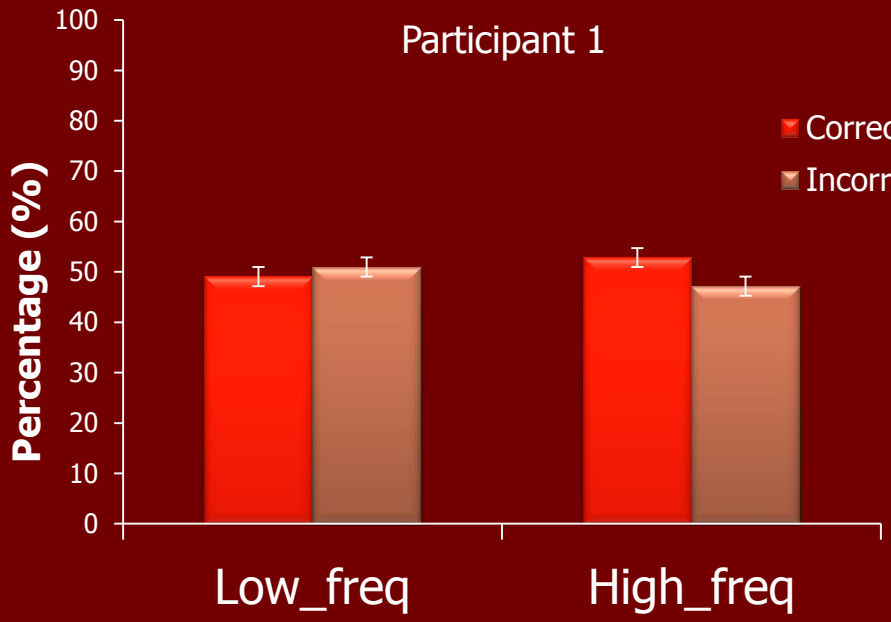
  - 4 directions of movement : up, down, left, right.
  - Moving from 10° to 36° on the x axis and from 20° upper field and 20° lower field.

- Pointing task

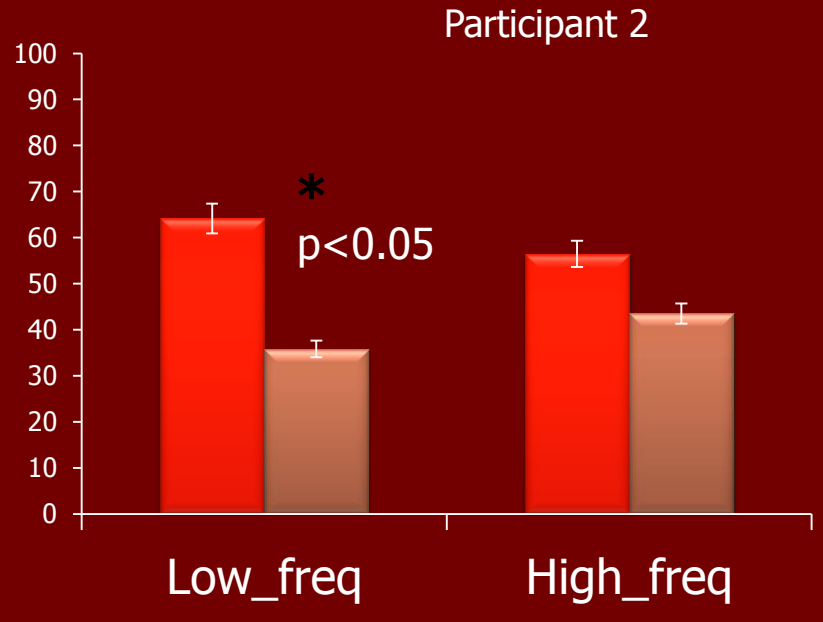
  - Gray flash presented in random positions.

Low and high frequency Gabor patch presented vertically or horizontally

Orientation discrimination in a forced-choice paradigm

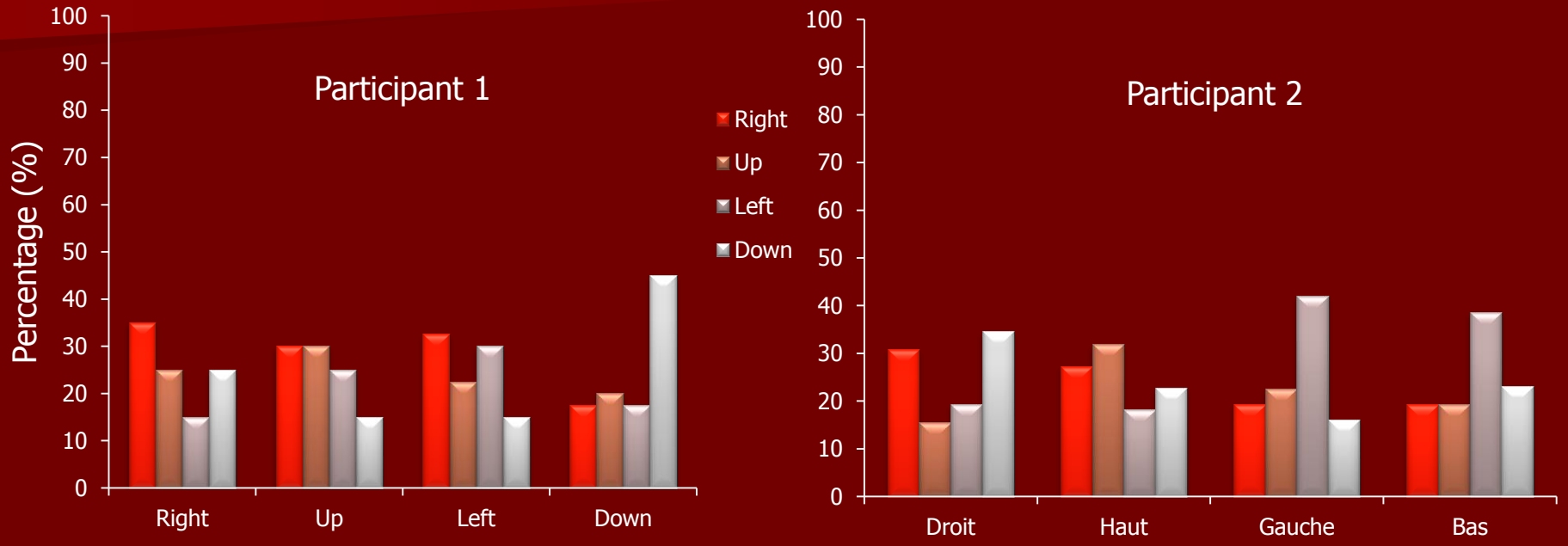


No differences between conditions for participant 1.



** Participant 2 had significantly better responses to low frequency than to high frequency.*

Motion detection of a single bar



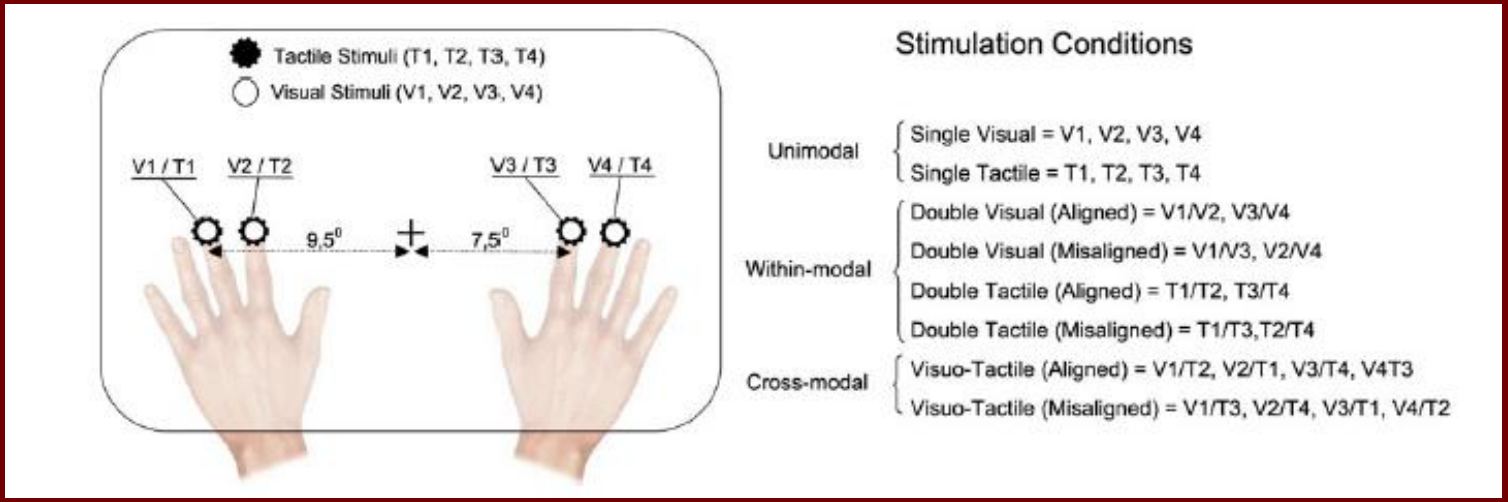
Direction of motion presented

The participants could not detect the direction of the moving bar when presented in their blind field.

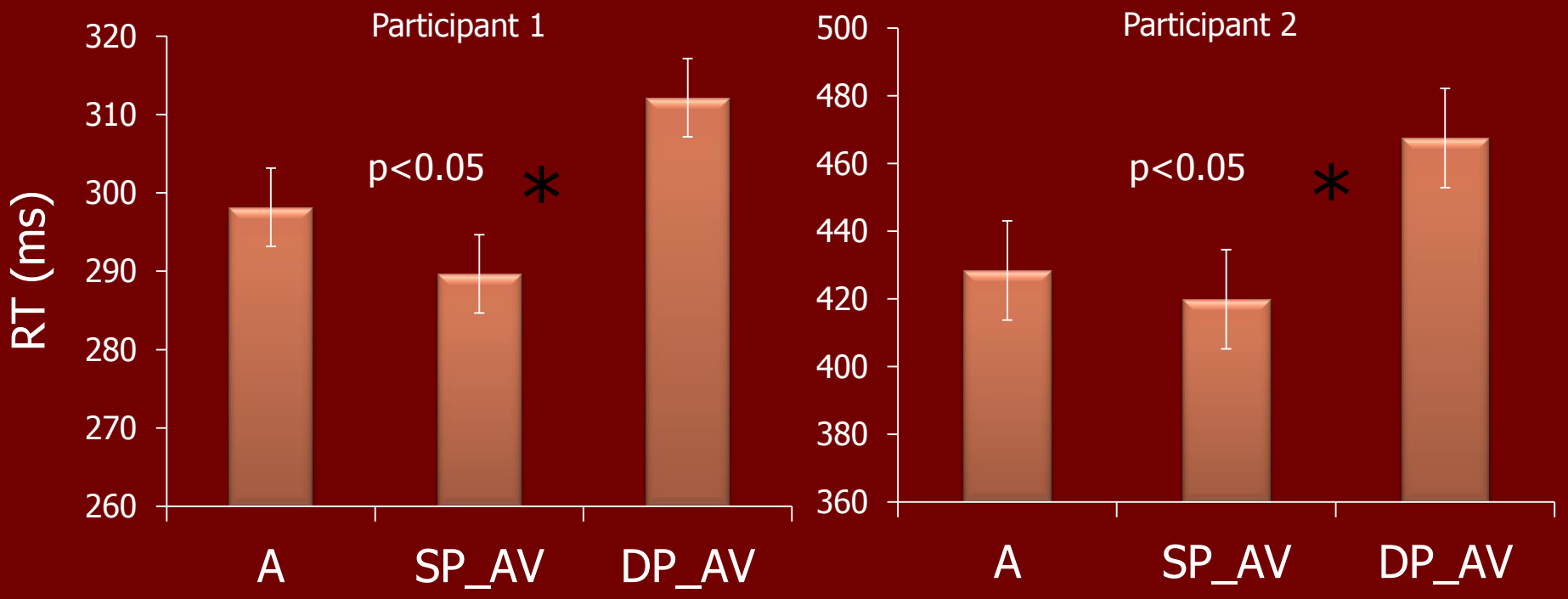
Pointing task: *No relation was found between the position of the target and the position aimed.*

Multisensory integration

- Audio-visual paradigm (gray flash of 2 °)
  - 4 positions (x/y) : 8°/20 °; 8°/-20°; 36°/20°; 36°/-20°.
  - Soft white noise presented alone (A), at the same position (SP) or at a different position (DP) of the visual stimulus.
  - Localisation of the sound at 8 ° or 36°.
  - Reaction time was measured.
- Visuo-tactile paradigm

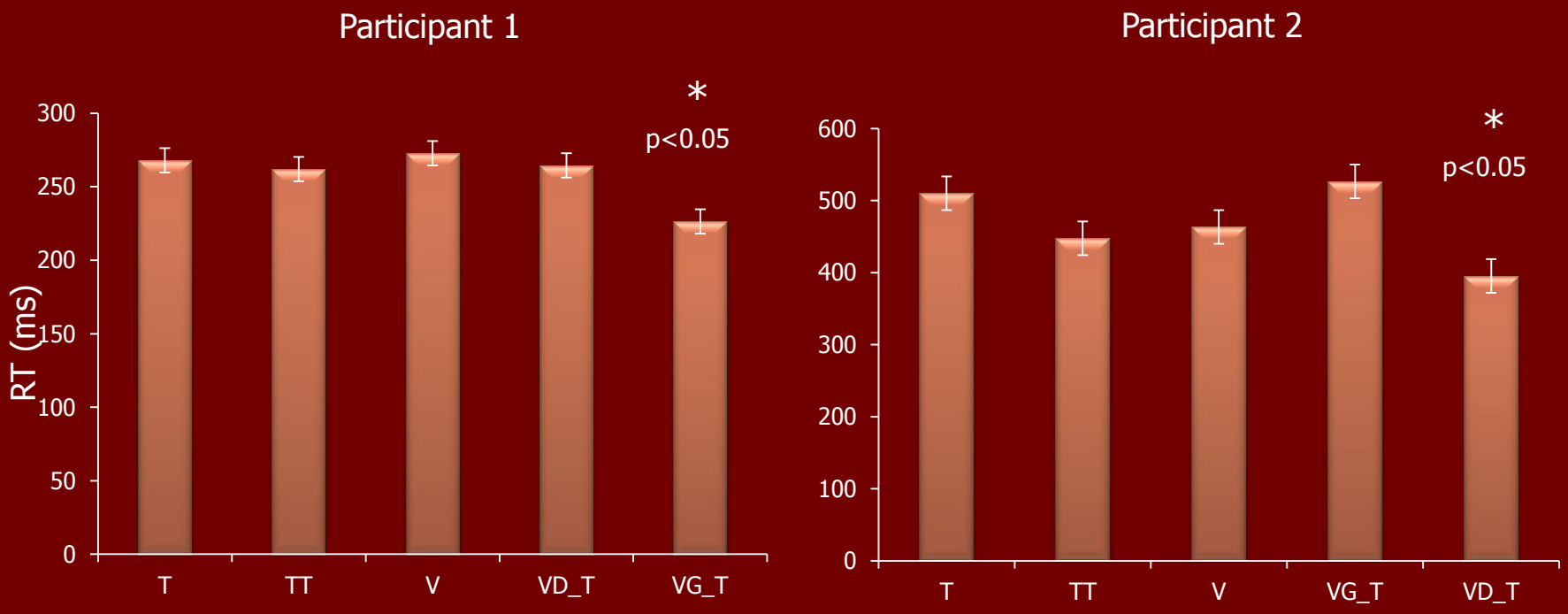


Audio-visual integration in a localisation task presented in the blind field



* *Faster RT in same position (SP_AV) condition compared to different position (DP_AV), reflecting in integration with unseen visual stimuli.*

Impact of the spatial congruence of redundant targets on within-modal and cross-modal integration (tactile and visual)



Slower RT for combinations of cross-modal stimuli than for combinations of within stimuli shown only when the visual was presented in the normal field.

Magnetic Resonance Imaging
Hypothesis & Scanning session

- Hypotheses : Hemianopic participants present different pattern of activation when seeing stimulus movement depending on their blindsight performances
- -they could also present different white matter tracks supporting their behavioural performances.

- MRI Scanner Siemens Trio 3T :
  - Anatomical scan
  - Diffusion Tensor Imaging scan
  - BOLD scan :
    - Whole brain
    - 17 slices Thalamic focused scan
  - Resting State scan

Statistical approaches

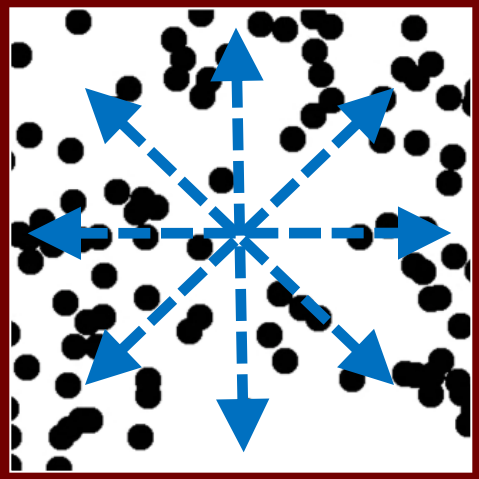
- Whole brain analyses :
  - GLM analyses of the visual mouvement induced activations
- ROI based Superior Colliculus (SC) imaging :
  - Noise-Reduction ROI based analysis (ROI : SC ; Anterior Cerebellum ; V1 ; V5 ; LGN)

  (De Zwart et al. 2008)
  - Custom HRF with max amplitude pick at 4s

  (Wall et al. 2010)
- ROI based DTI :
  - Using the same ROI : creation of tracks linking vision and movement perception for cortical sub-cortical areas (Leh et al. 2006)

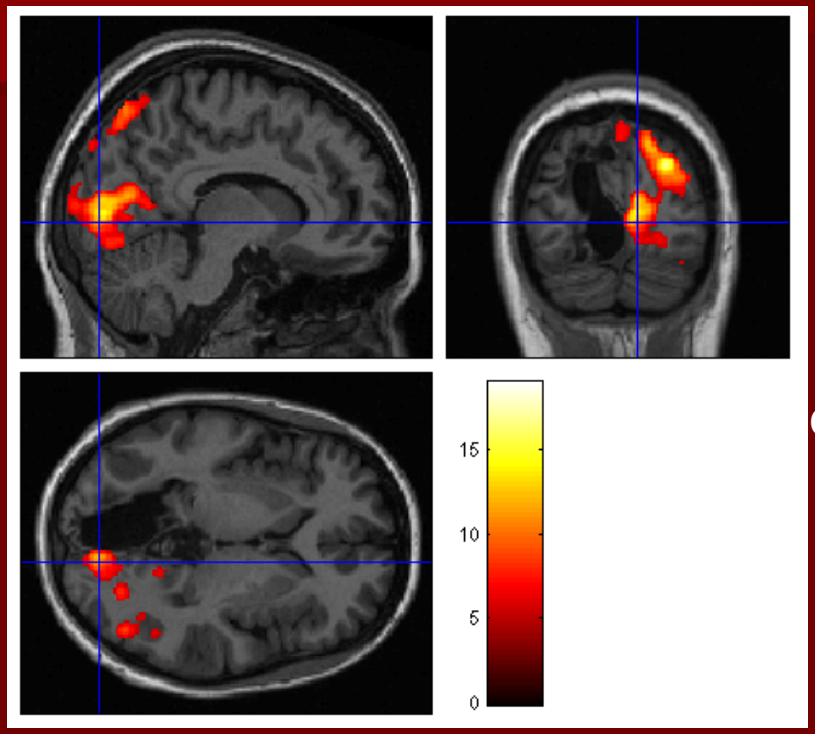
Preliminary results
In-scan performances

- Stimuli : Presentation of moving dots patches in the left or the right visual hemifield
- Task : Report any feeling or sensation of presence of the stimulus in the blind field
- Results : Detection in the blind hemifield 89,23 % ($P<0,05$)
- Control : MR-Video Eye-tracker, the excentricity has been tested in order to avoid any stimulation that could occur in both hemifields.

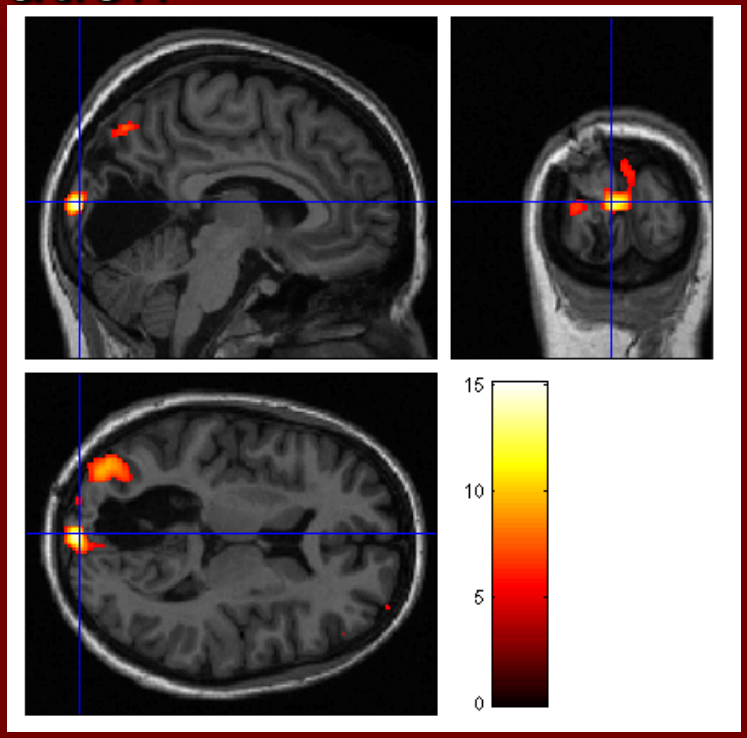


Preliminary results

WB BOLD activation



cipant 1



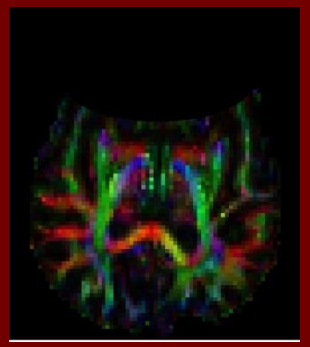
Left cortical activations (stimuli presented in the right hemifield) (p< 0,05(FWE))

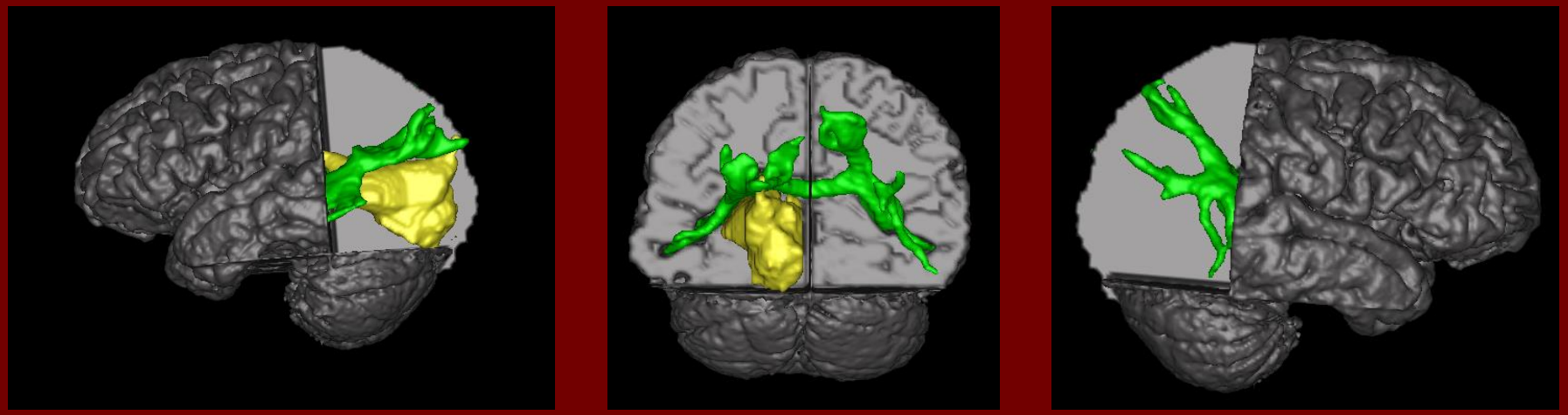
Right cortical activations (stimuli presented in the left hemifield) (p< 0,05(FWE))

There are contra-lateral BOLD activations during visual presentation in the blind hemifield

Preliminary Results
Diffusion Tensor Imaging

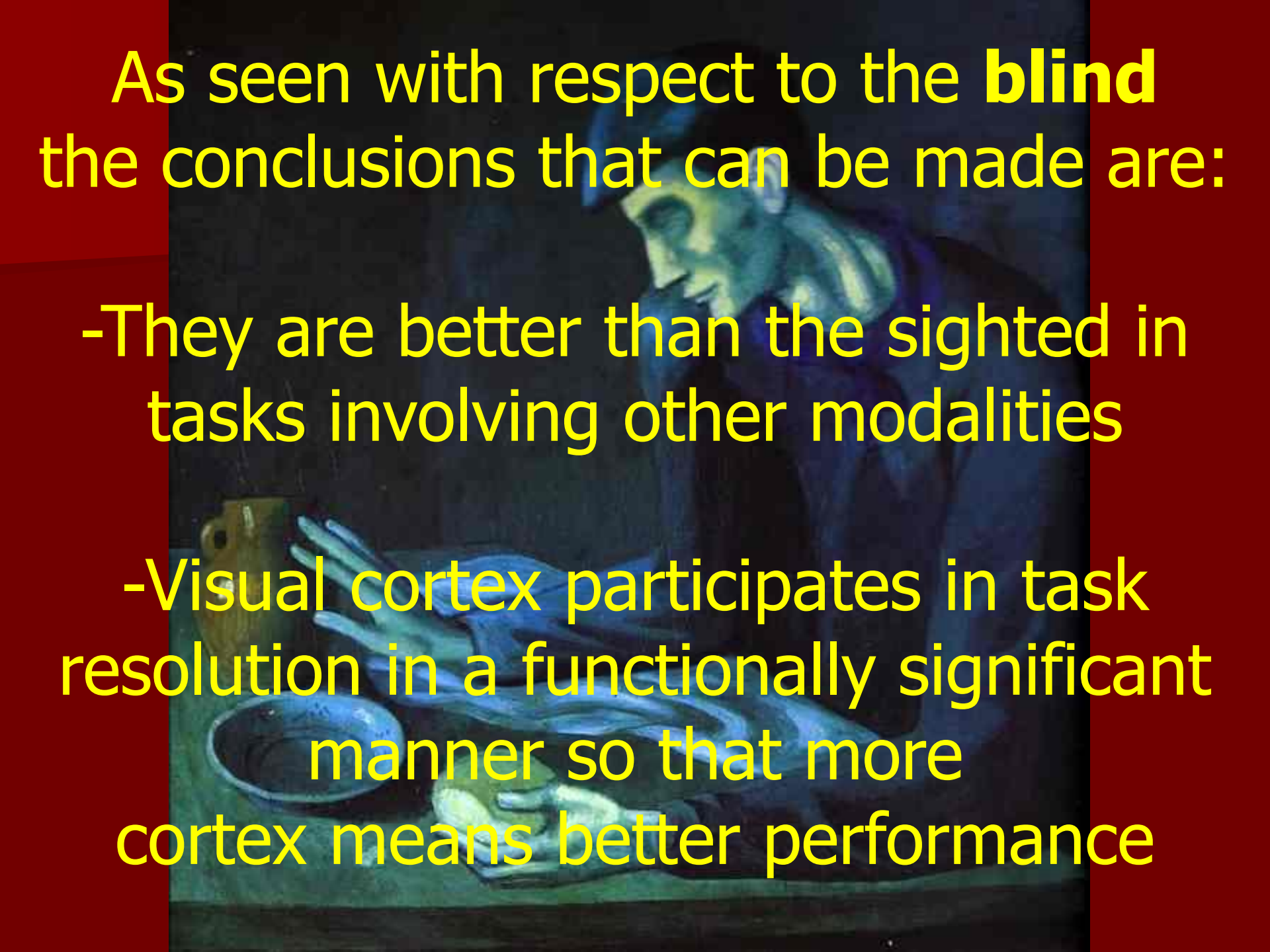
Plotted regions : Striate Cortex (V1) ; Extra-Striate Cortex (V5) ; Sub-Cortial areas (Pulvinar ; Superior Colliculus ; Lateral Geniculate Nucleus) Other Regions (Cerebellum; Corpus Callosum)





Corpus Callosum posterior tracts (green) and surgery caused lesion (yellow) (participant 1)

The lesion induces a structural asymetry between left and right tracks



As seen with respect to the **blind** the conclusions that can be made are:

-They are better than the sighted in tasks involving other modalities

-Visual cortex participates in task resolution in a functionally significant manner so that more cortex means better performance

Next step…

Test 10 other hemianopic participants (cortical stroke and delimited surgical lesion groups).

- Begin the audio-visual and the moving dots training.

Training of 2 hours /day for 10 consecutive days.

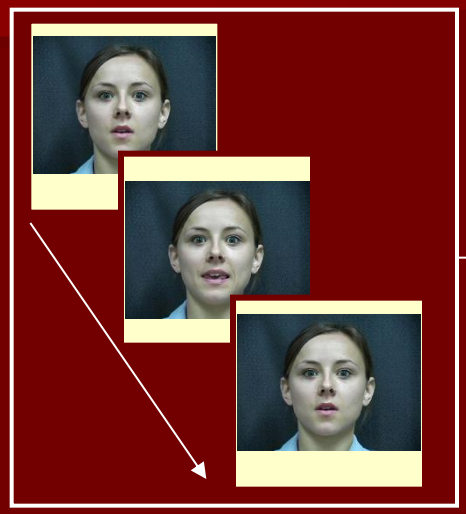
- Audio-visual training :
  - Visual stimulation presented with a white noise to improve the oculomotor search.
- Moving dots training :
  - Forced choice paradigm of the discrimination of the direction of moving dots (same pardigm seen before).

- **Compare** the results obtained in the behaviour and fMRI tasks **before and after training**, while also comparing the **lesion** of each participant.

- Develop a readaptive technique to restore partially the vision in the blind field.

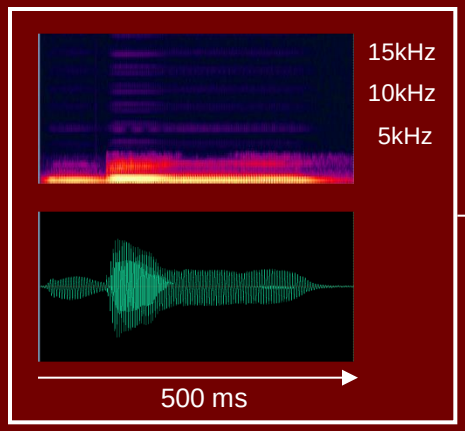
But what about specialized function, which in humans are generally treated in specialized areas or structures? Are they alsotransferred to these structures?
-The spatial navigation and the Hyppocampus (involved in route learning i.e., the London taxi drivers
-Human vocalizations, that are generally treated in structures within the superior temporal sulcus (STS)

Visual-Auditory interactions: The McGurk effect



« ga »

« da »



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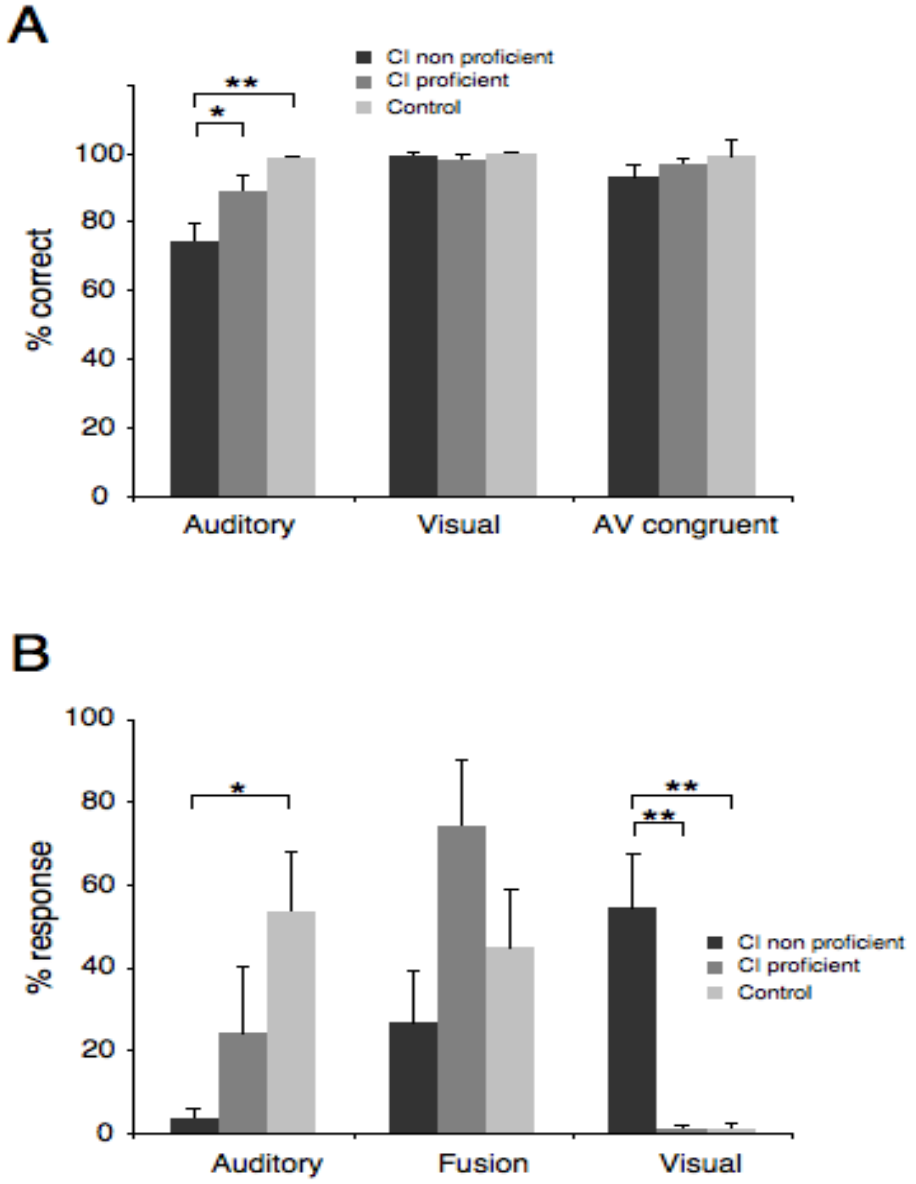
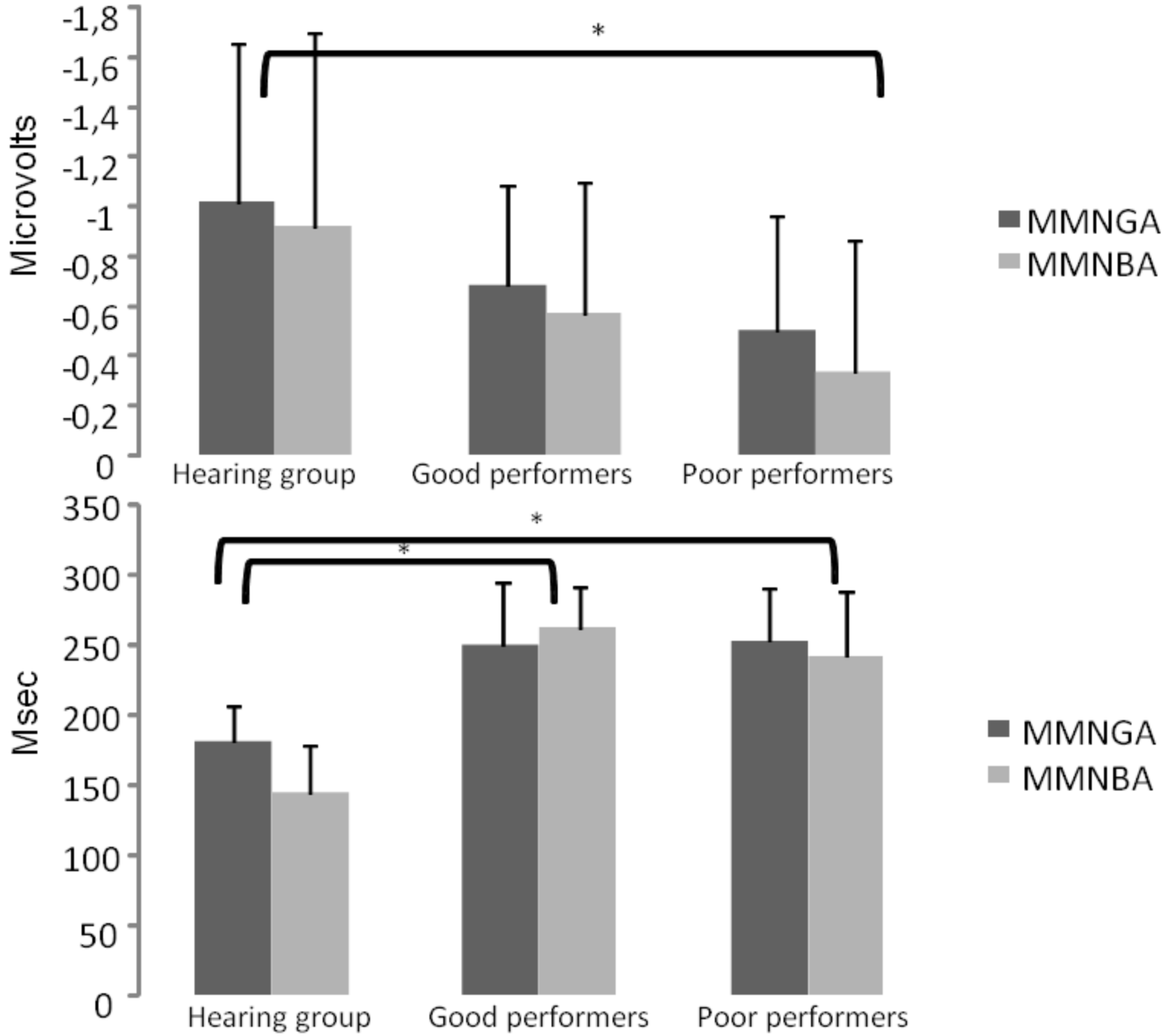
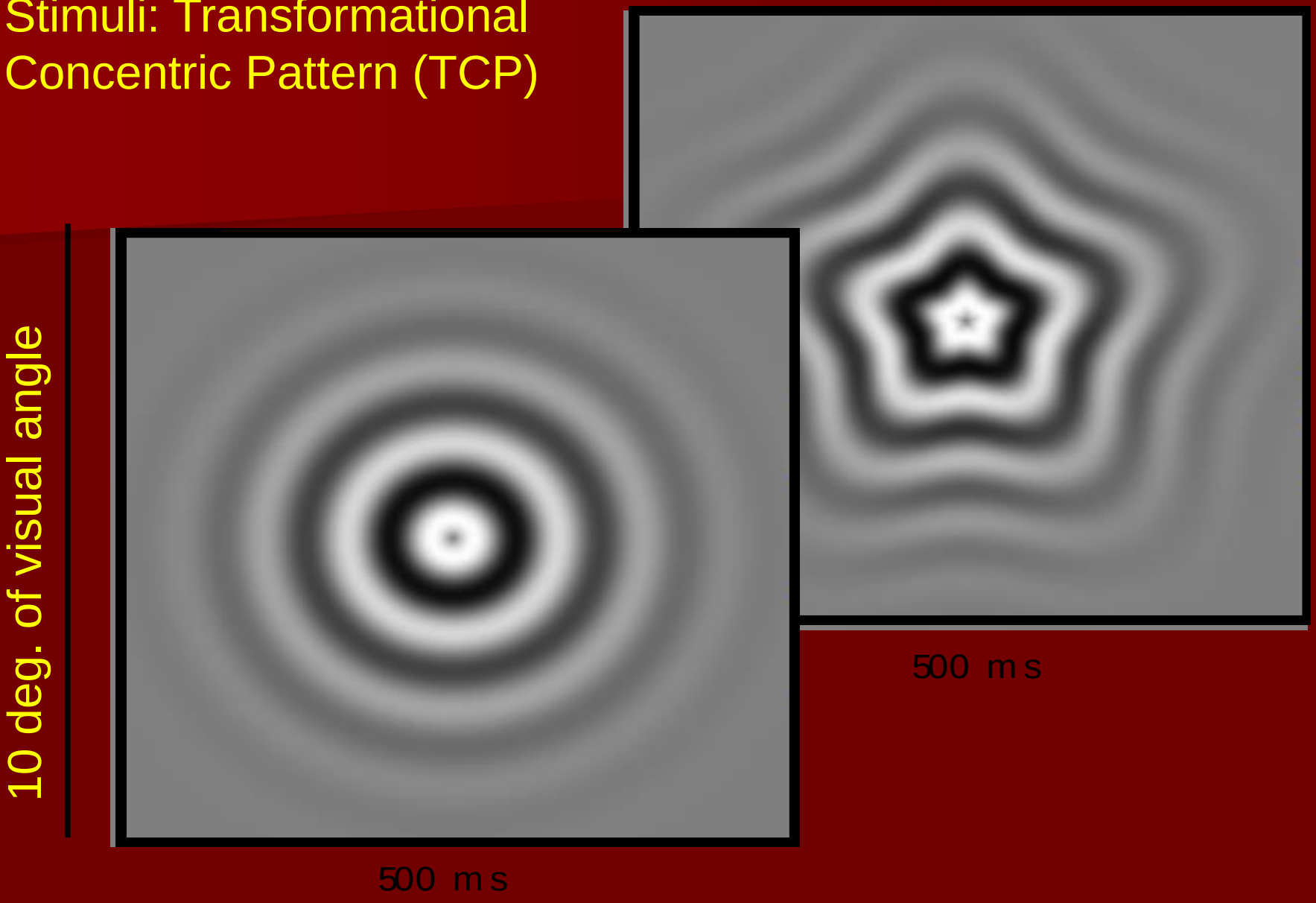


Performance in McGurk audio-visual trials for normal, pCI and npCI groups

Tremblay, Champoux, Lepore et al Rest Neurol Neurosci, 2010


Microvolts
-1,8
-1,6
-1,4
-1,2
-1
-0,8
-0,6
-0,4
-0,2
0
*
Hearing group
Good performers
Poor performers
MMNGA
MMNBA
Msec
350
300
250
200
150
100
50
0
*
*
Hearing group
Good performers
Poor performers
MMNGA
MMNBA

Stimuli: Transformational Concentric Pattern (TCP)

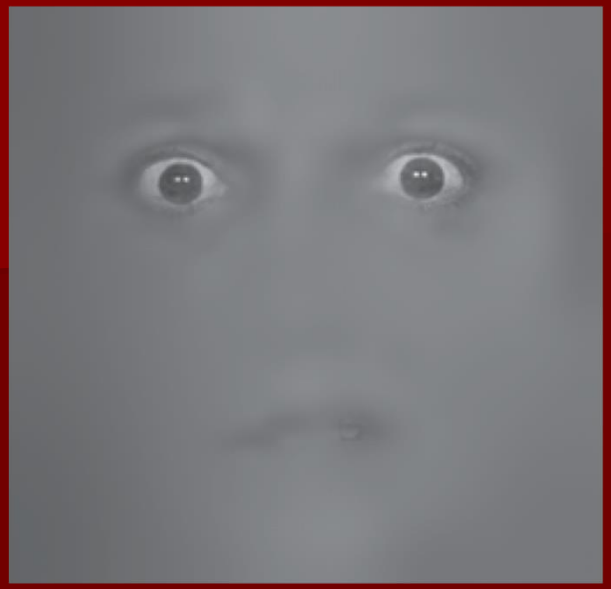


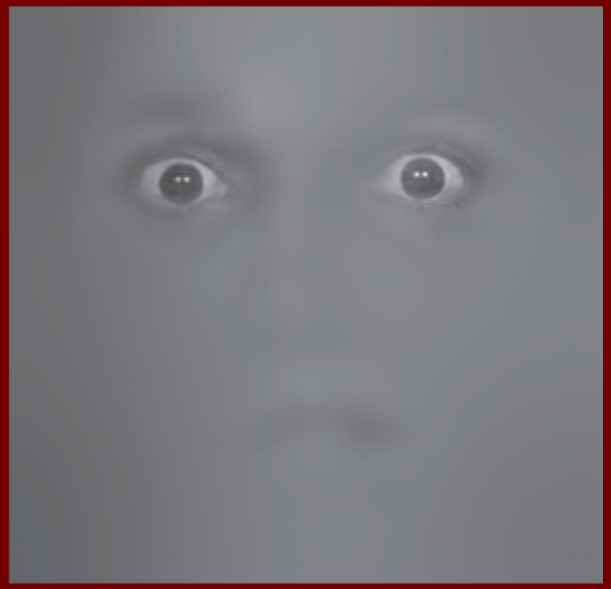
Doucet, Lassonde, Lepore et al, Brain, 2006

Control

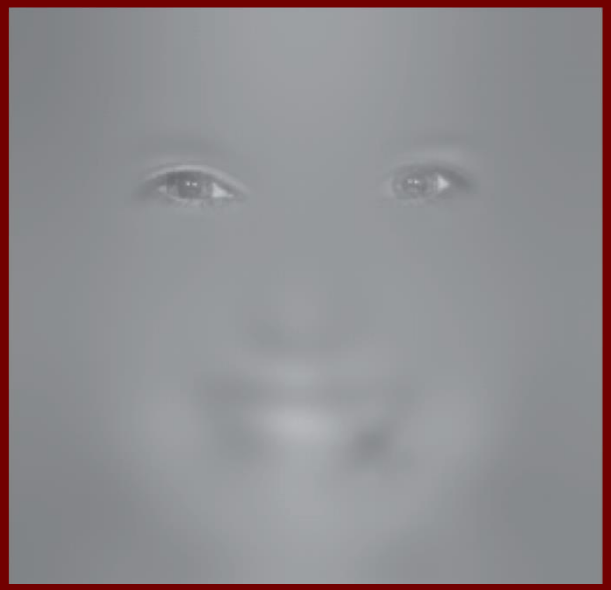
Deaf

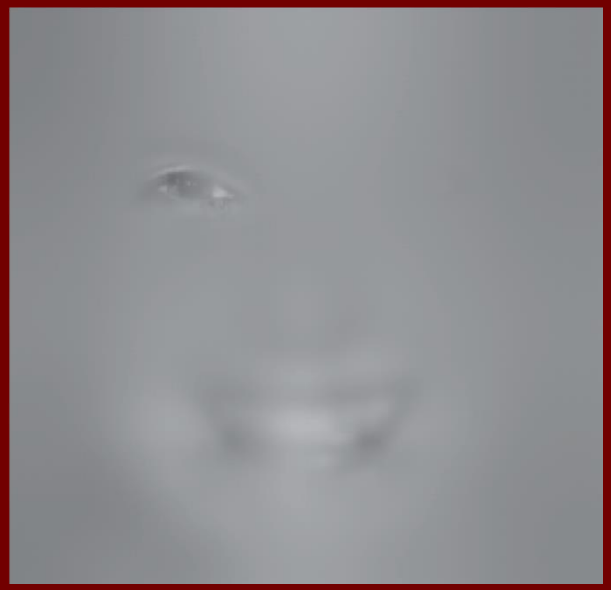
Fearful





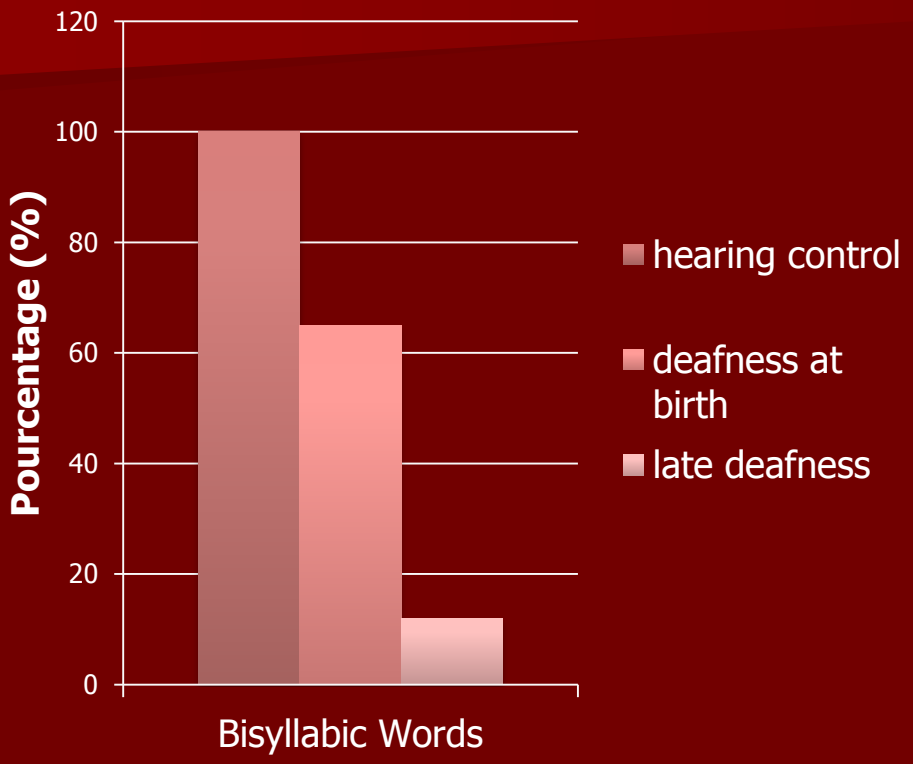
Happy

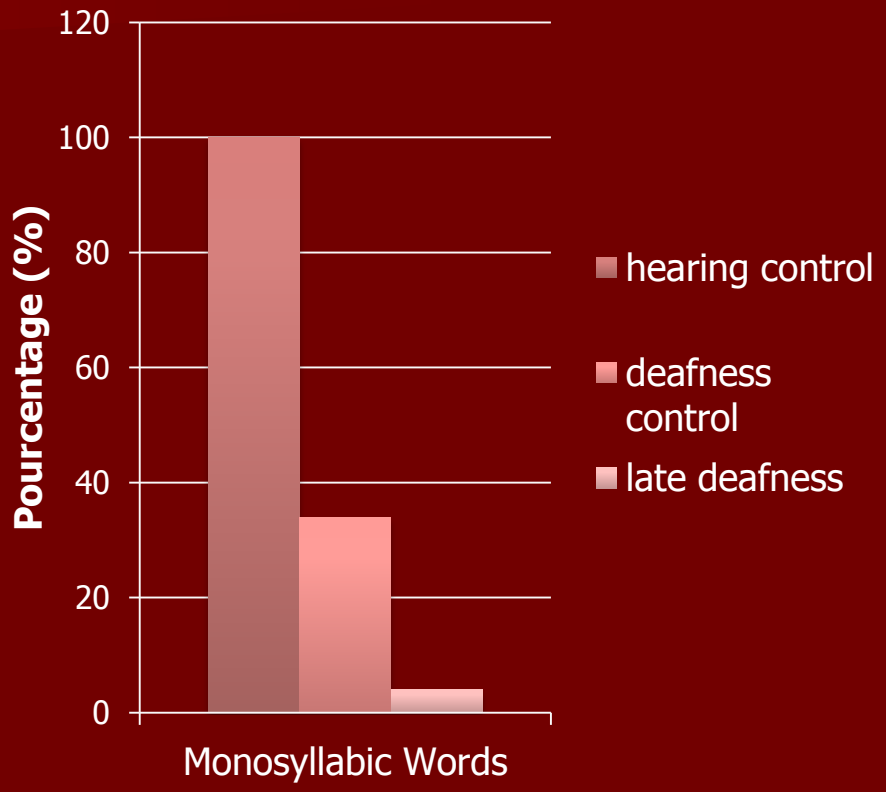


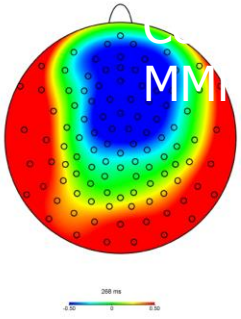


Doucet, Gosselin, Lepore, et al ECVP 2008

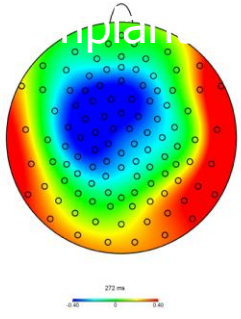
Speech discrimination in silence



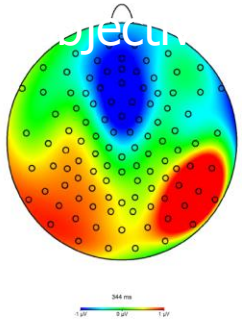




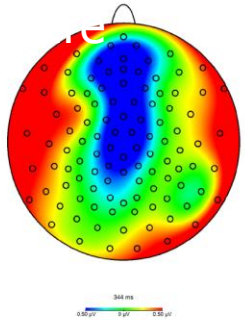
MMN GA Normal Hearing



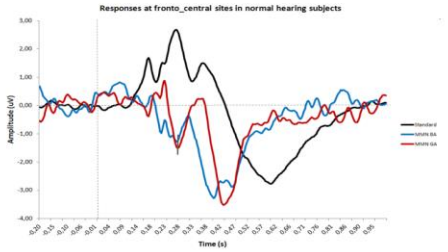
MMN BA Normal Hearing

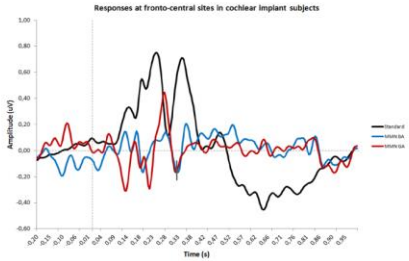


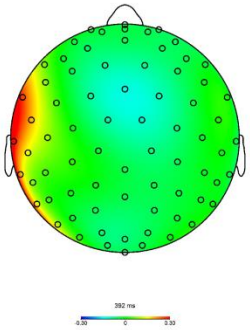
MMN BA Cochlear Implants



MMN GA Cochlear Implants

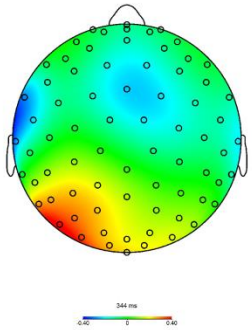




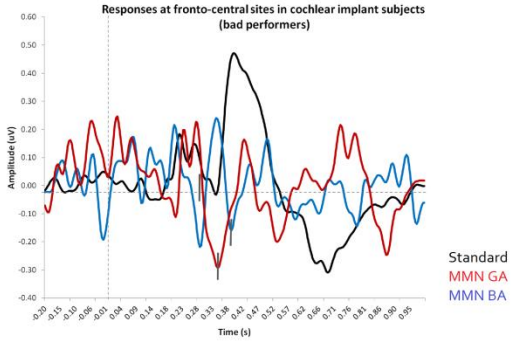


MMN BA Cochlear Implants

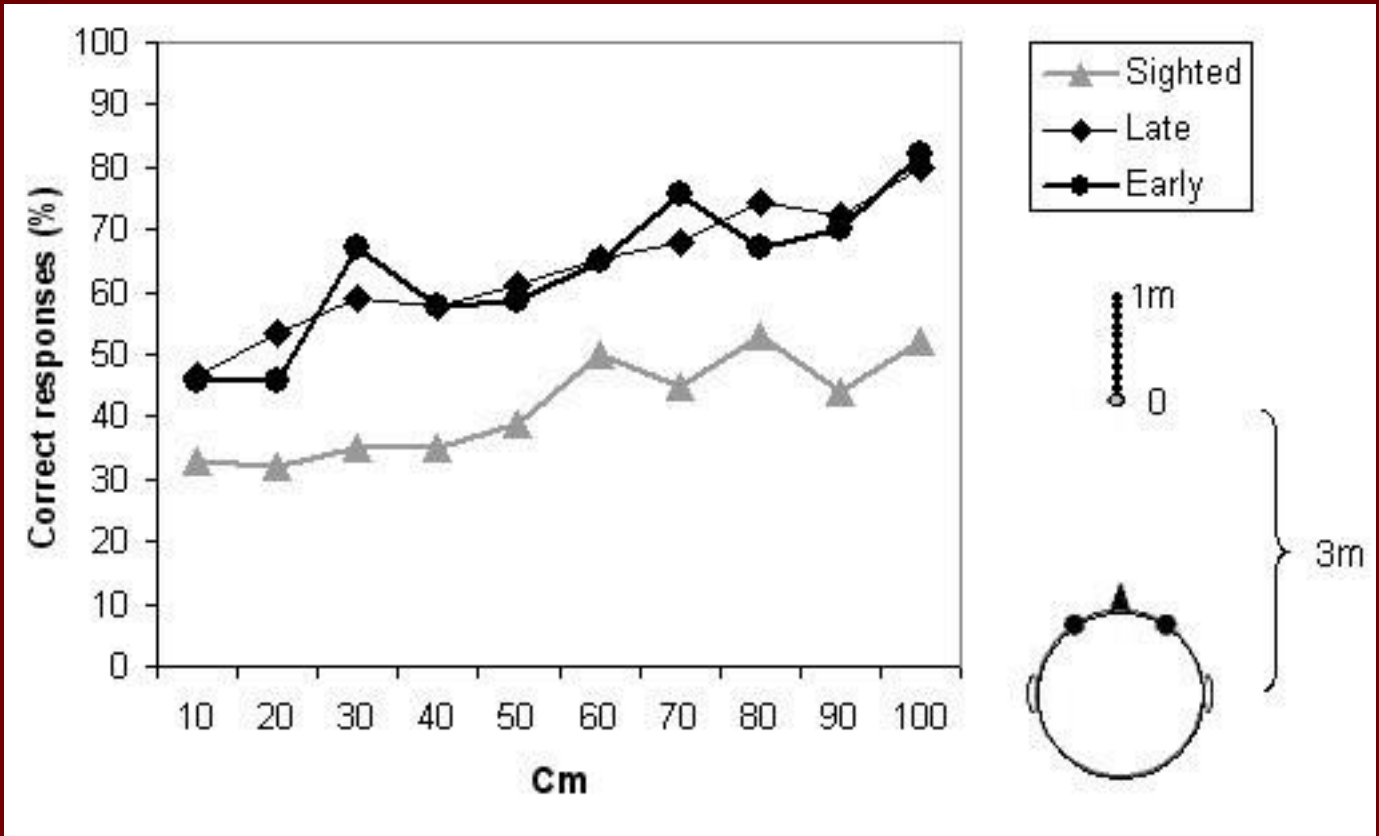
Bad performers



MMN GA Cochlear Implants

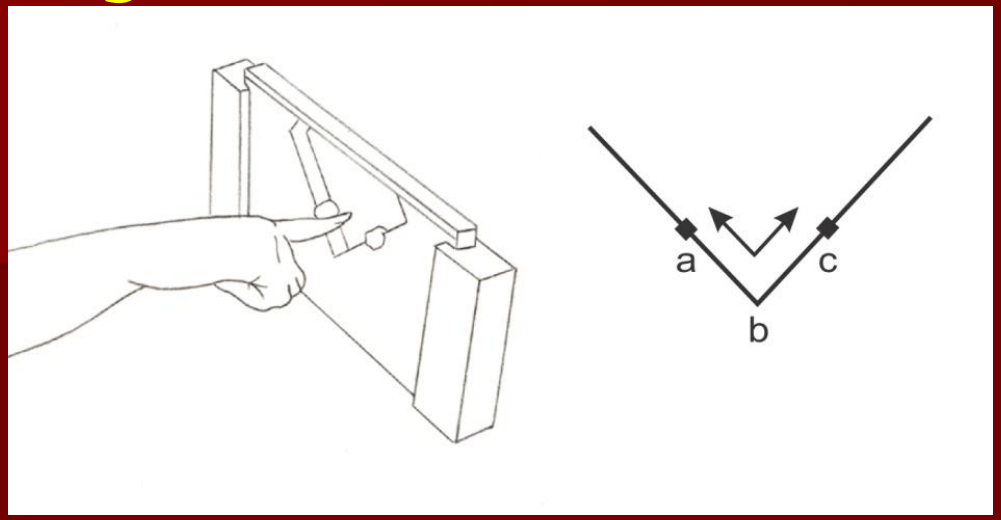


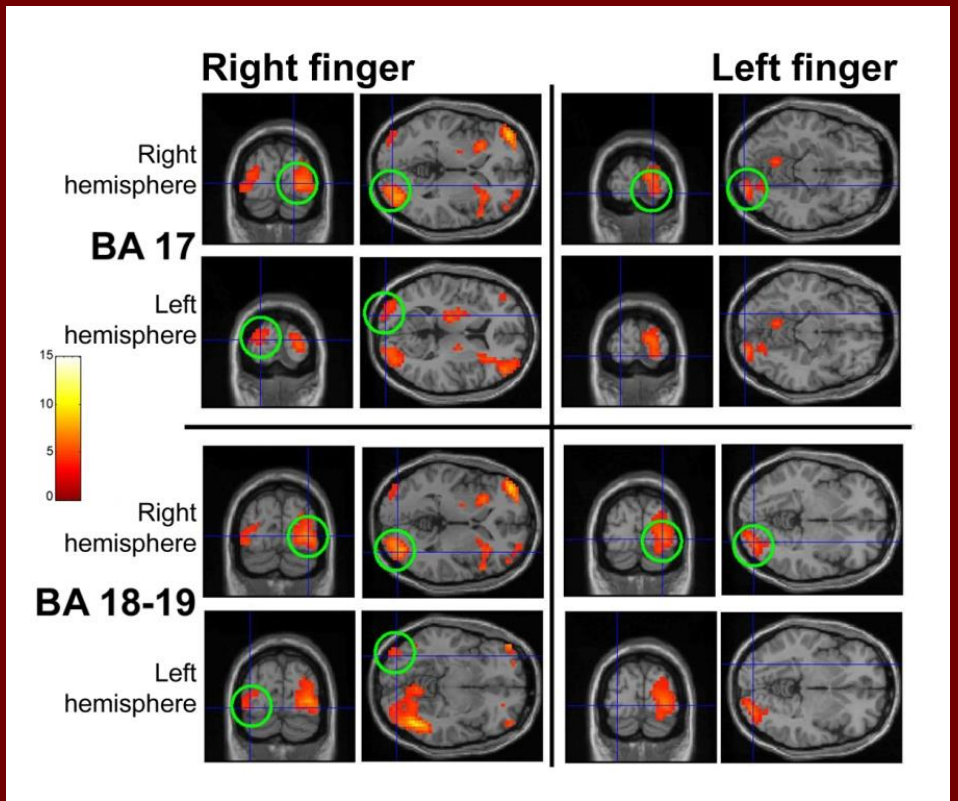
Sound discrimination in far space

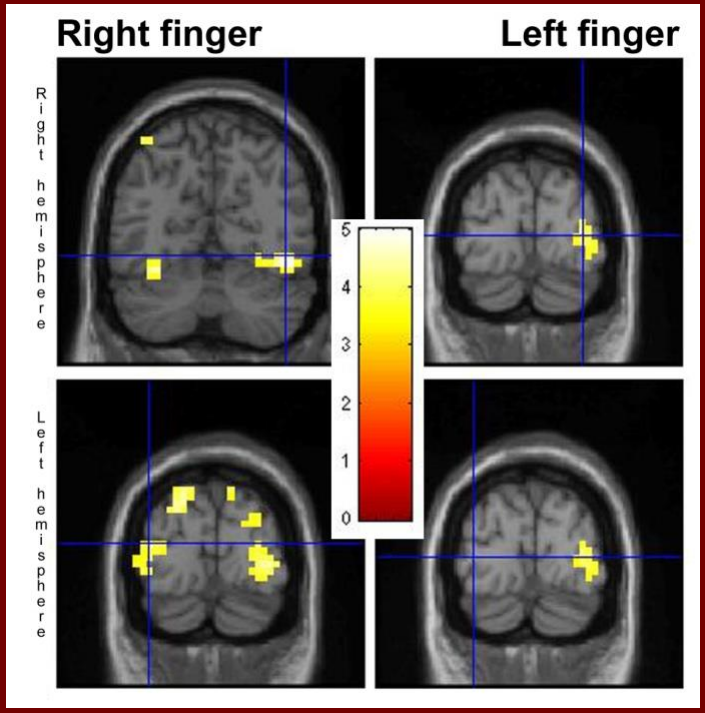


Voss, Lassonde, Gougoux, Fortin, Guillemot, Lepore (2004) Current Biology

Tactile : angle discrimination in the blind



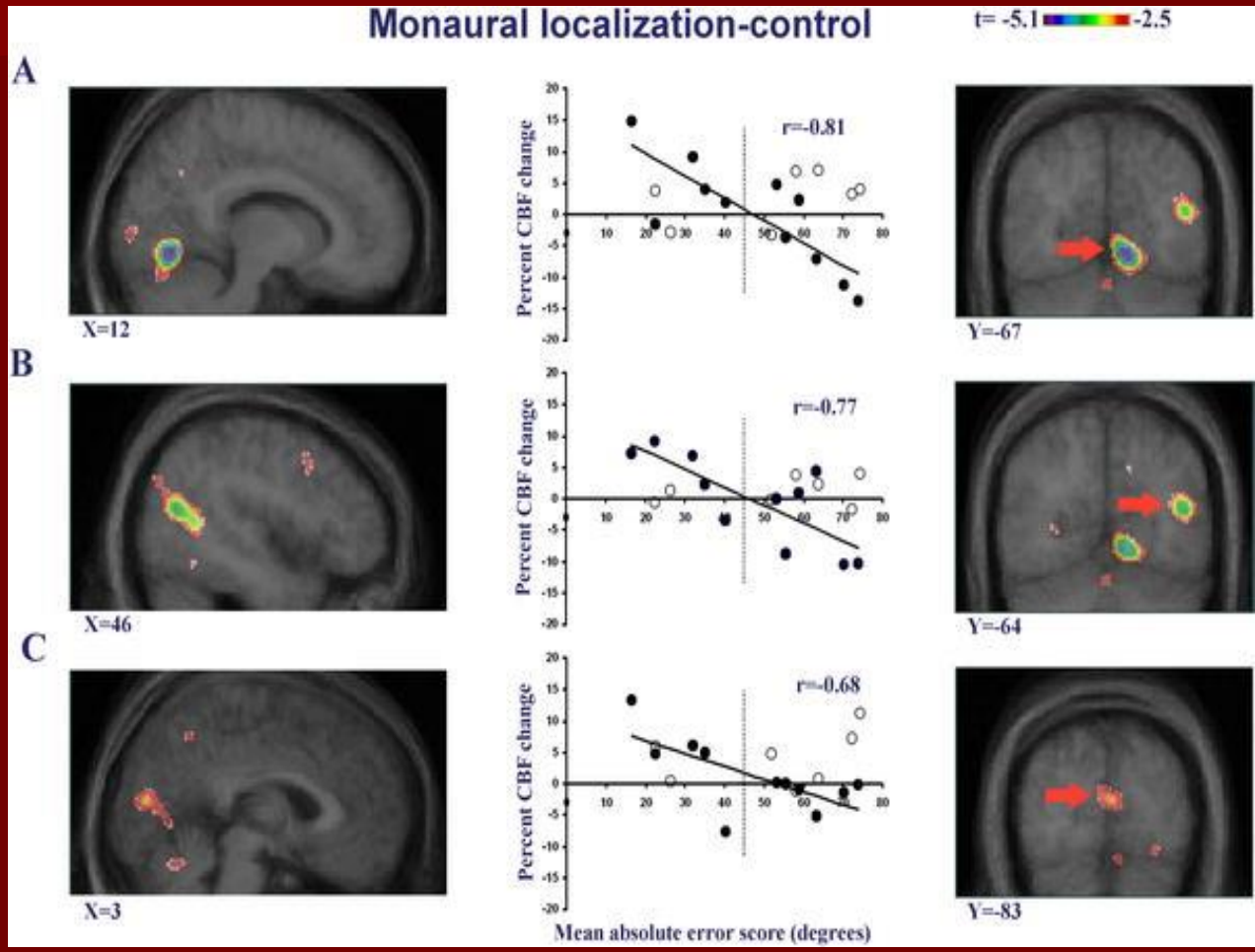




Monaural localization and PET

A strong activation was observed in different regions of visual cortex in the blind individuals

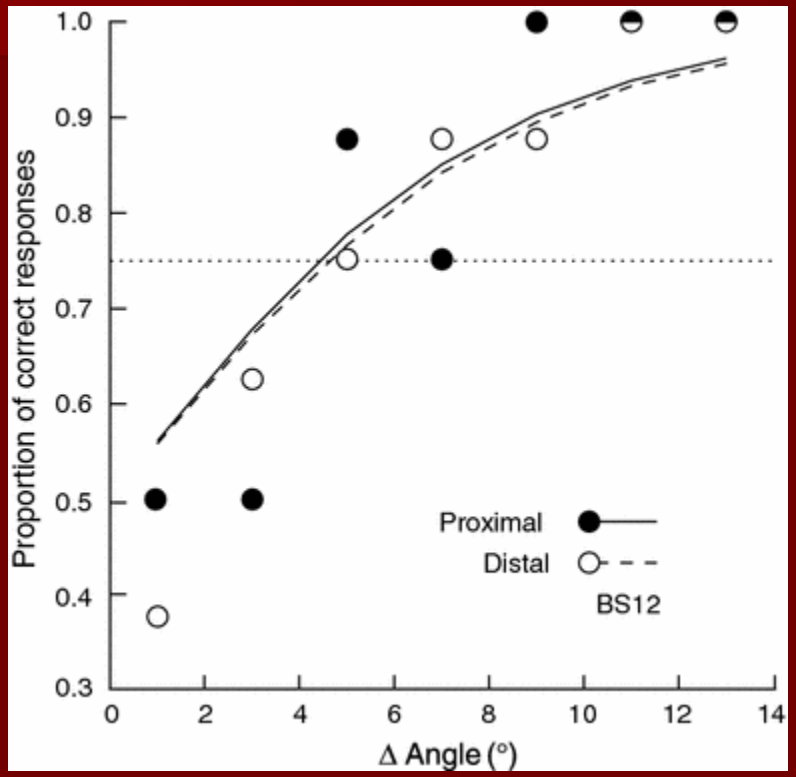
But more importantly, there was a correlation between degree of activation and localization performance

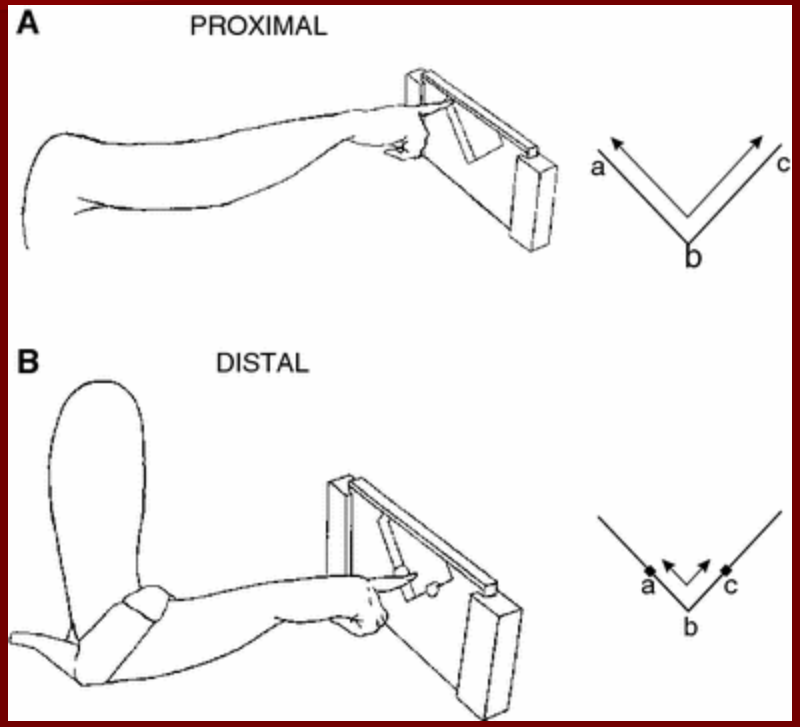


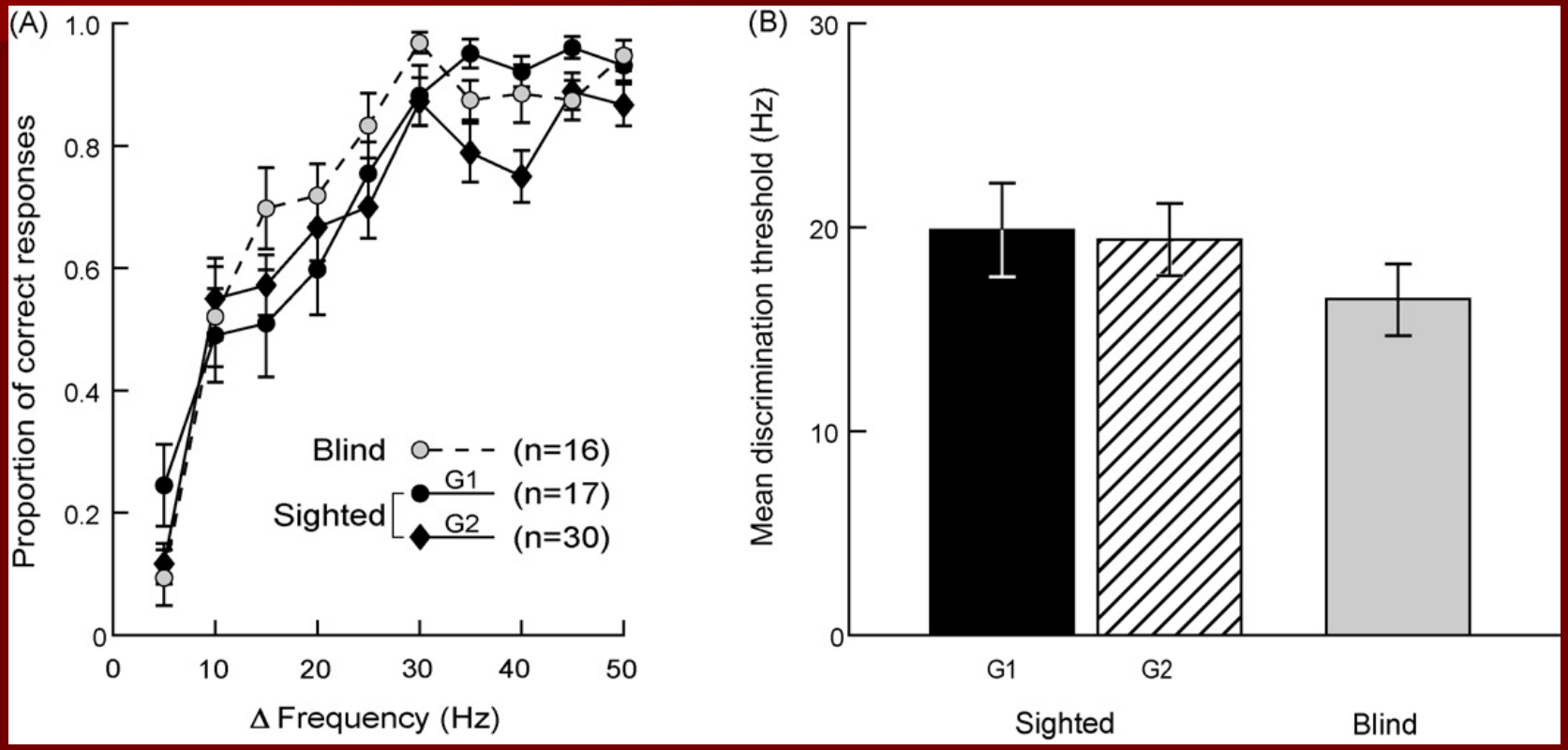
Gougoux, Zatorre, Lassonde, Voss, Lepore, (2005) PLoS Biology

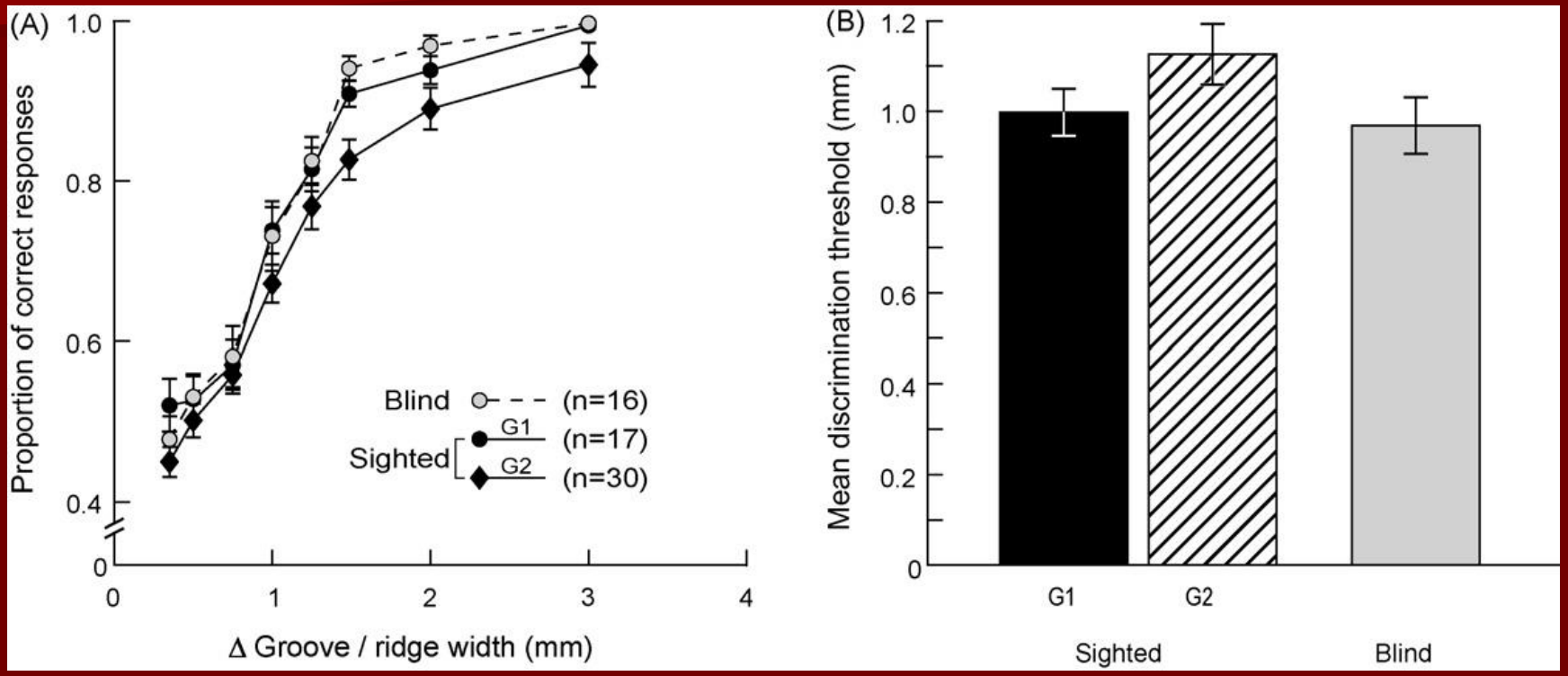
- 1800 1600 1400 1200 1000 800 600 400 200 0
- *
- **Temps de réaction**
- Congénitaux Tardifs Contrôles
- Détection
- Identification
- Localisation

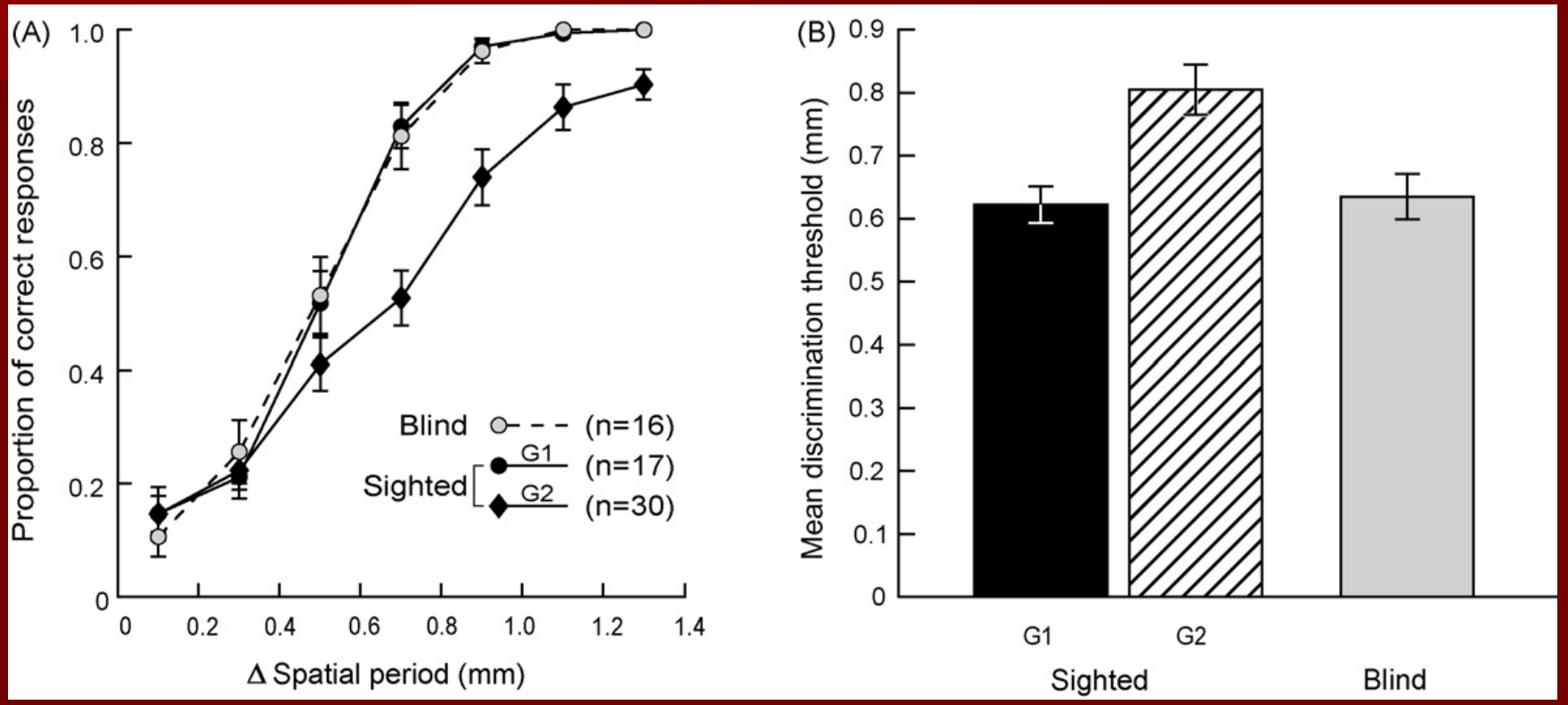
18001600140012001000 800 600 400 2000***Temps de réactionCongénitaux Tardifs**
ContrôlesDétection**Identification**Localisation**


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Proportion of correct responses
0
2
4
6
8
10
12
14
Δ Angle (°)
Proximal
Distal
BS12

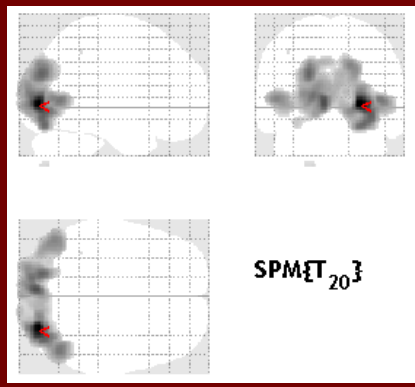

A
PROXIMAL
a
b
c
B
DISTAL
a
b
c


(A)
Proportion of correct responses
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
Δ Frequency (Hz)
Blind (n=16)
Sighted
G1 (n=17)
G2 (n=30)
(B)
Mean discrimination threshold (Hz)
30
20
10
0
G1
G2
Sighted
Blind

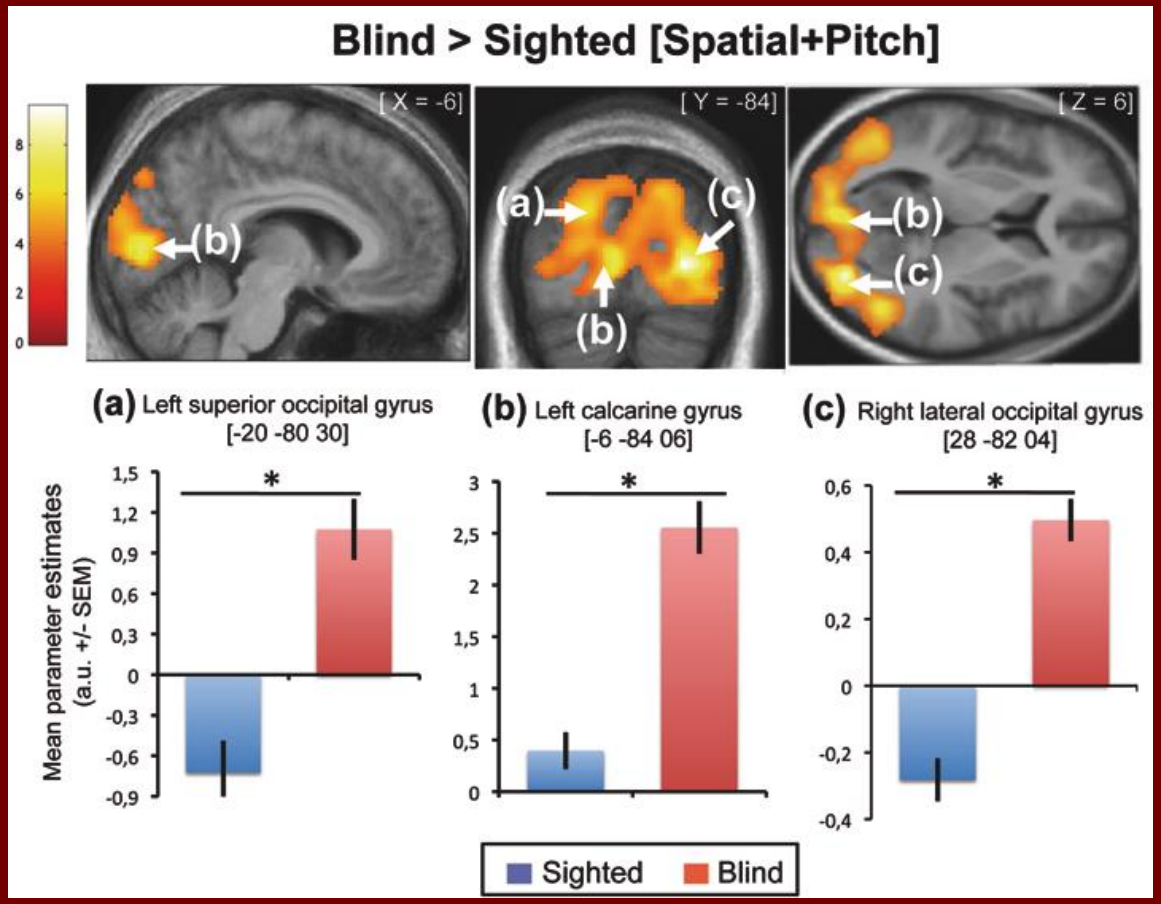

(A)
Proportion of correct responses
1.0
0.8
0.6
0.4
0
0
1
2
3
4
Δ Groove / ridge width (mm)
Blind
(n=16)
Sighted
G1
(n=17)
G2
(n=30)
(B)
Mean discrimination threshold (mm)
1.2
1.0
0.8
0.6
0.4
0.2
0
G1
G2
Sighted
Blind

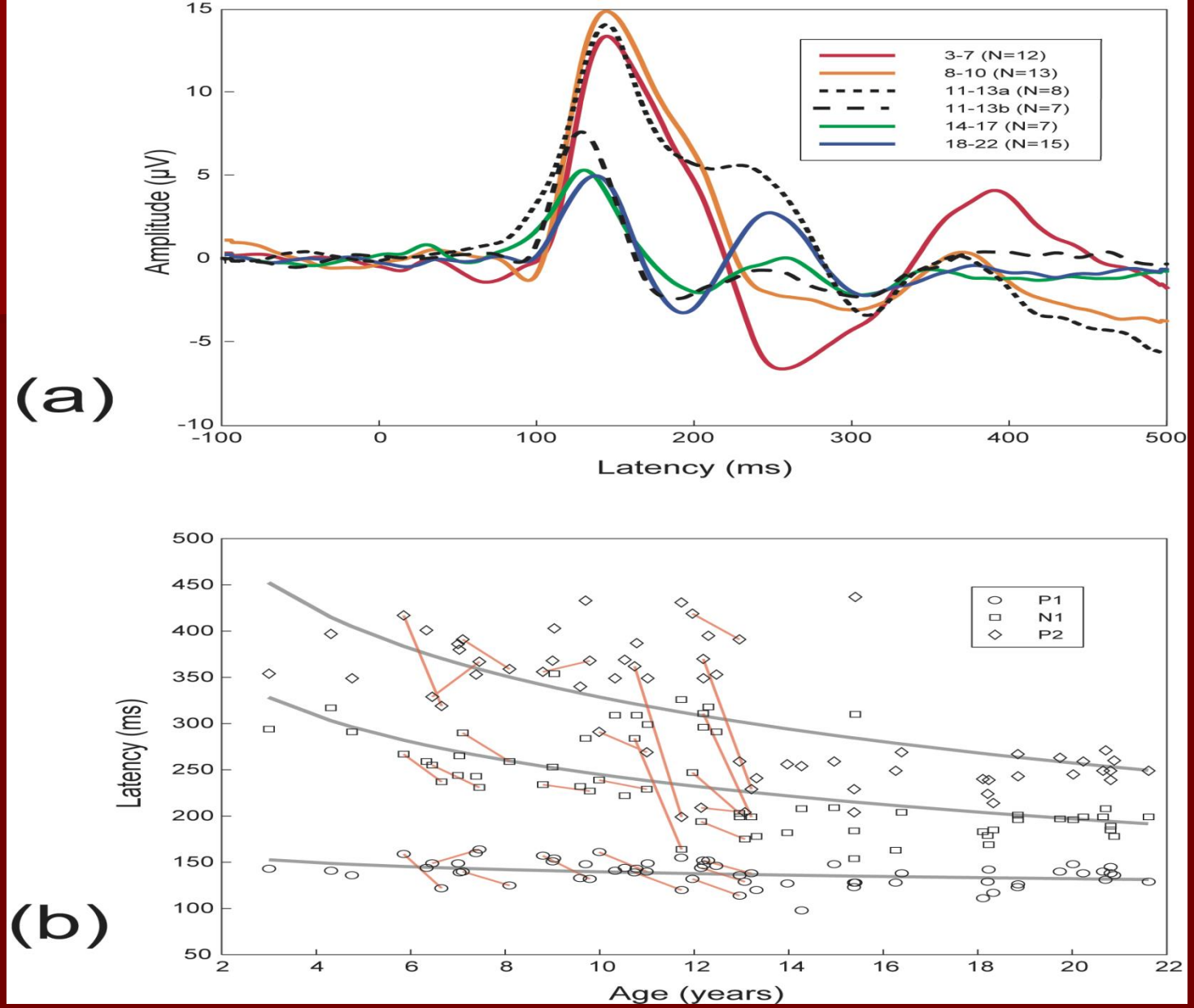

(A)
Proportion of correct responses
Δ Spatial period (mm)
Blind (n=16)
Sighted G1 (n=17)
G2 (n=30)
(B)
Mean discrimination threshold (mm)
G1
G2
Sighted
Blind

Glass brain



Blind > Sighted [Spatial+Pitch] :

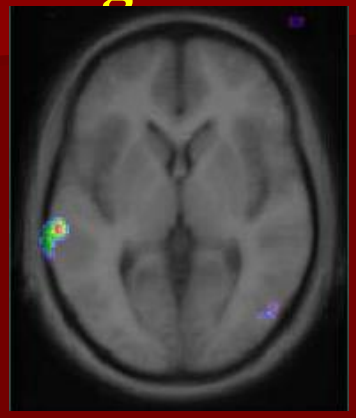


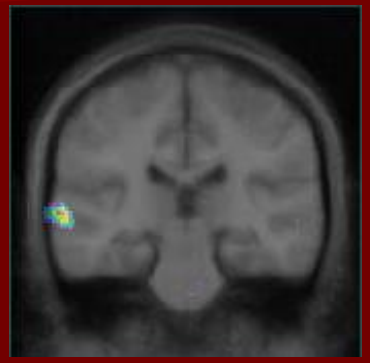


Doucet, Lassond, Lepore et al 2005, NeuroReport

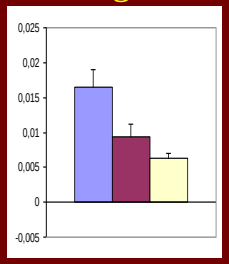
Vocal versus non-vocal
Inter-group contrasts

congenital vs acquired



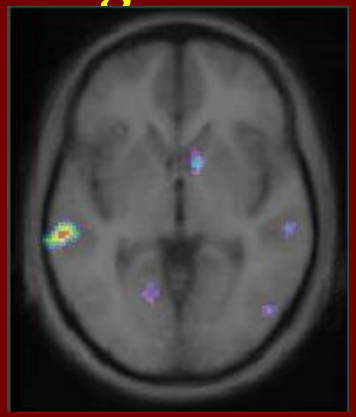


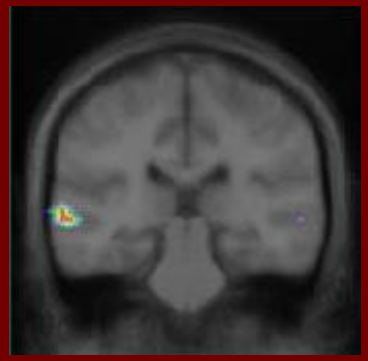
congenitally blind
acquired blind
sighted

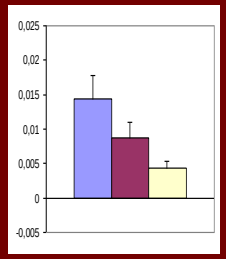


y=-28

congenital vs sighted



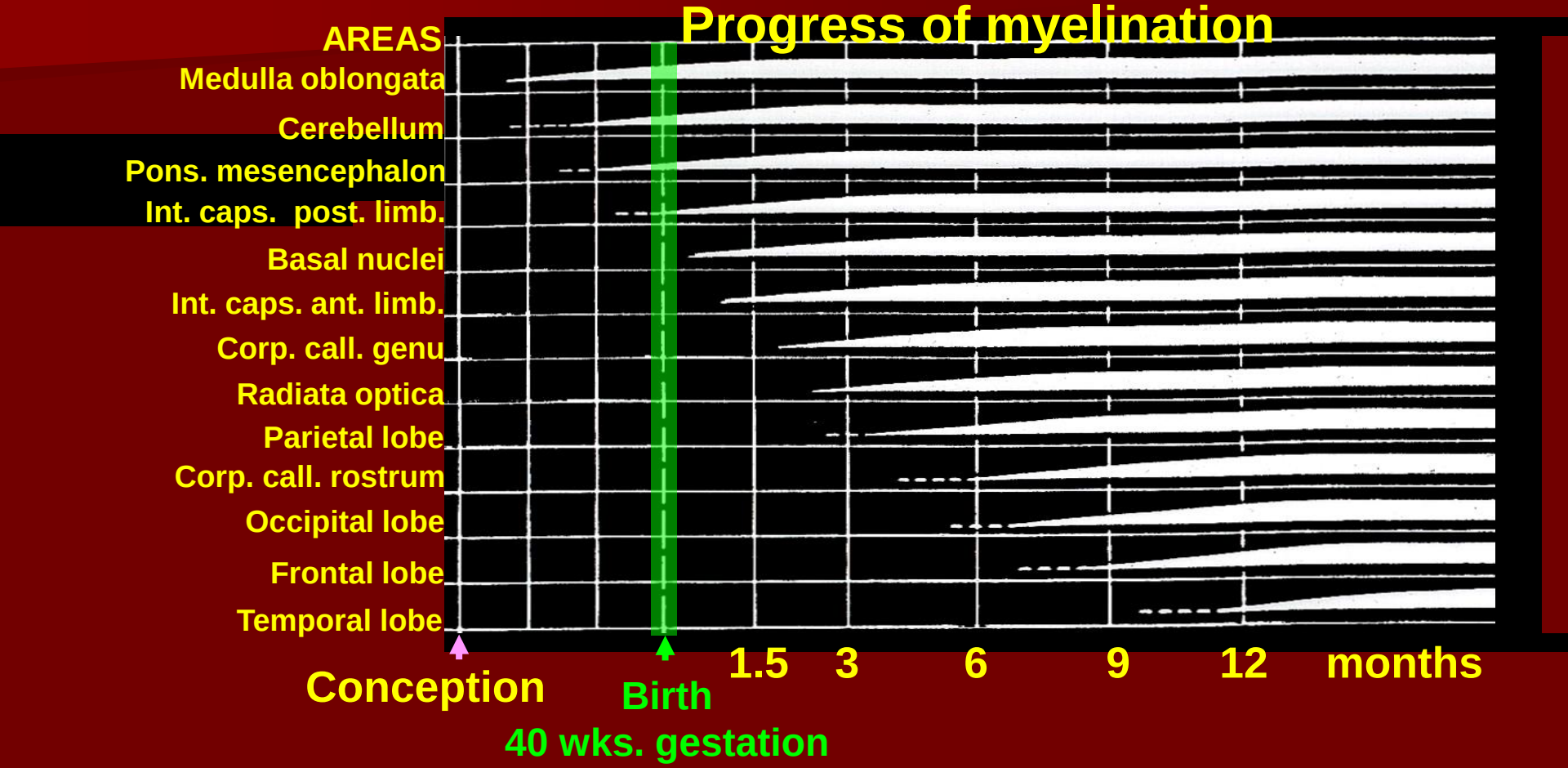


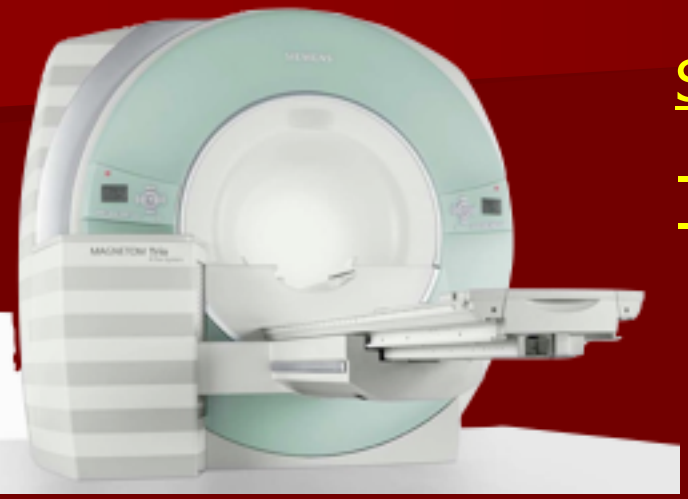


y=-30

Gougoux, Lassonde, Zatorre, Voss, Belin, Lepore (Neuropsychologia, 2009)

Myelinisation

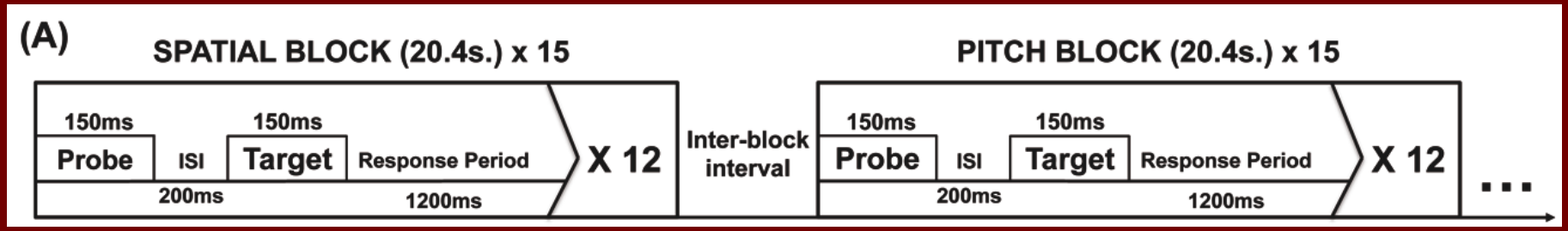


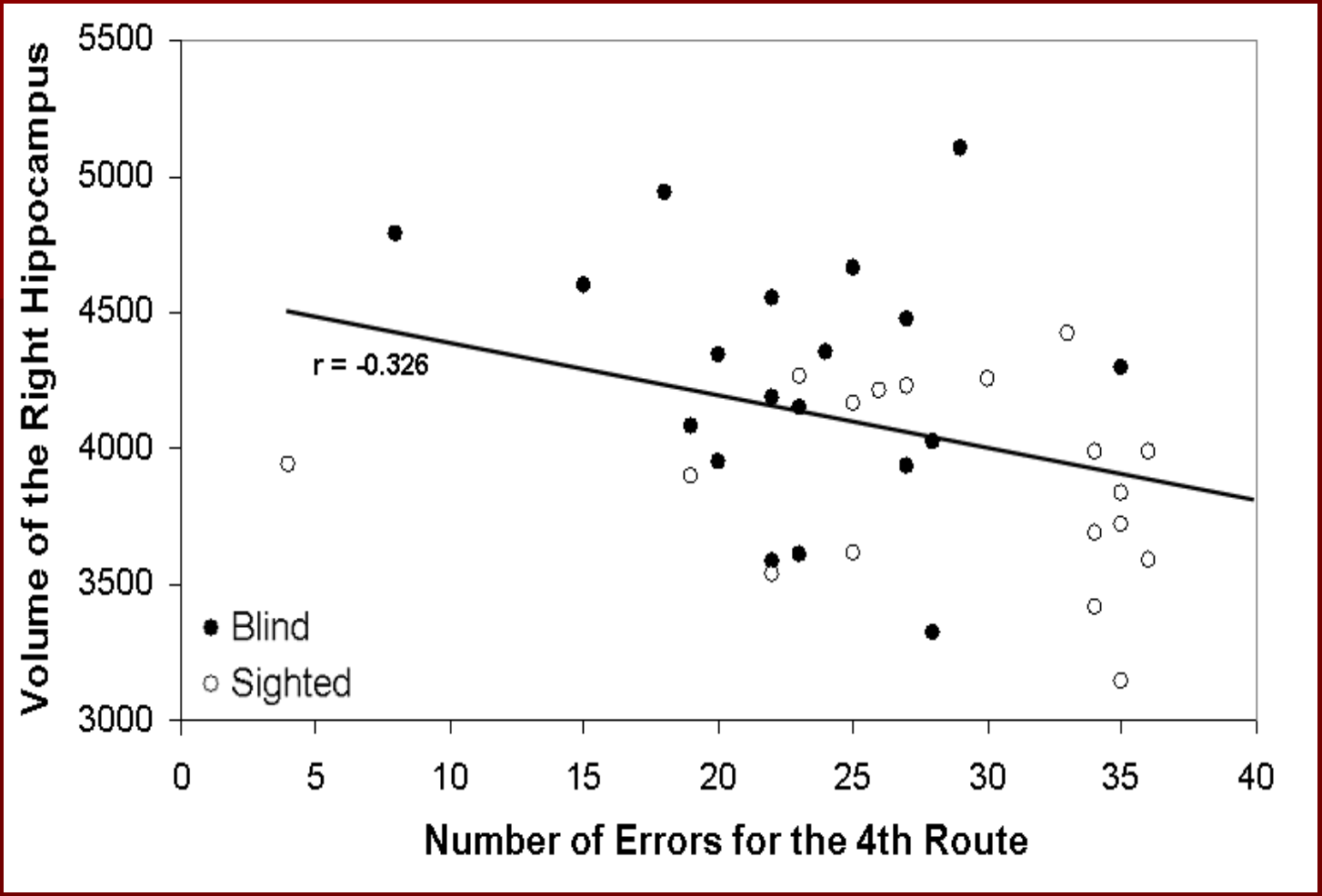


Sample :

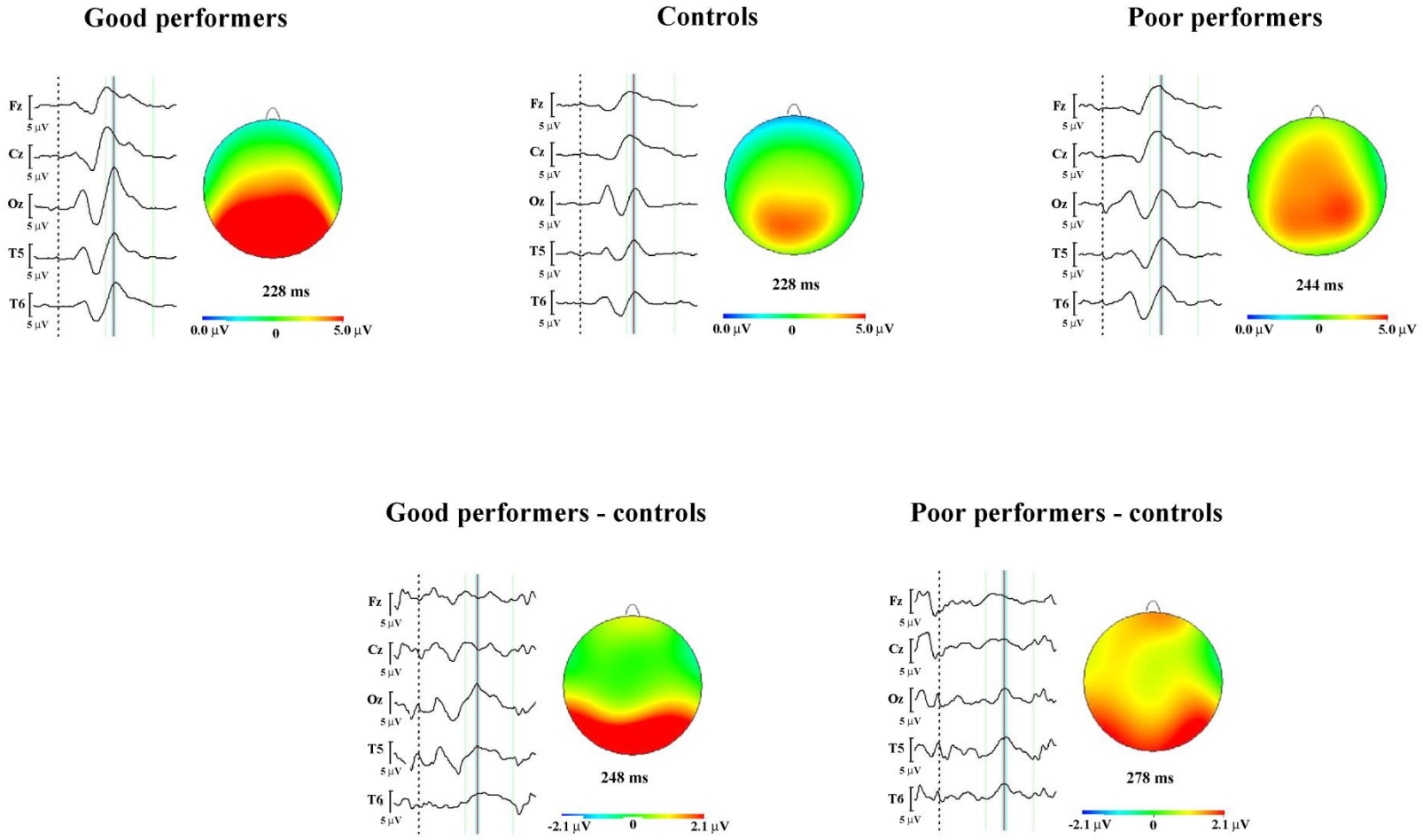
- 11 congenitally blind participants
- 11 matched blindfolded sighted controls

functional Magnetic Resonance Imaging (fMRI) [3T Trio-TIM (Siemens)]



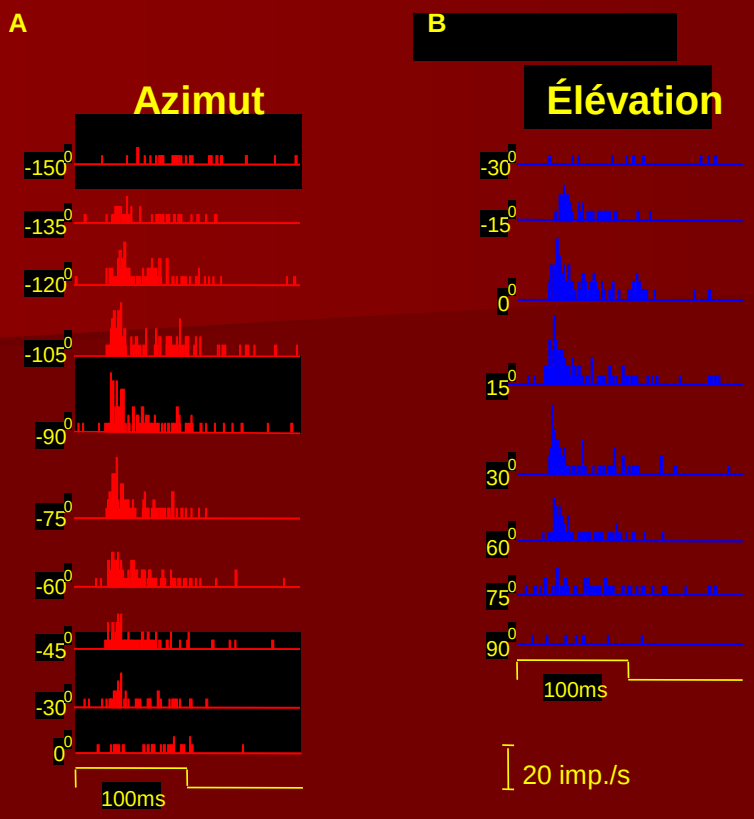


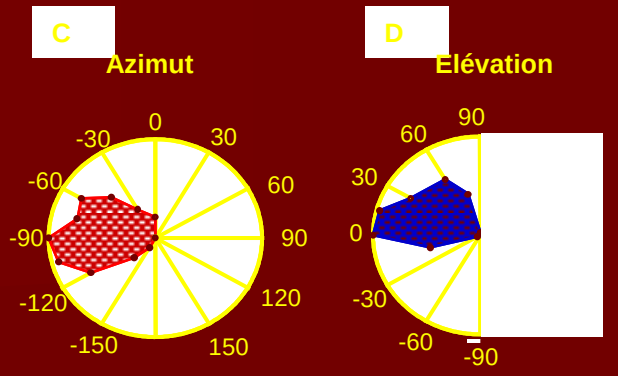
Fortin, Voss, Lassonde, Belin, Zatorre, Lepore, 2008, Brain

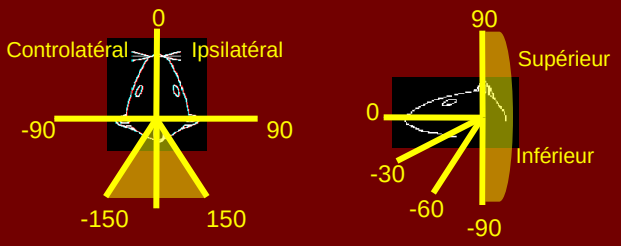


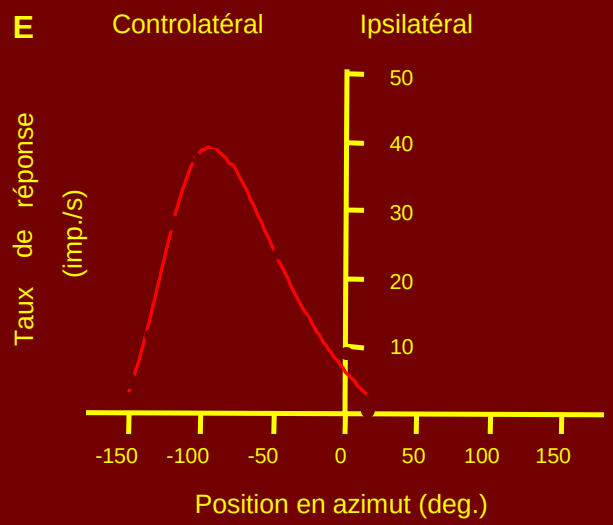
Visual evoked potentials to the presentation of the transformational apparent motion stimulus for good performing and badly performing subjects

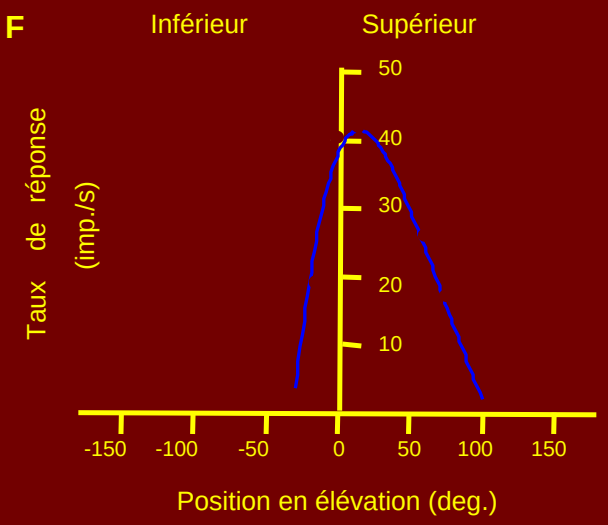
Doucet, Lassonde, Lepore et al, Brain, 2006


A
Azimut
-150°
-135°
-120°
-105°
-90°
-75°
-60°
-45°
-30°
0°
100ms
B
Élévation
-30°
-15°
0°
15°
30°
60°
75°
90°
100ms
20 imp./s

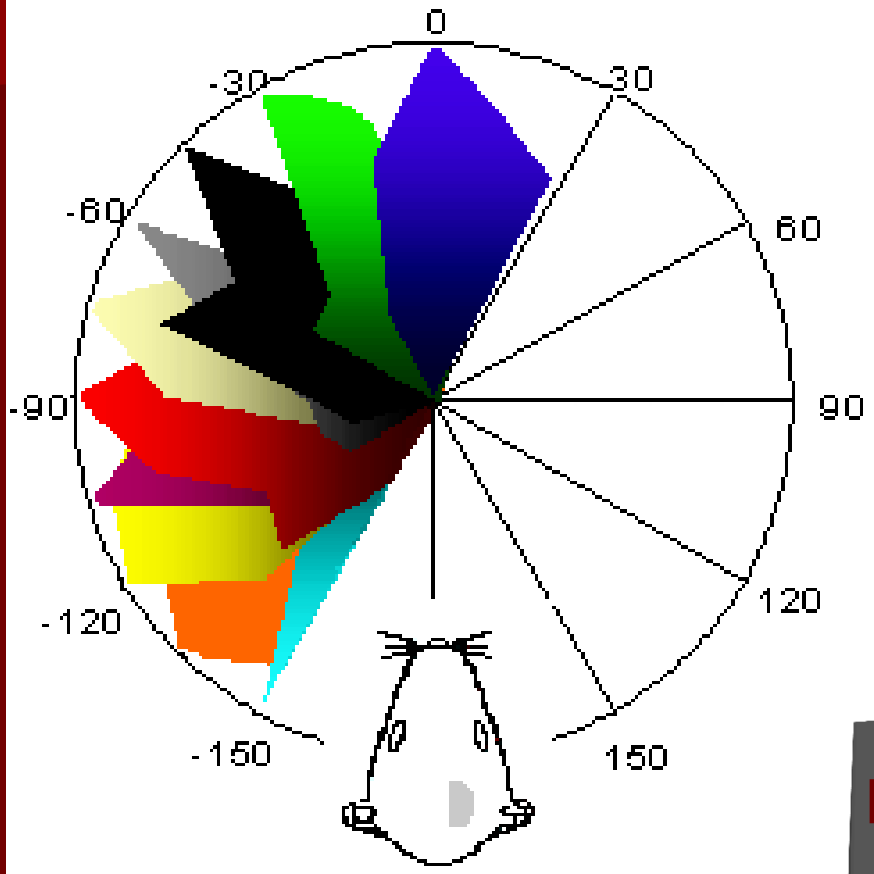

C
Azimut
0
30
60
90
120
150
-30
-60
-90
-120
-150
D
Élévation
90
60
30
0
-30
-60
-90


Controlatéral
Ipsilatéral
0
-90
90
-150
150
90
Supérieur
0
Inférieur
-30
-60
-90

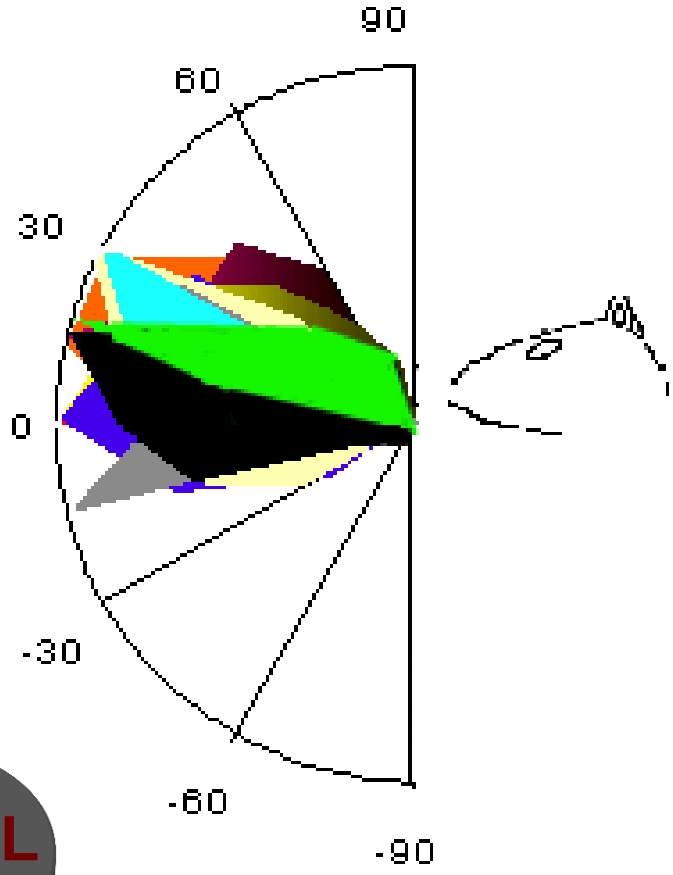

E
Controlatéral
Ipsilatéral
Taux de réponse (imp./s)
50
40
30
20
10
-150
-100
-50
0
50
100
150
Position en azimut (deg.)

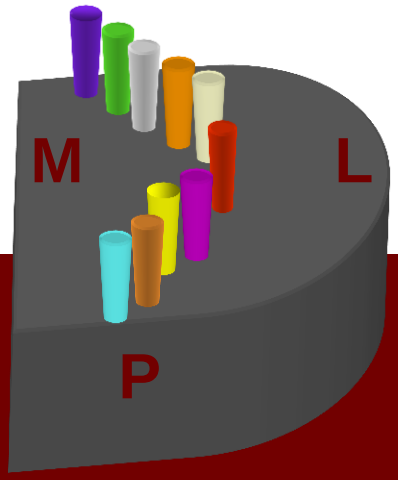

F
Inférieur
Supérieur
Taux de réponse (imp./s)
50
40
30
20
10
-150
-100
-50
0
50
100
150
Position en élévation (deg.)

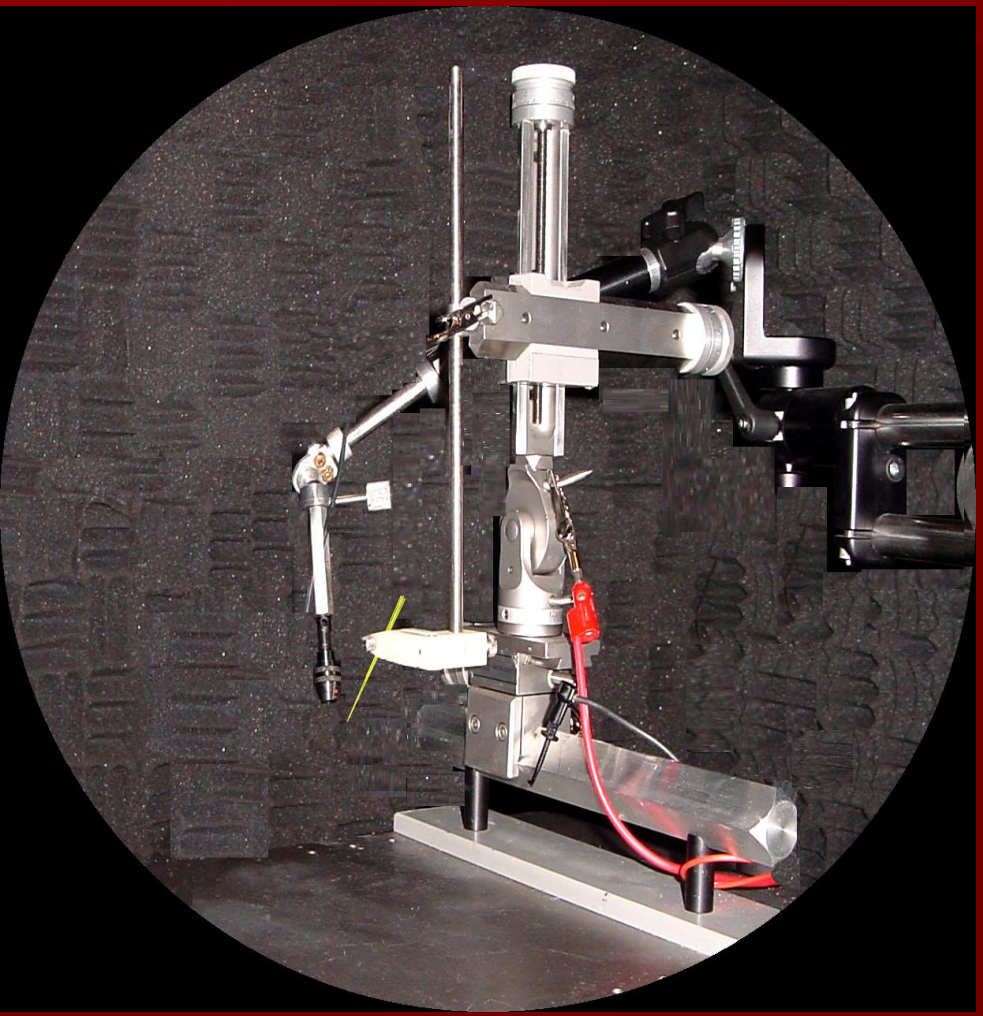
Azimut

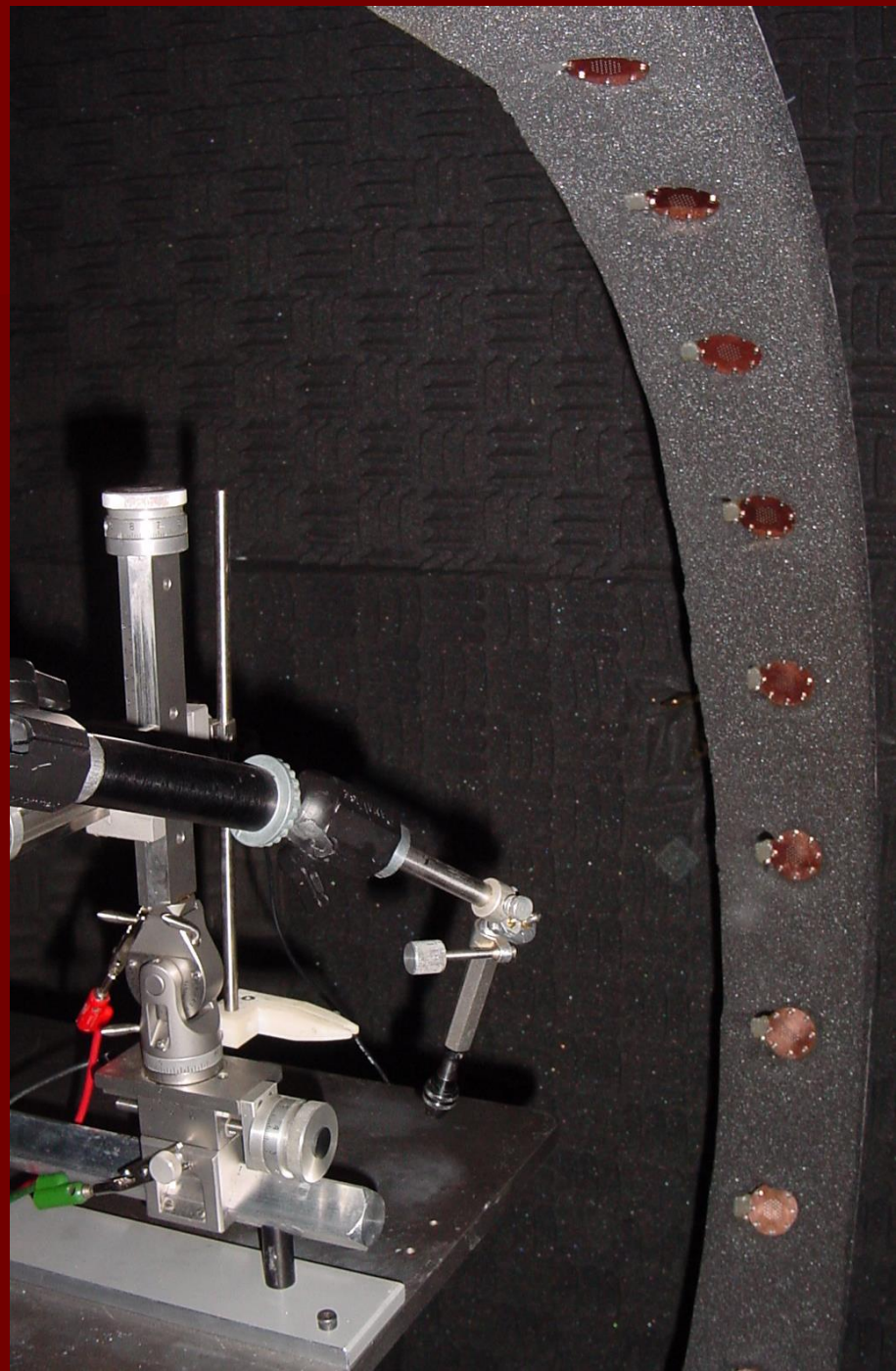


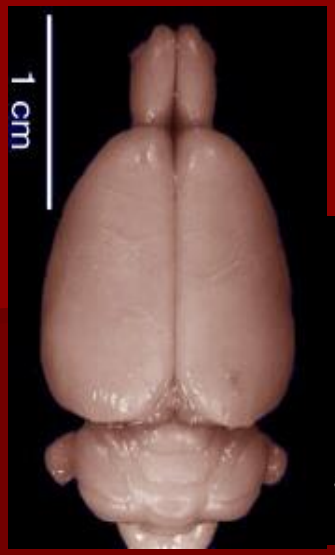
Elevation

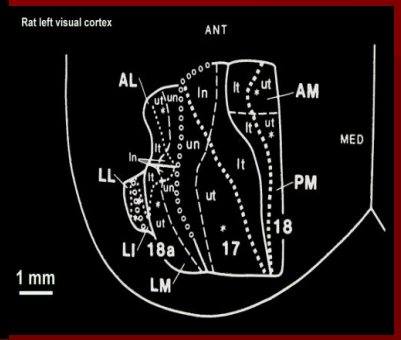




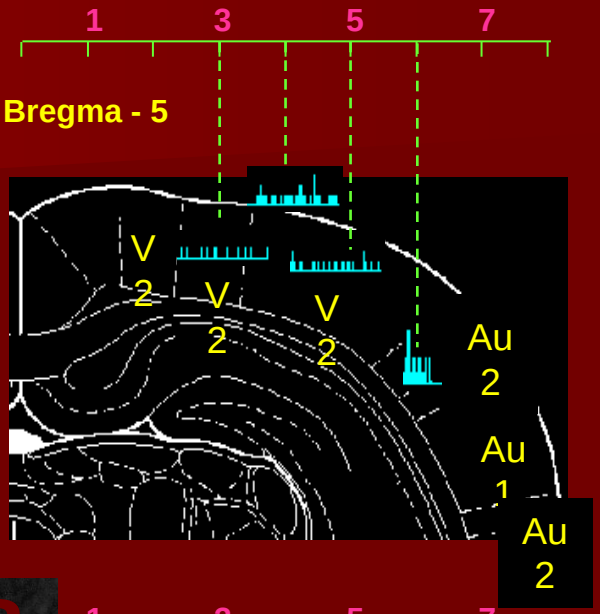


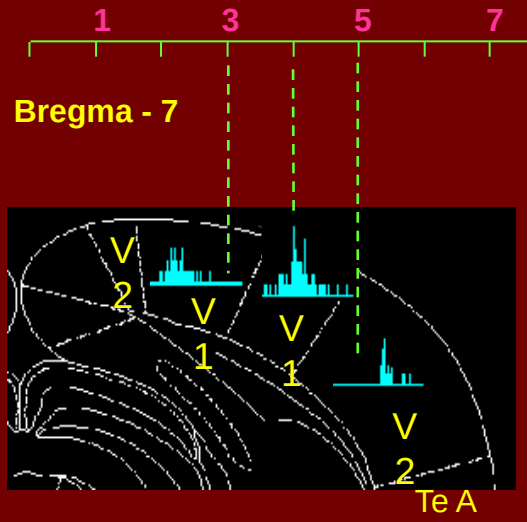


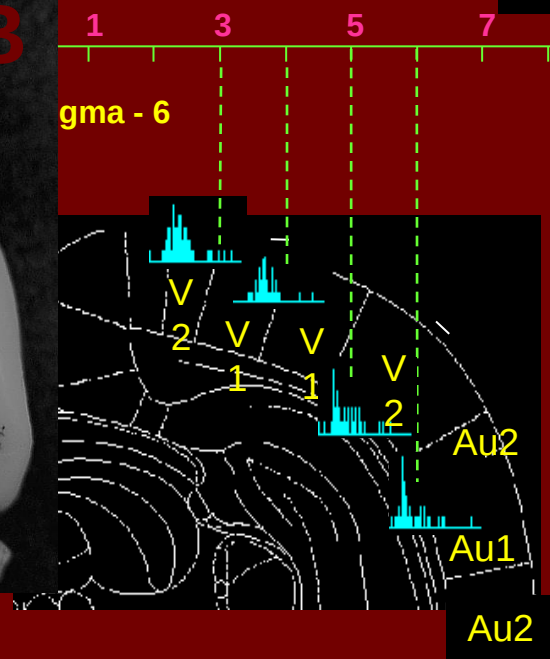


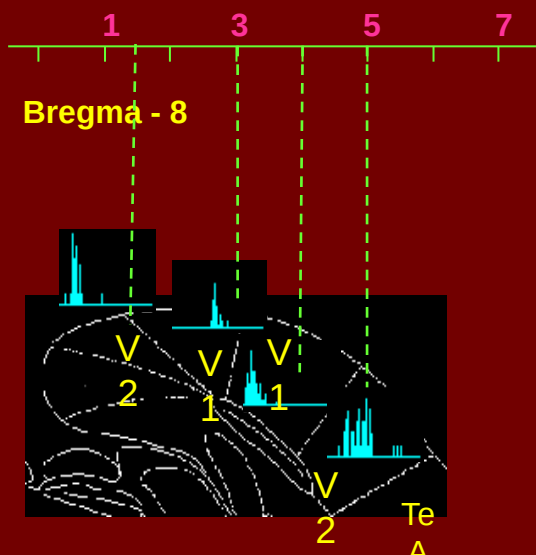


Blind **Normal**

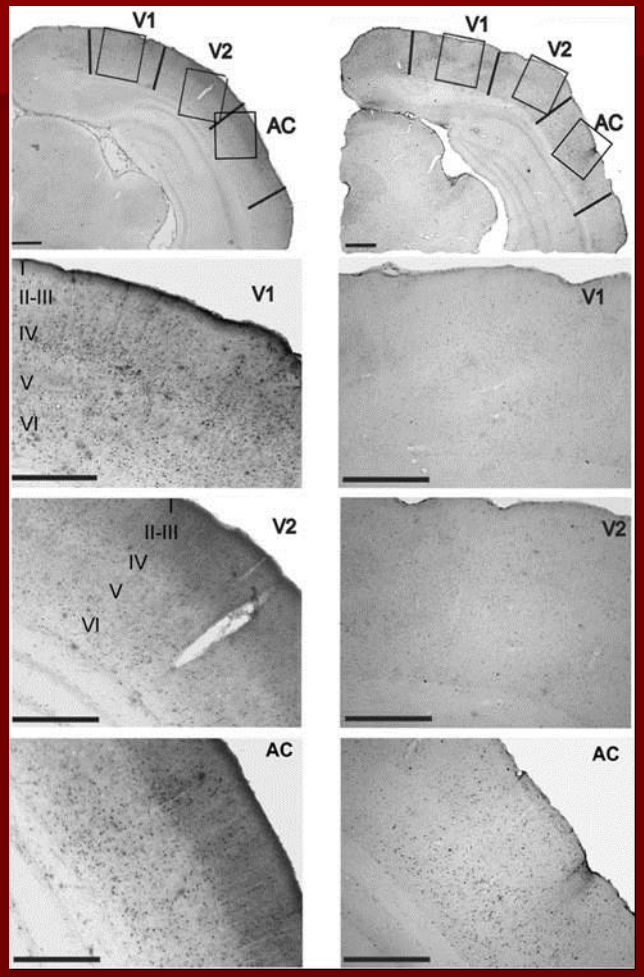


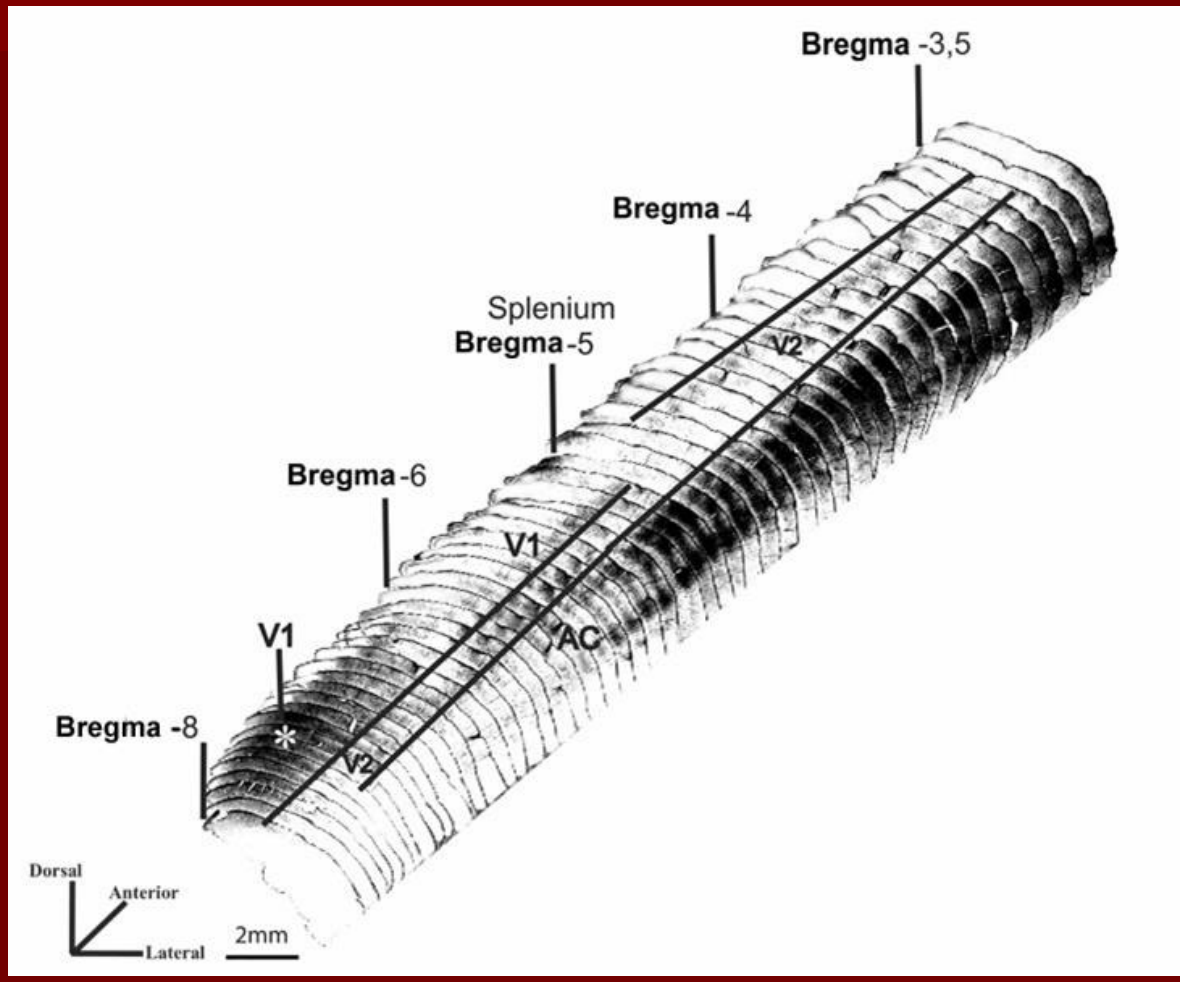


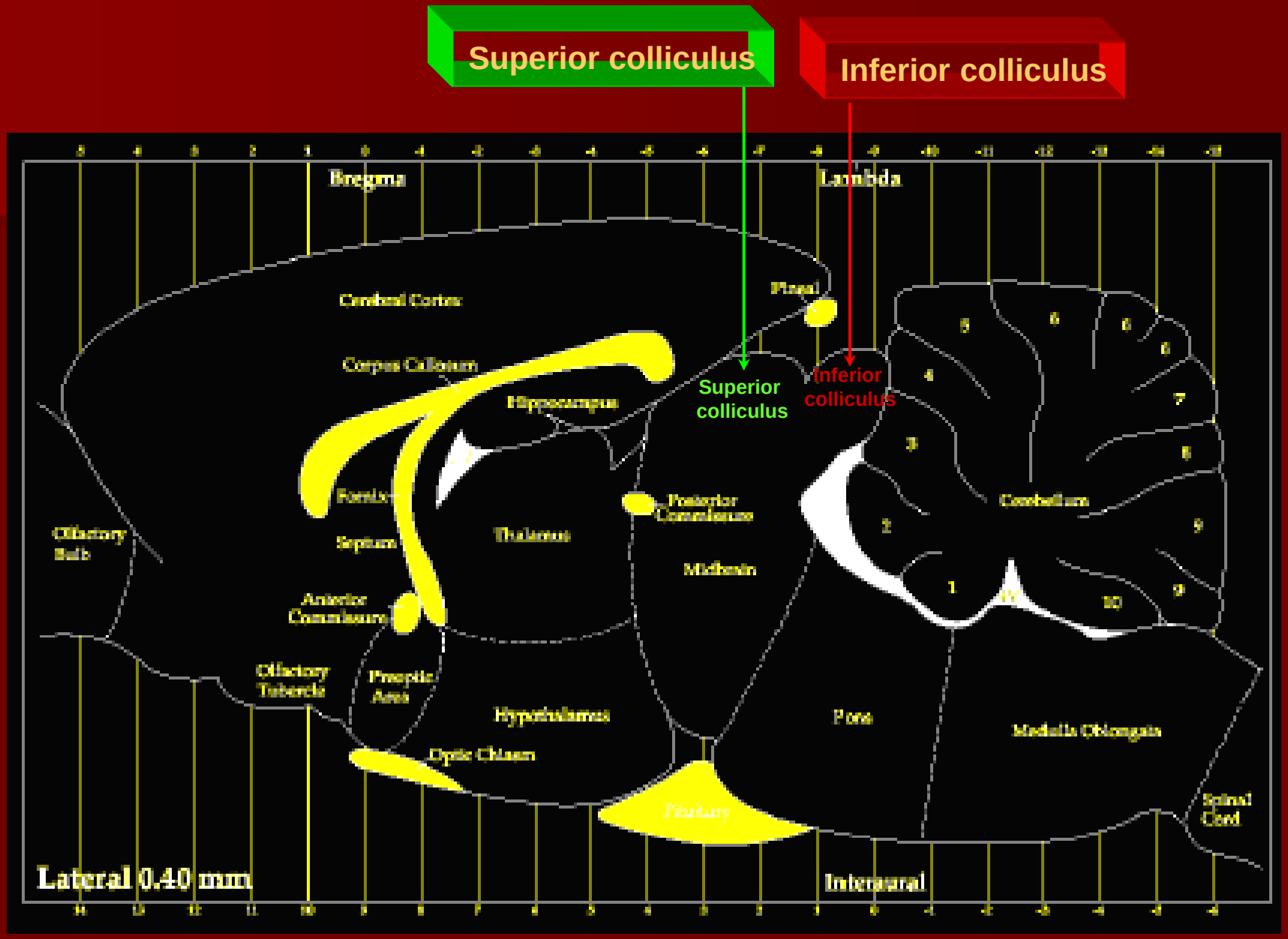




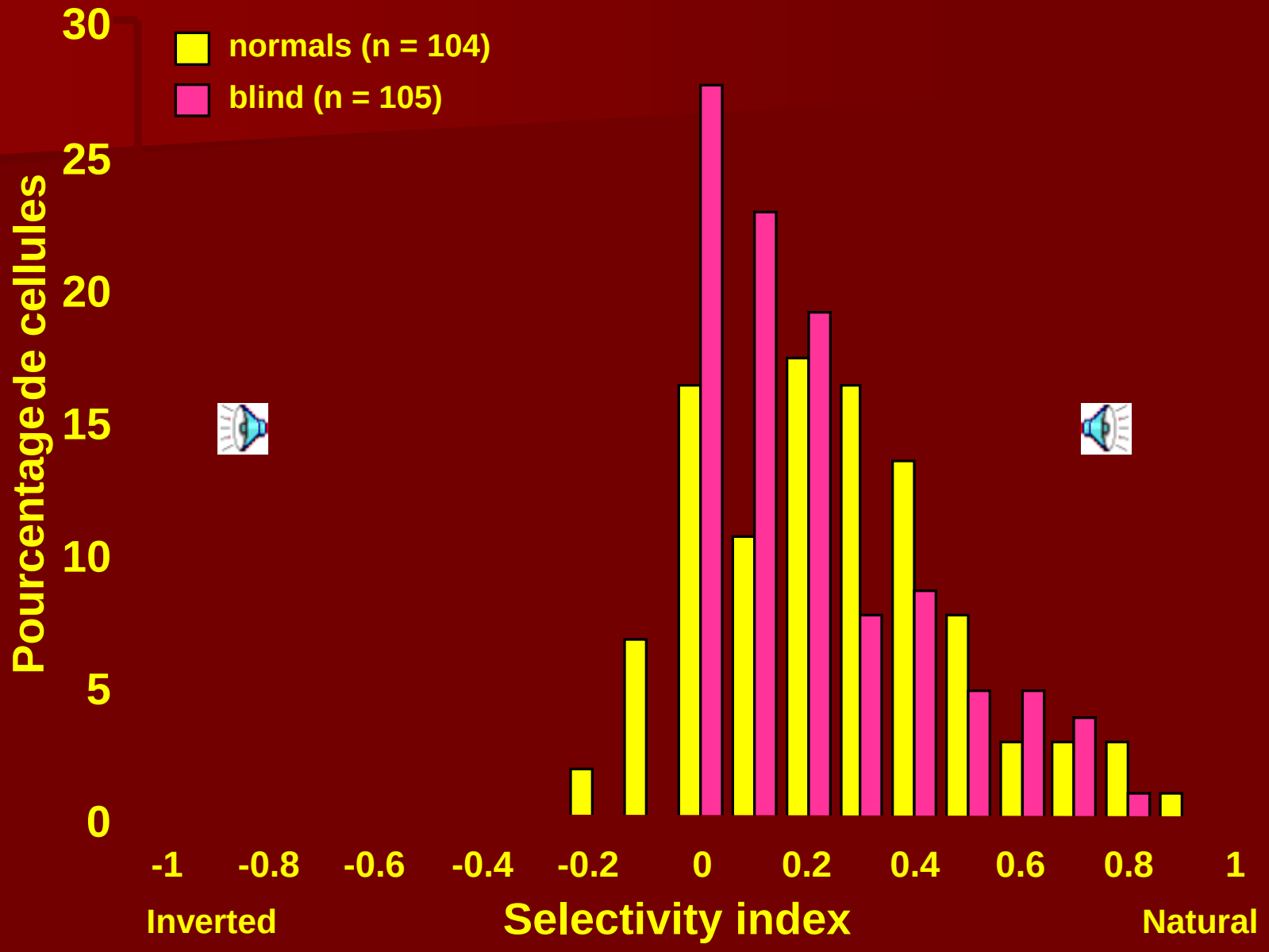
C-Fos Immunohistochemistry






Superior colliculus
Inferior colliculus
Bregma
Lambda
Cerebral Cortex
Corpus Callosum
Hippocampus
Fornix
Septum
Thalamus
Olfactory Bulb
Anterior Commissure
Olfactory Tubercle
Preoptic Area
Hypothalamus
Optic Chiasm
Pituitary
Pineal
Posterior Commissure
Midbrain
Pons
Cerebellum
Medulla Oblongata
Spinal Cord
Lateral 0.40 mm
Interaural

Species specific vocalizations



The first question: is there cortical reorganisation in deaf individuals?