Predicting the Outcome of Cochlear Implantation:
Structural Constraints on Speech Functional Plasticity.

Laboratoire de Neurosciences Cognitives
Inserm U960

ETUDES Cognitives
Département d'Etudes Cognitives · Ecole normale supérieure

Paris, France
Anne-Lise Giraud
Diane Lazard

Lyon, France
Eric Truy

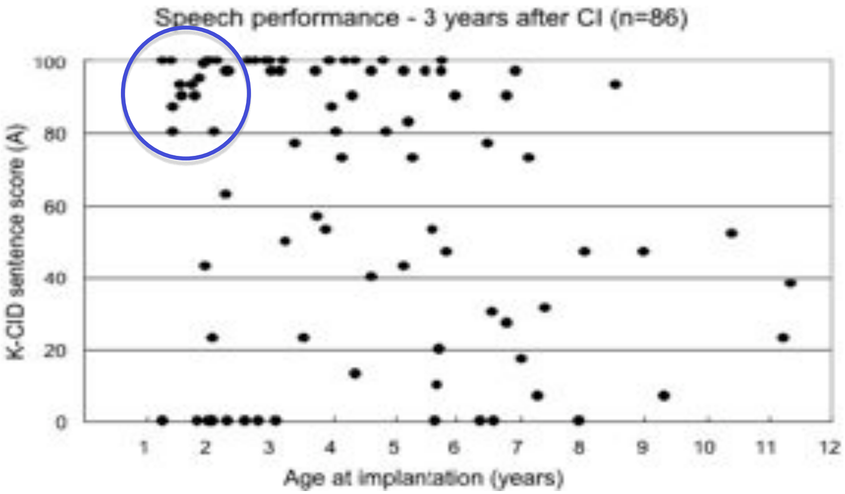
Seoul, South Corea
Hyo-Jeong Lee
Eunjoo Kang
Chong-Sun Kim

London, UK
Richard Frackowiak
John Graham
Cathy Price

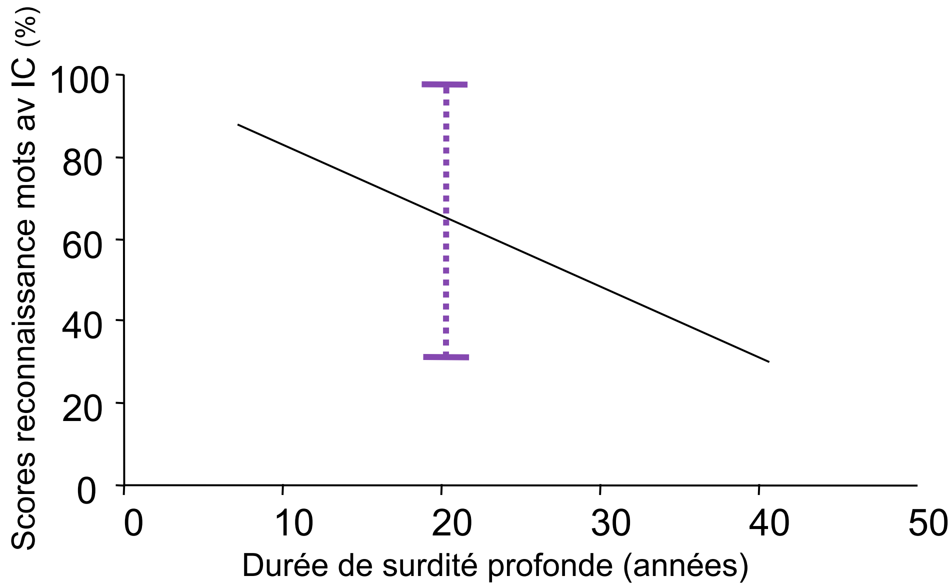
AIDAME-April 3rd 2009

Facteurs prédictifs connus de la performance post-implant

✓ Âge d'implantation chez enfant sourd congénital



✓ Durée de privation auditive chez sourd post lingual



Recherche de facteurs d'ordre neurofonctionnels

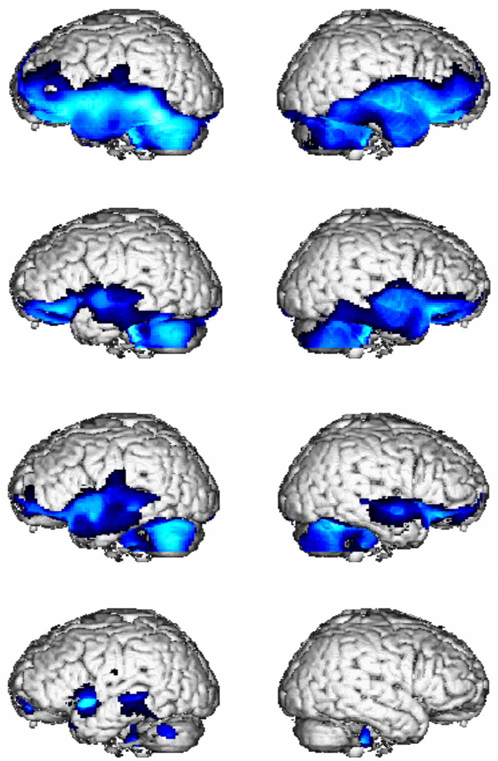
Giraud AL, Lee HJ. Restor Neurol Neurosci. 2007.
Blamey P, et al. Audiol Neurootol. 1996;

Crossmodal reorganisation and implantation outcome

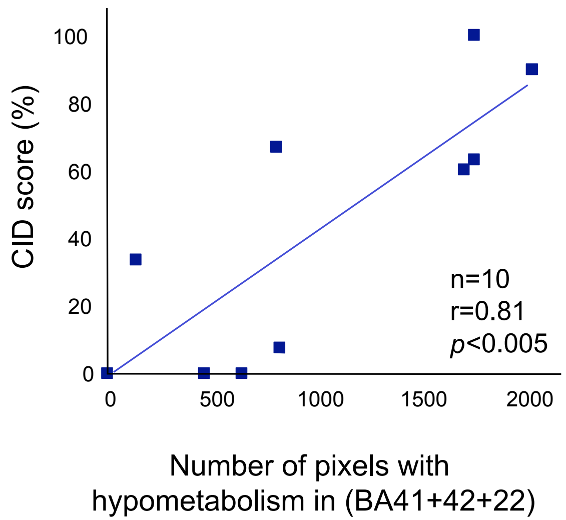
FDG-PET at rest before implantation and speech perception scores after CI.

Normal-hearing adults (n=12) > Prelingual deafs (n=10, age: 2.2 to 23.3)

Score in auditory sentence recognition (years of training)		**Deafness duration** = age at implantation
90 % (3.8 y)		**6.5 y**
67 % (1.1 y)		**6.5 y**
7 % (1.4 y)		**11.2 y**
0 % (1.9 y)		**20.3 y**



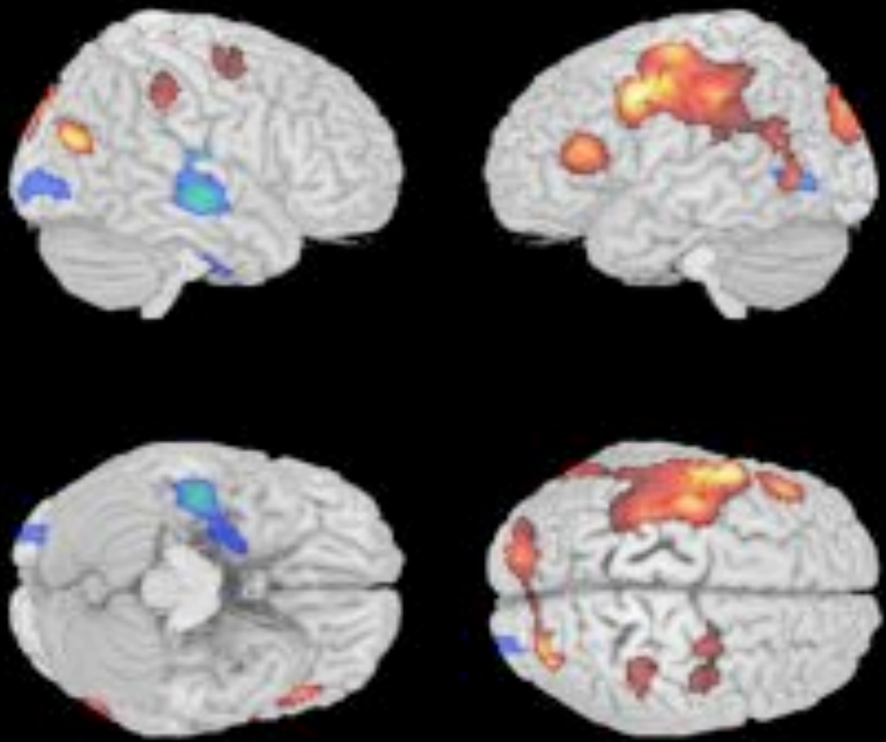
Extent of Hypometabolism in superior temporal gyrus

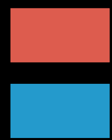


Lee DS et al., Nature, 2001

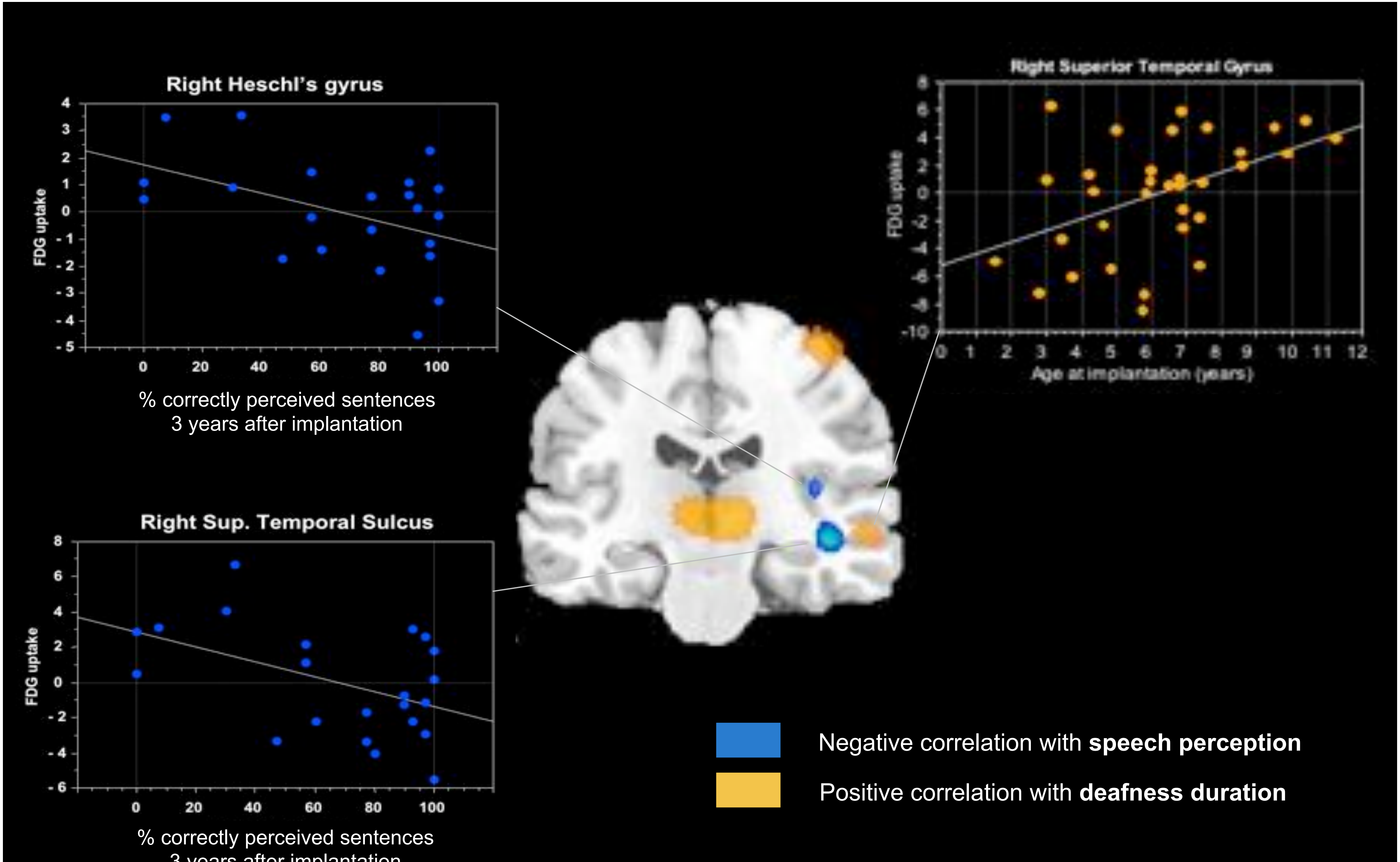
Neurometabolic profiles (FDG-PET): Correlation with speech comprehension measured 3 years after cochlear implantation, <u>irrespective of age at implantation</u> (deafness duration)

33 congenitally deaf children, age : 1.5 to 11 years





Lee HJ et al., Cerebral Cortex 2006

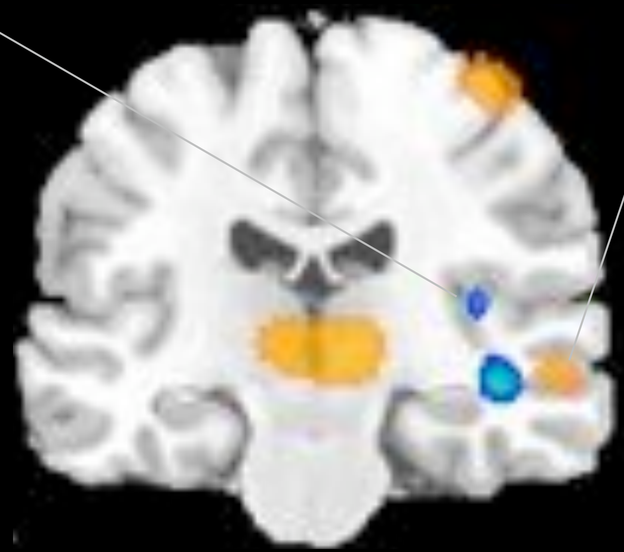


Lee HJ et al., Cerebral Cortex 2006

Auditory cortex (BA41/42):
plasticity that took place before birth

1- stabilized prenatal cross-modal plasticity,
hard (re-) wiring?
2- embryonic synaesthesia in some children,
which cannot regress due to auditory deprivation

In some children, auditory cortex is not strictly auditorily tagged.

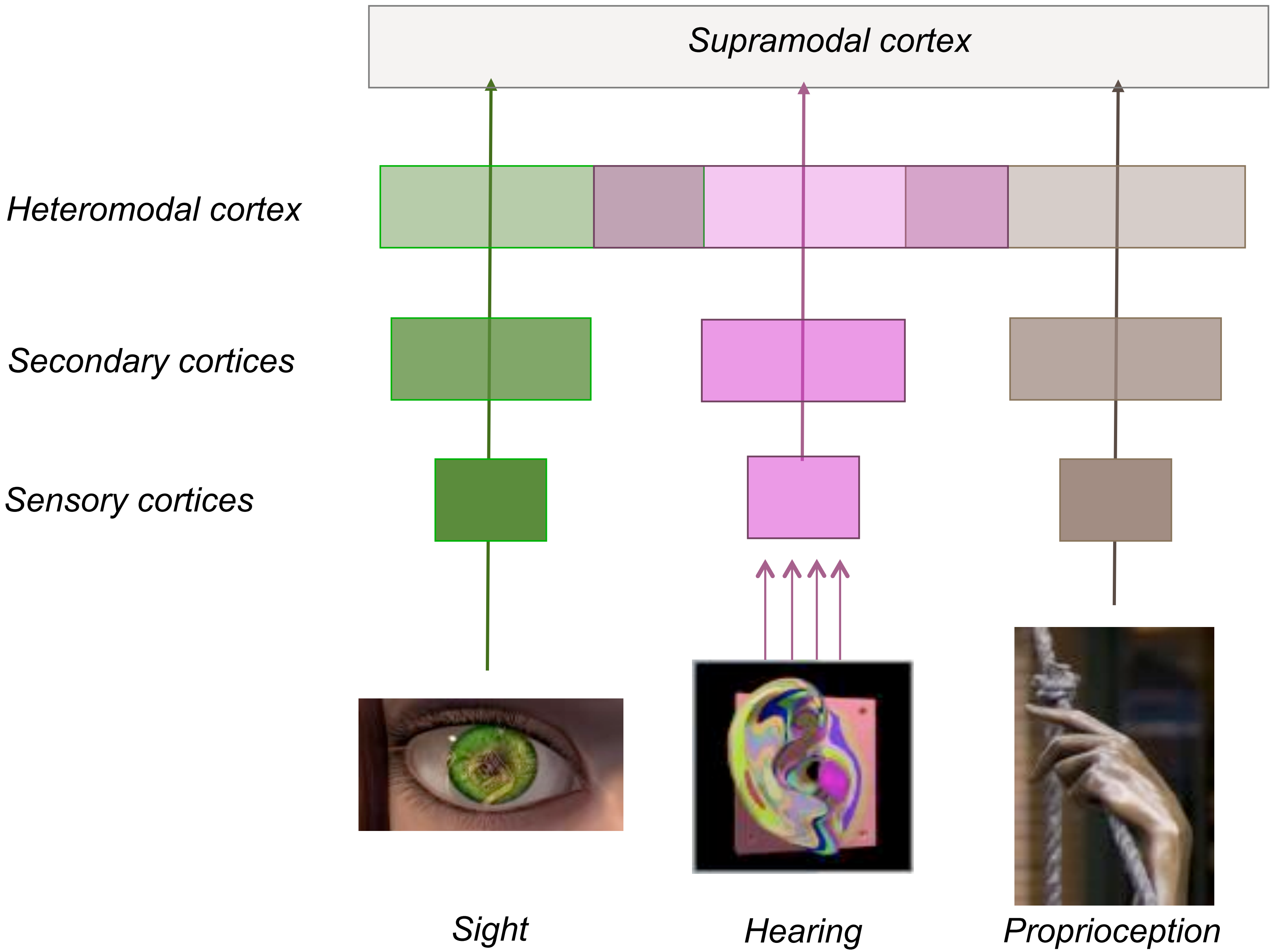


Heteromodal cortex:
cross-modal takeover by other sensory modalities or cognitive networks during prolonged deafness

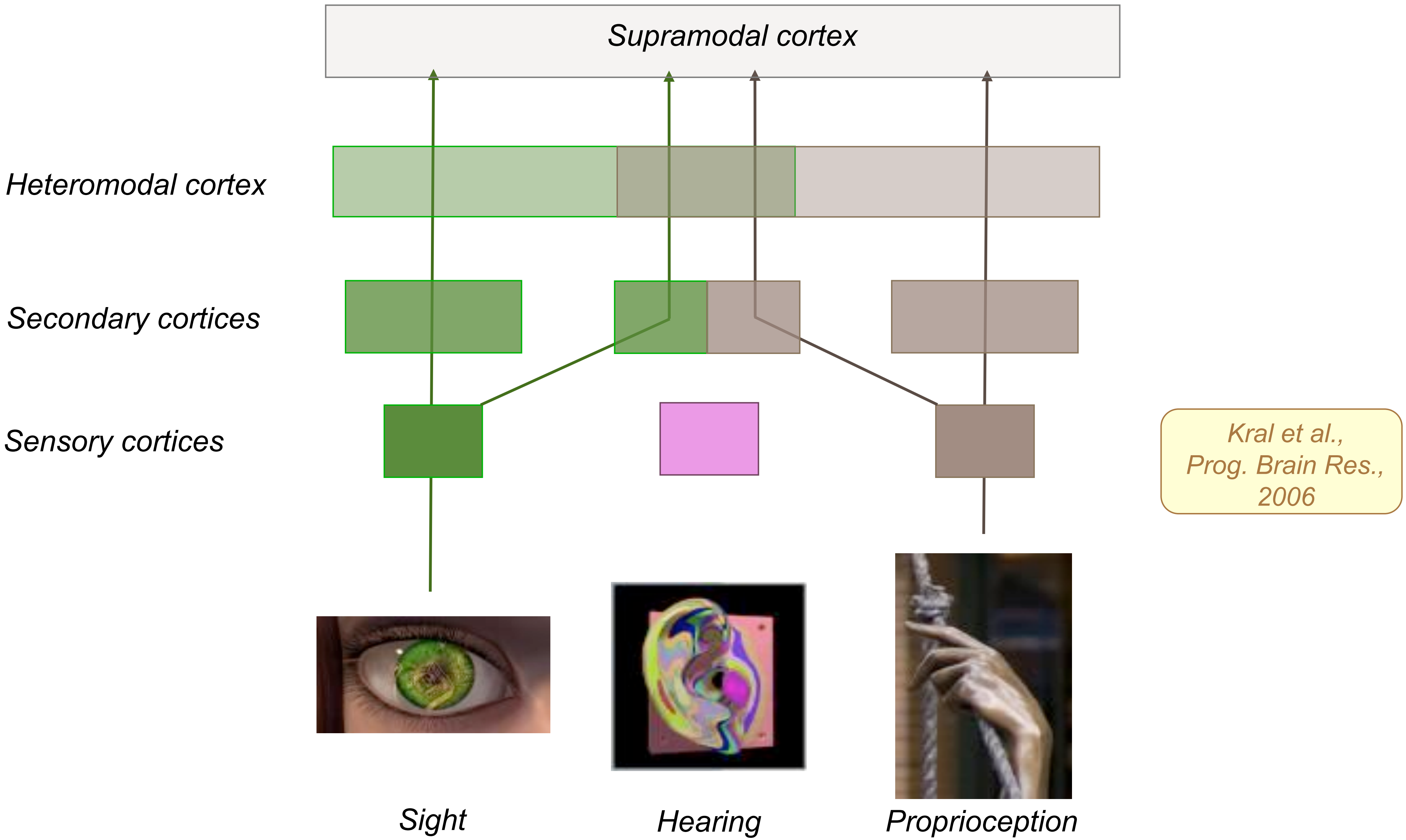
Age-independent effect
(high metabolism = low speech scores)
Age-dependent plasticity
(high metabolism = older children)

Lee HJ et al., Cerebral Cortex 2006

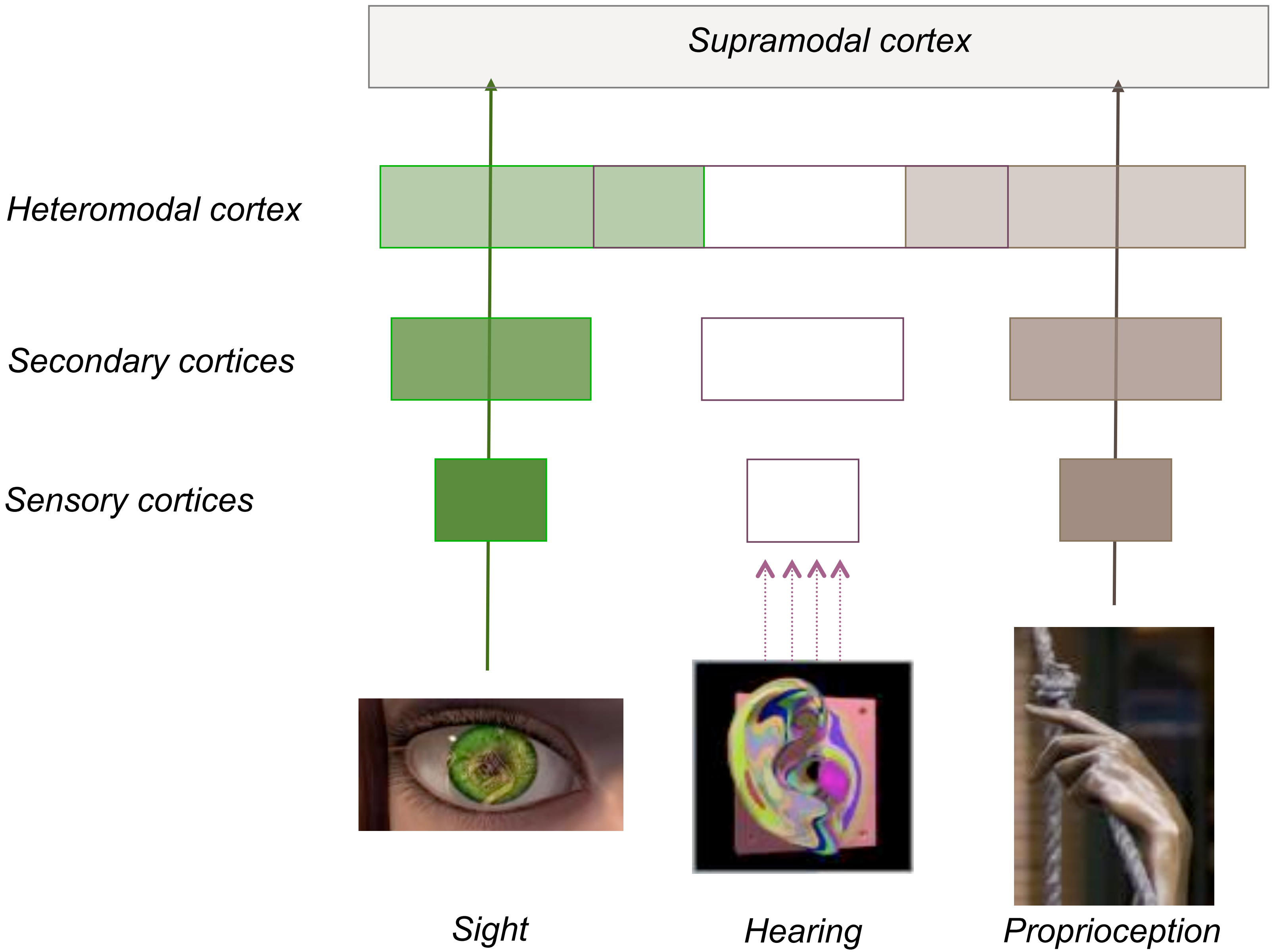
Case 1: Auditory cortex correctly afferented



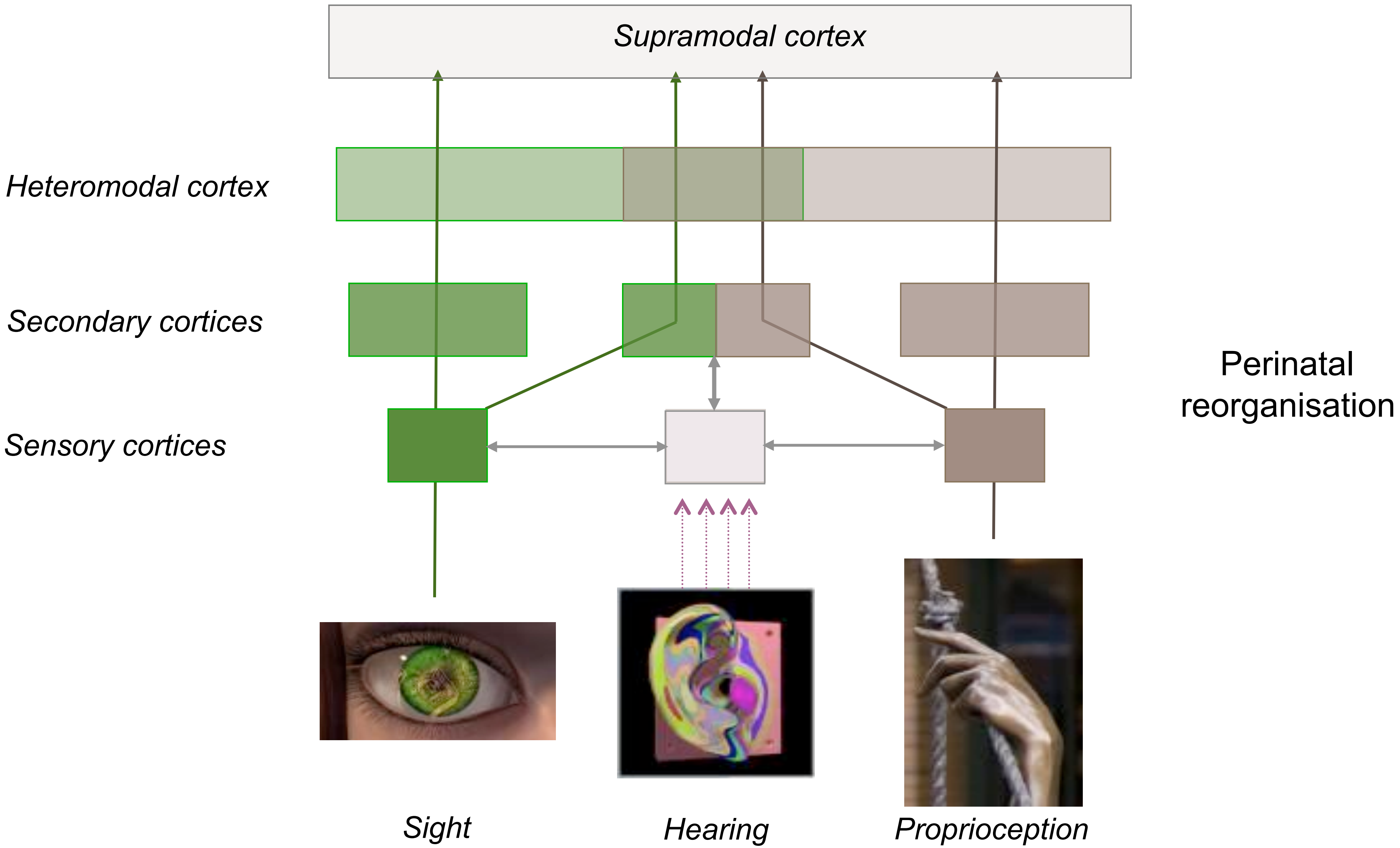
Case 1: Auditory cortex correctly afferented



Case 2: Auditory cortex insufficiently afferented



Case 2: Auditory cortex insufficiently afferented



Conclusion

Children with poor speech perception after implantation
show signs of irreversible pre/peri-natal cross-modal plasticity.

The degree of this effect varies between individuals,
and does not depend on post-natal deafness duration.

Until it becomes possible to assess the amount of cross-modal plasticity in all
deaf babies, it seems advisable to provide them with auditory input
as early as possible, even before language development,
to ensure (the maintenance of) correct labelling of the auditory cortex.

Cooperation between the senses for speech processing

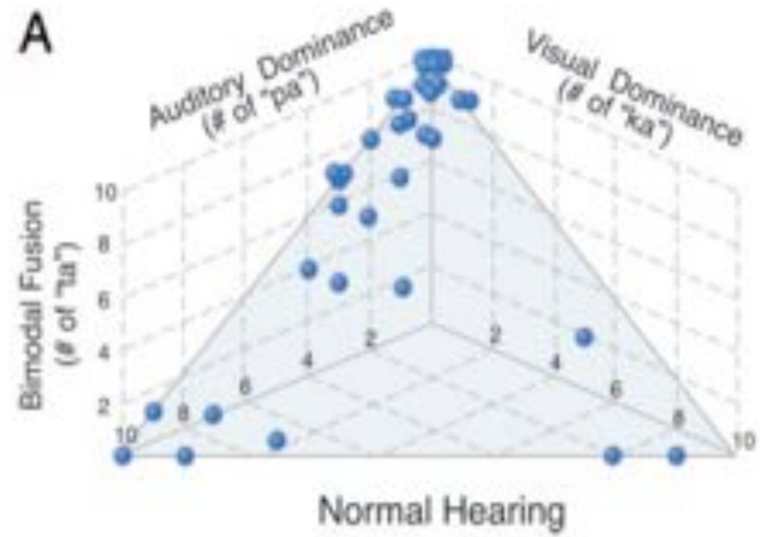
How do vision and hearing complement each other after implantation?
Is cooperation between vision and hearing subject to plasticity?

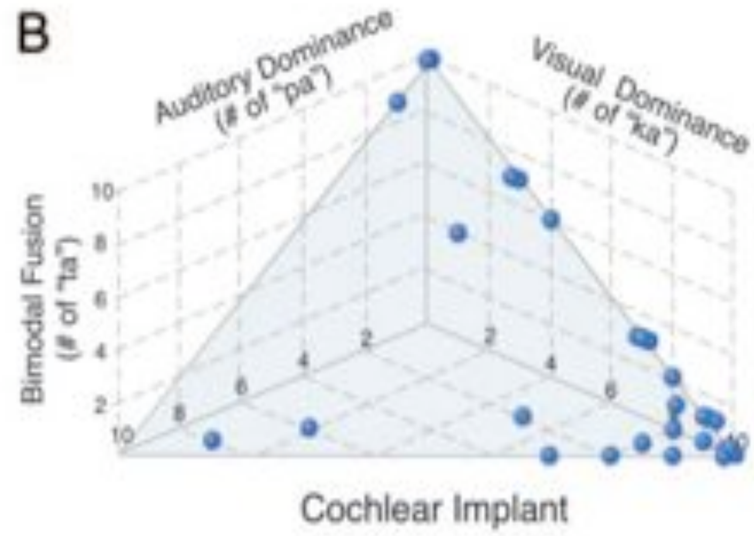
McGurk effect (*Nature,* 1976)

Audio (ba) + Visual (ga) = da

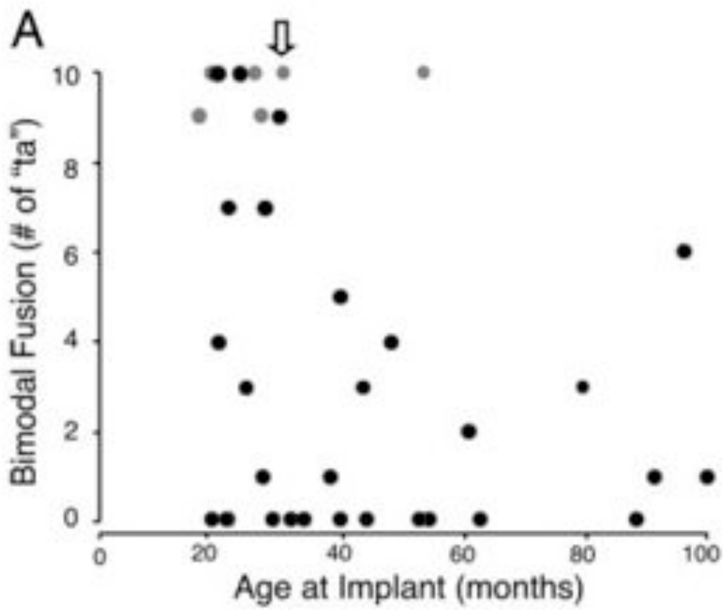
Audio (pa) + Visual (ka) = ta

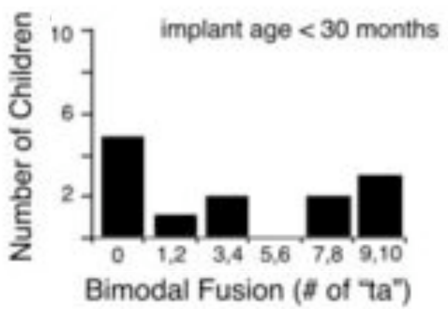
McGurk effect in congenitally deaf implanted children

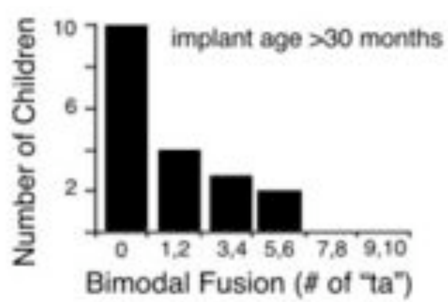




Schorr et al., PNAS 2005







Conclusion

2.5 years appears to be a critical upper age limit for plasticity of audio-visual cooperation.

After this age, vision becomes predominant in phonological processing (lip-reading).

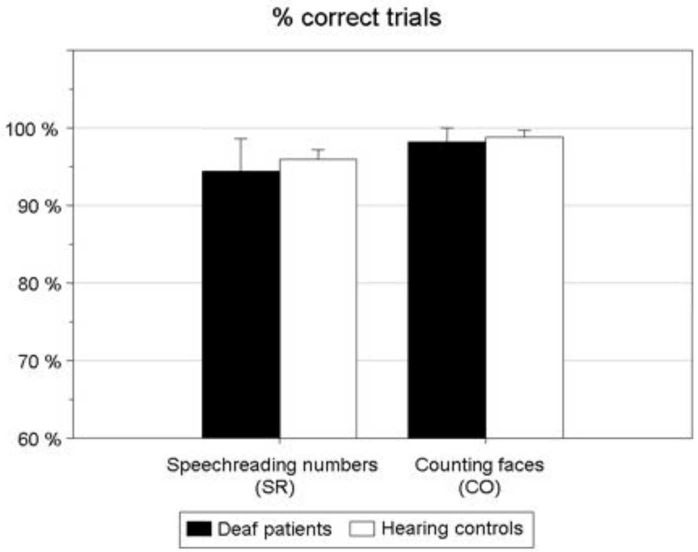
How does deafness duration affect speech visual processing ability in deafened adults?

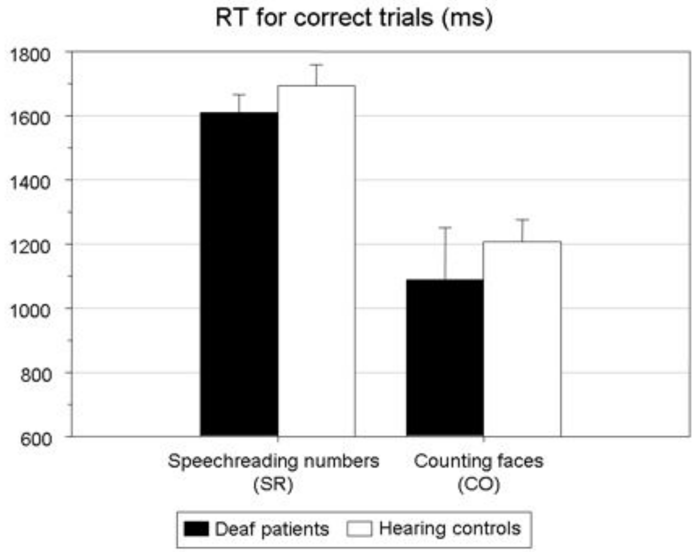
fMRI study of speechreading in 13 post-lingual deaf adults and 13 controls

Speaking vs. gurning face

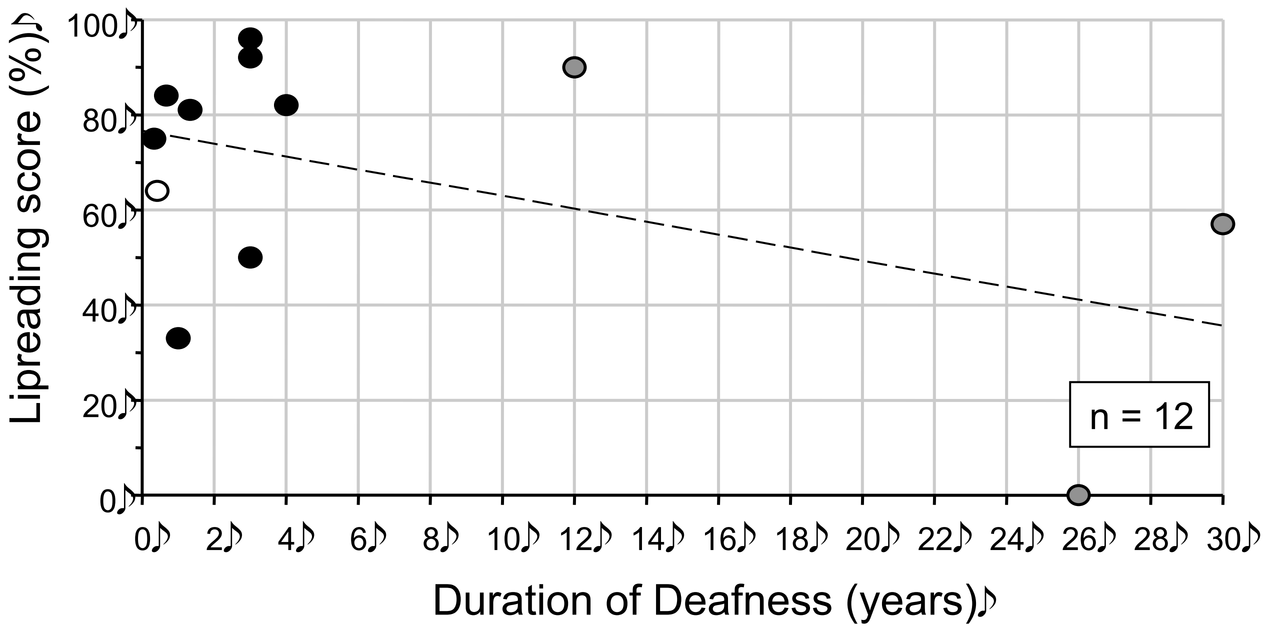
Closed set of stimuli:
Numbers from 1 to 10
Face gurning 10 differents movements

Task:
Reporting by buttonpress every even number / event

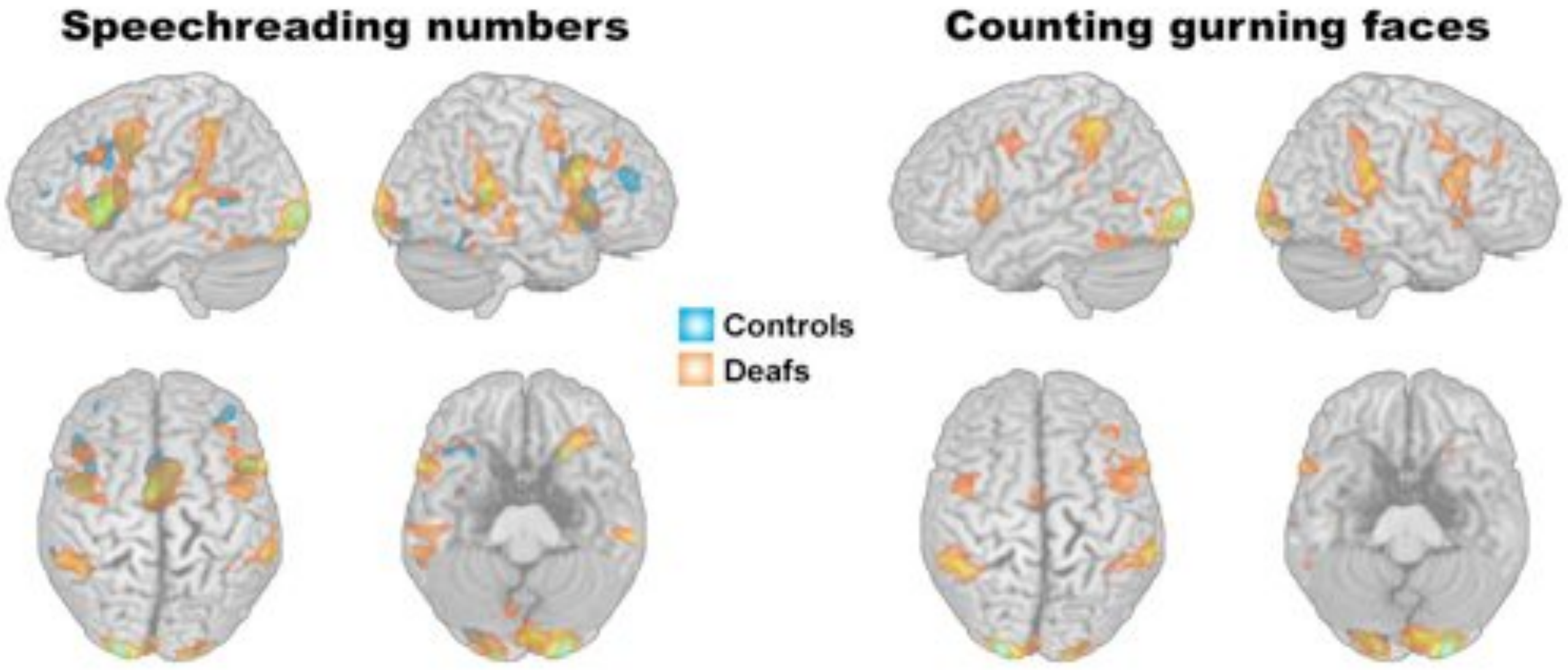




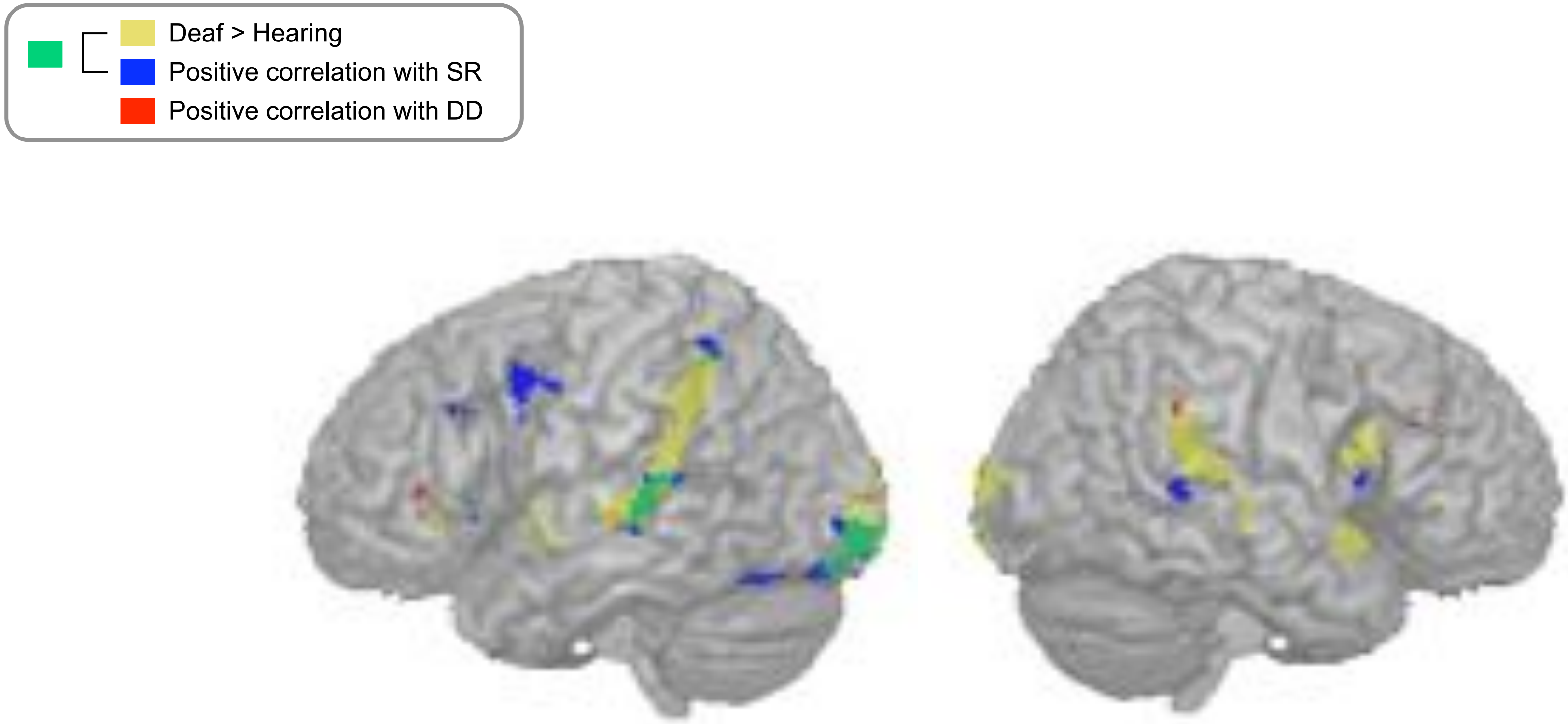
How does speechreading fluency evolve with deafness duration?



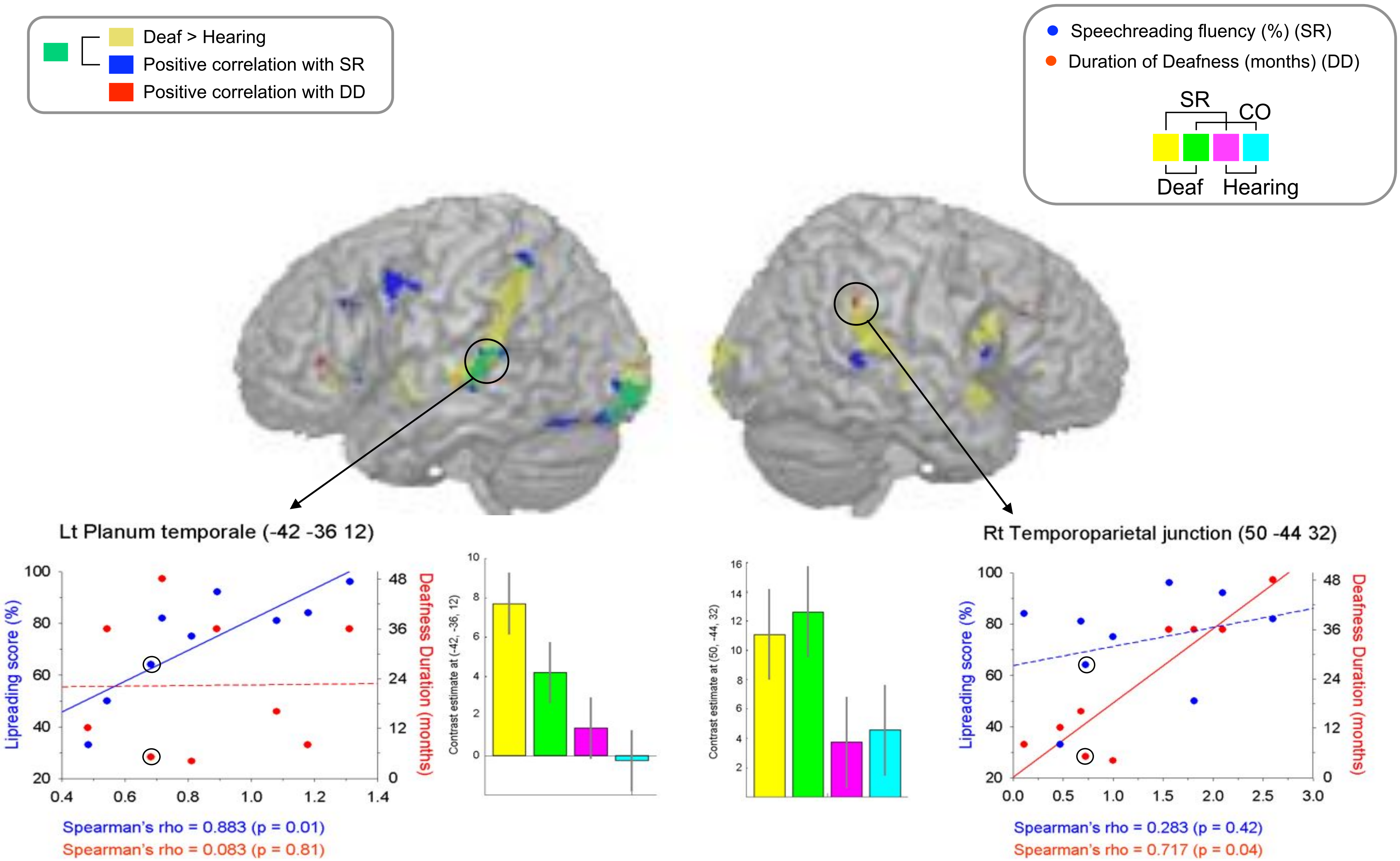
Effect of speechreading vs. watching gurning faces



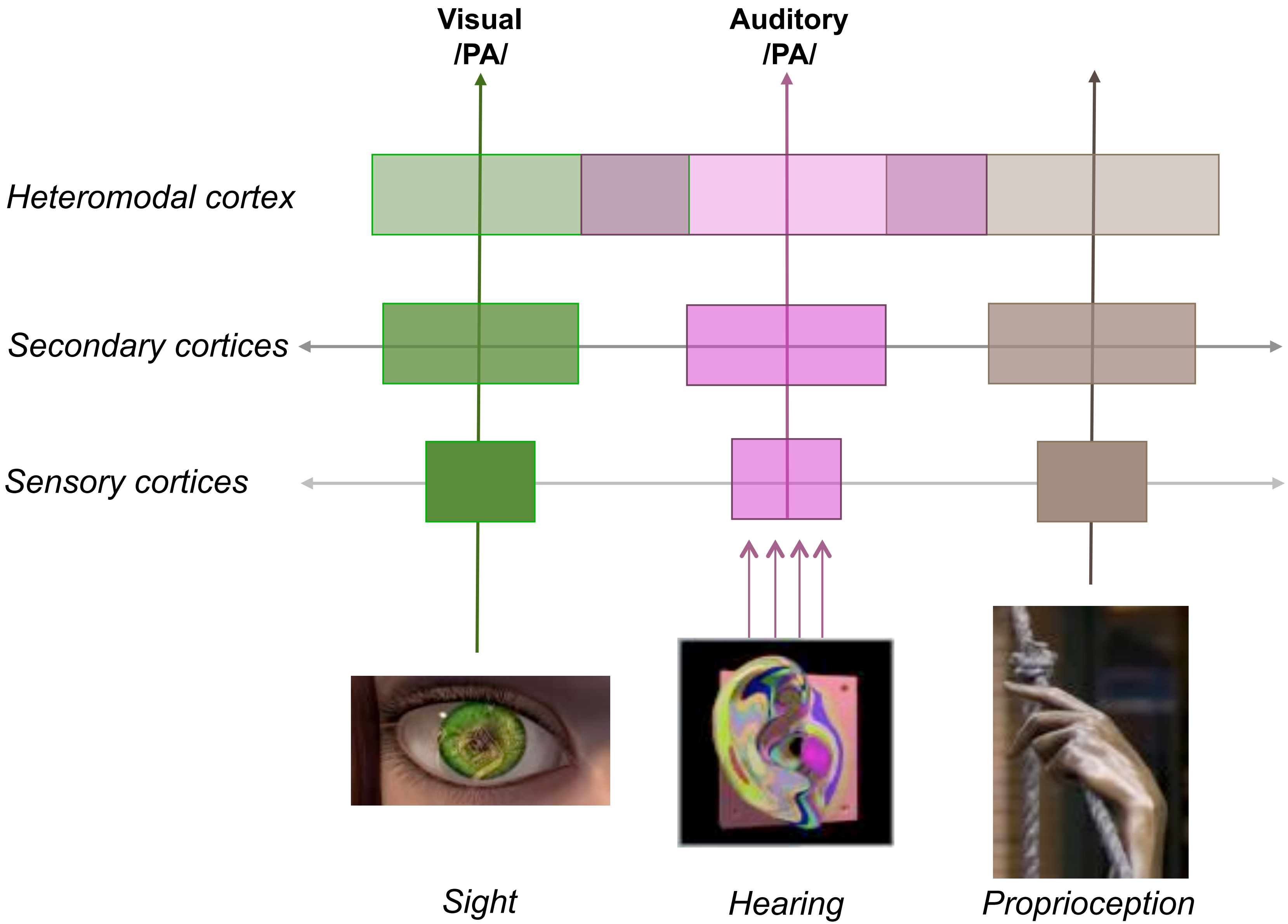
Effect of deafness duration (DD) and speechreading fluency (SR)



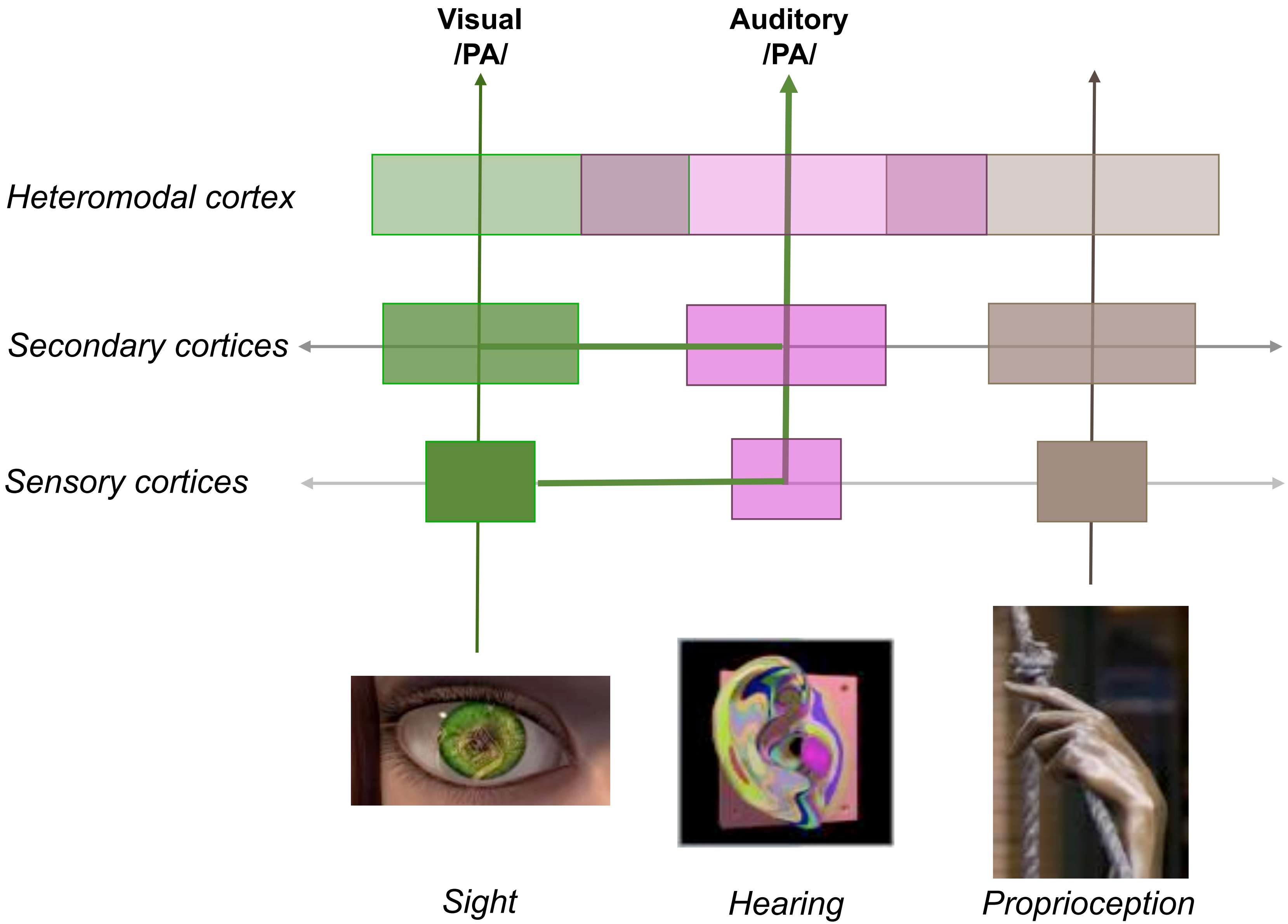
Effect of deafness duration (DD) and speechreading fluency (SR)



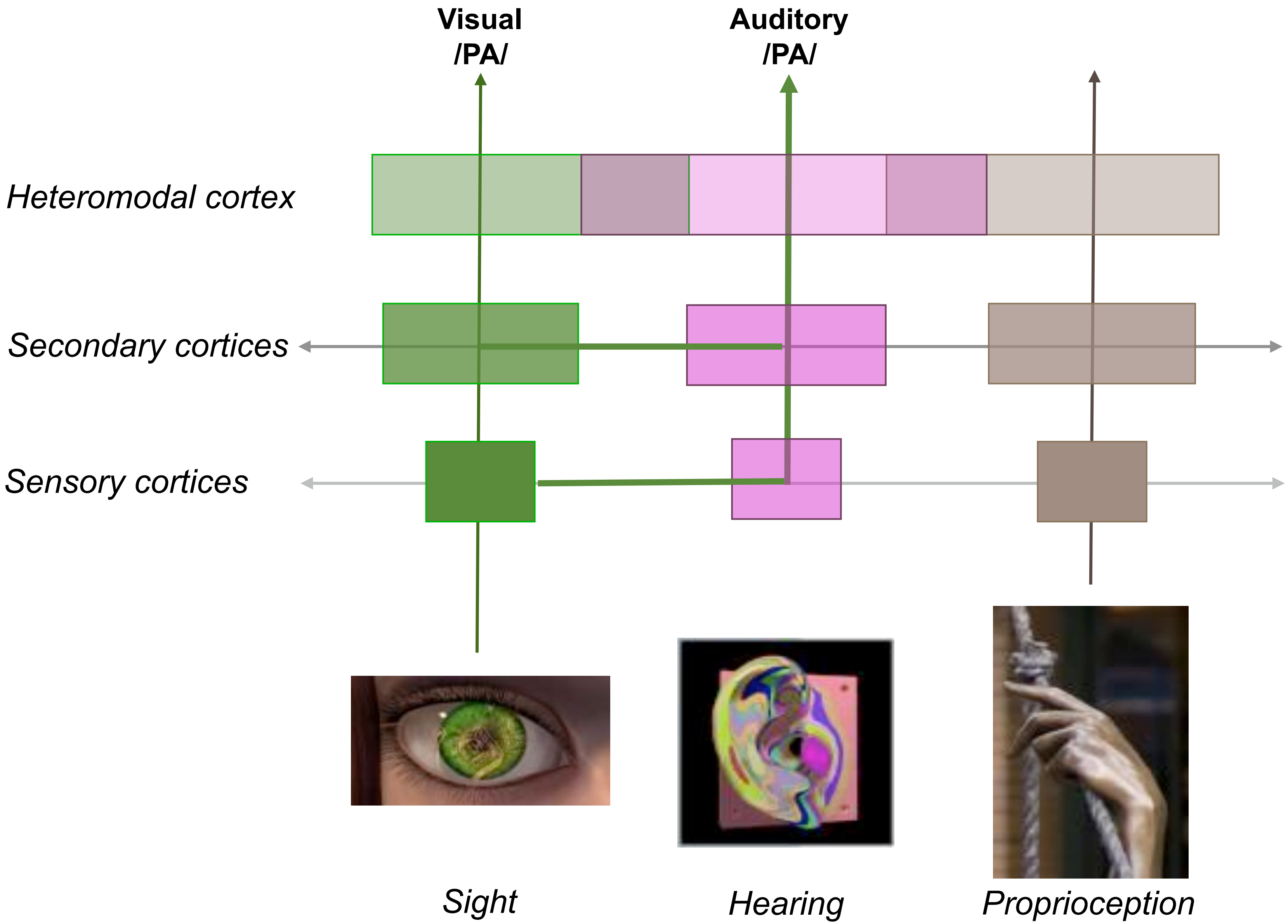
Pre-existing crossmodal connections …



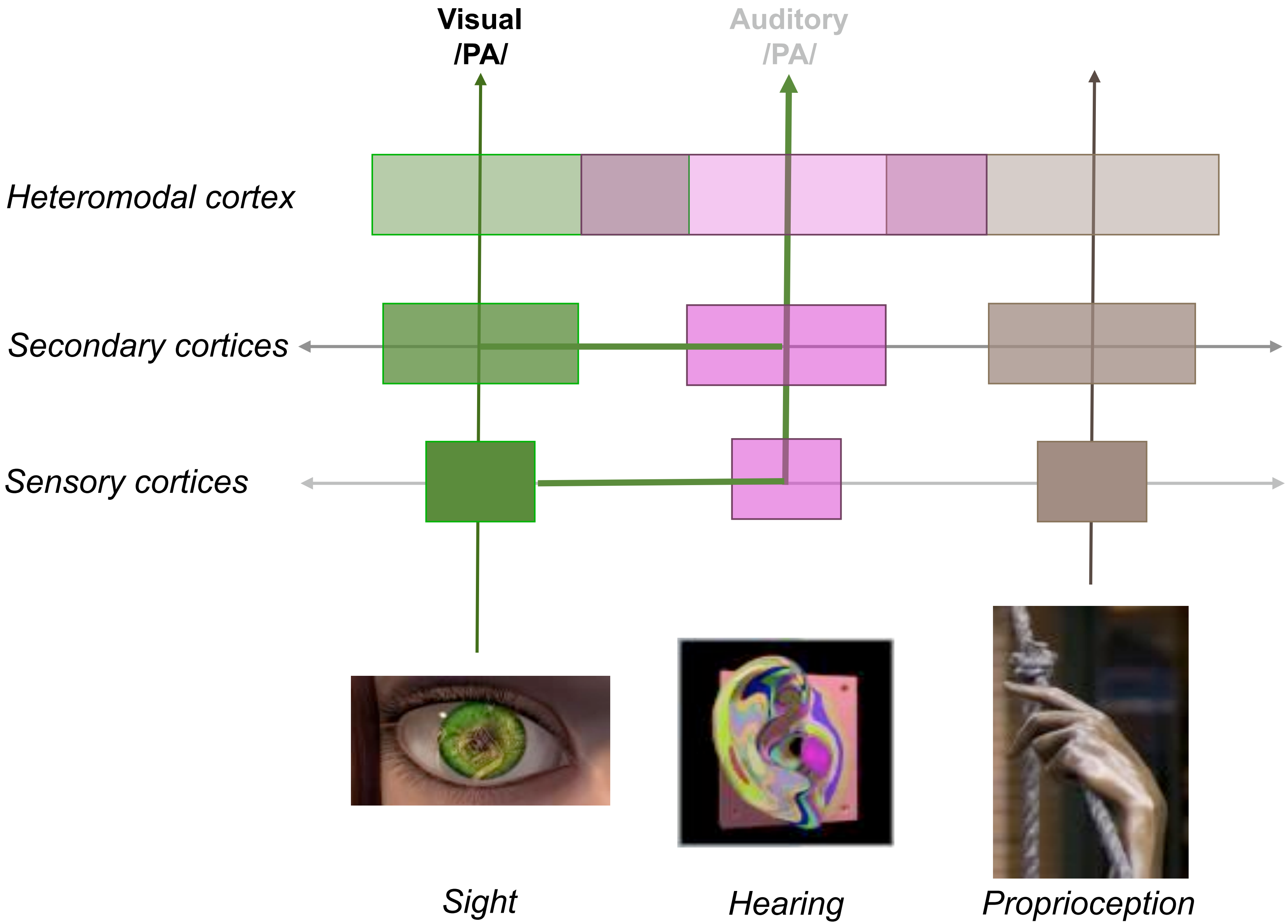
… are readily available after deafness …



… but phonological memory fades out



… but phonological memory fades out (?)

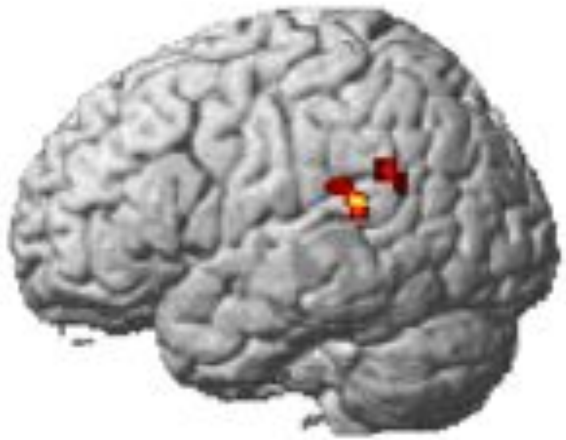


A phonological (rhyming) task in 8 deaf patients

Correlation with deafness duration

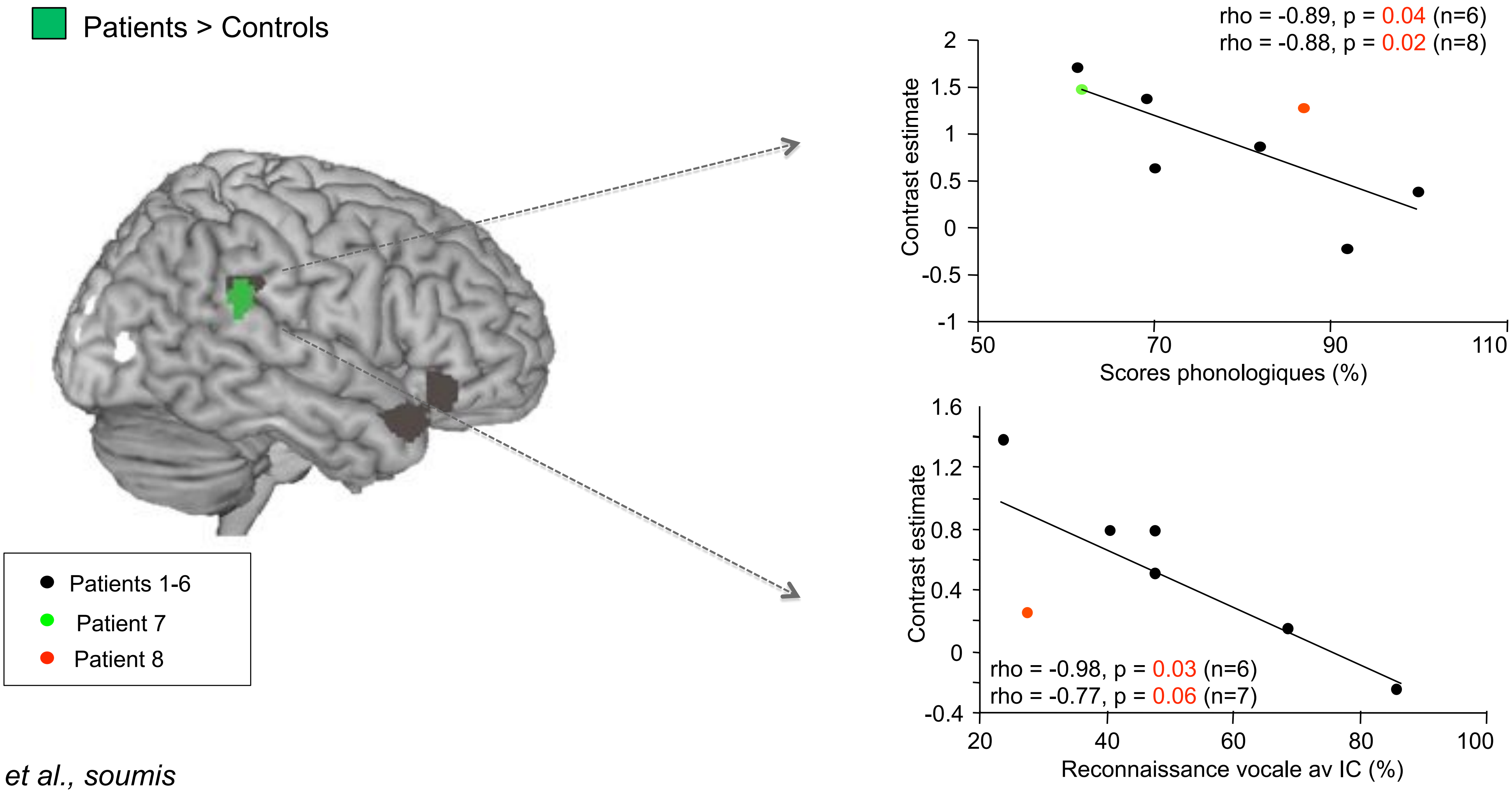
Do words rhyme irrespective of spelling?

Negative correlation with duration of deafness during a phonological (rhyming) task



Deleterious adaptation to deafness in the right temporo-parietal junction

= speech reading?



Lazard et al., soumis

Conclusion

Speechreading does not gain from long-term cortical plasticity
(audio-visual connections are established once for all
during development and early childhood).

Deafness prompts rapid unmasking of
latent visual speech networks.

Once audio-visual networks are established
they remain latently available for vision in case of auditory deprivation or
other situation where only vision is available.

<u>Early audio-visual exposure is crucial for the development
of audio-visual speech networks</u>

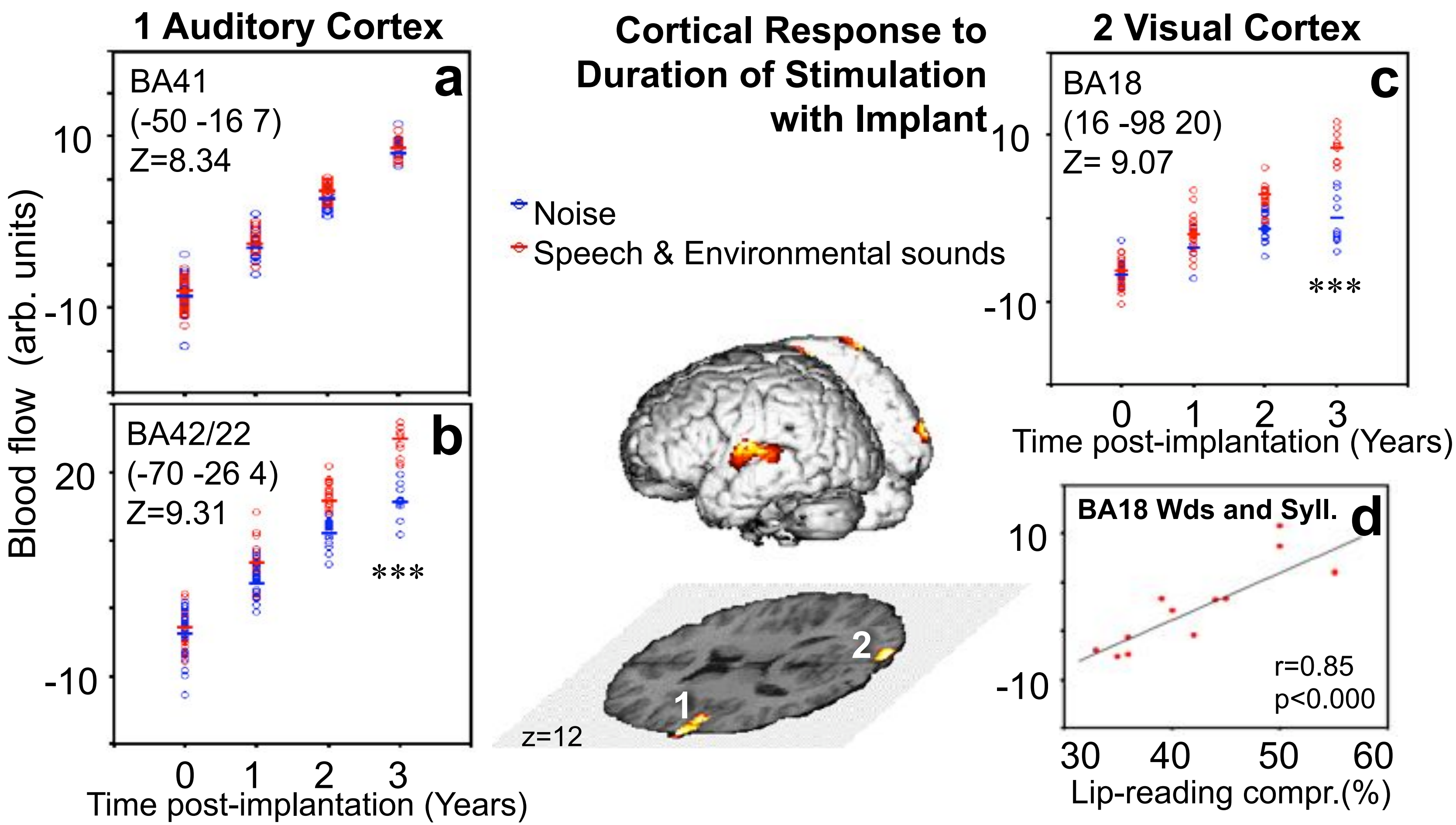
What happens to audio-visual phonological representations after cochlear implantation?

Audio-visual cooperation in adult post-lingual CI users

Brain regions where responses to speech and noise
increase with time elapsed since implantation

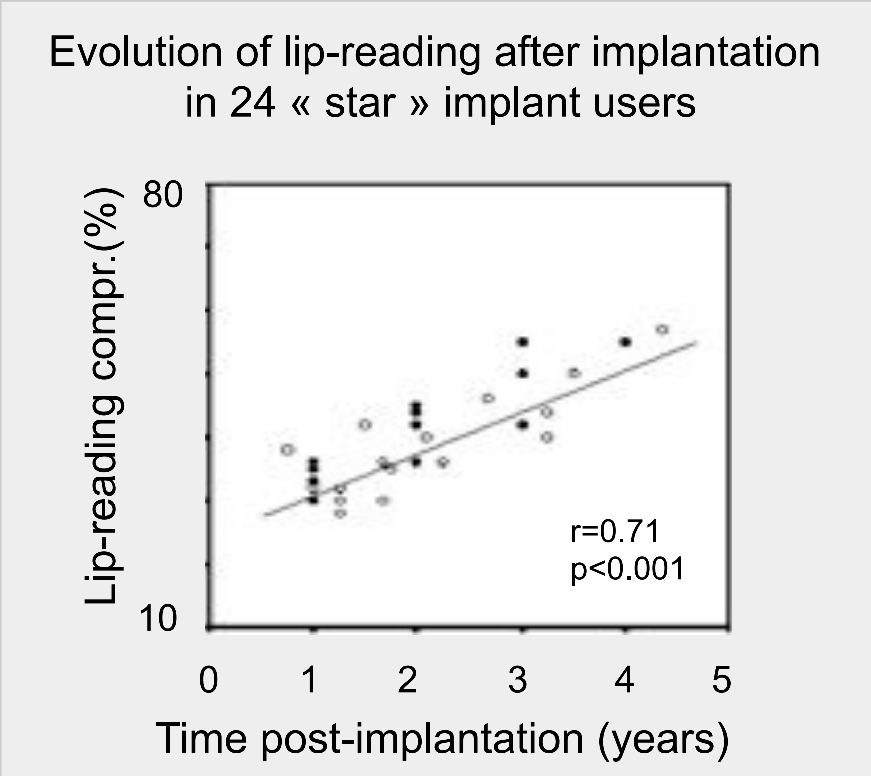
Giraud et al., Neuron 2001

Audio-visual cooperation in adult post-lingual CI users



Giraud et al., Neuron 2001

Audio-visual cooperation in 24 post-lingual CI users



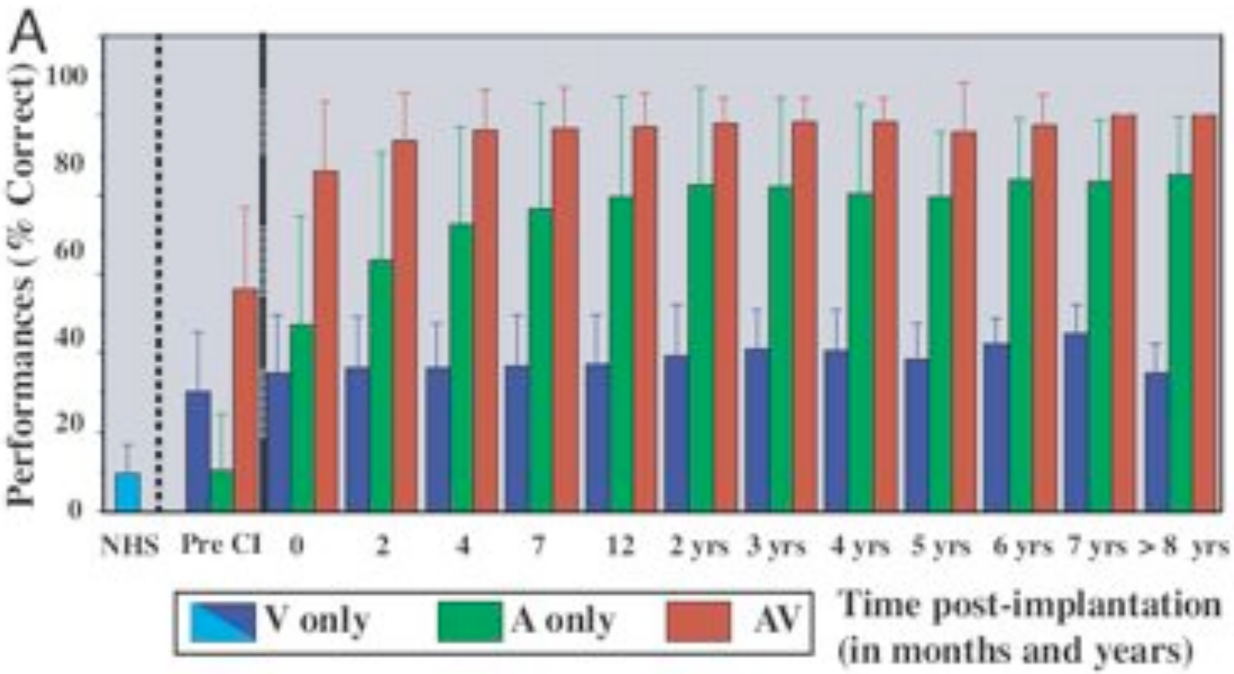
Utilization of visual cues
= speechreading

<u>Cooperation</u> between vision and hearing associated with learning new audio-visual relationships in speech.

Giraud et al., Neuron 2001

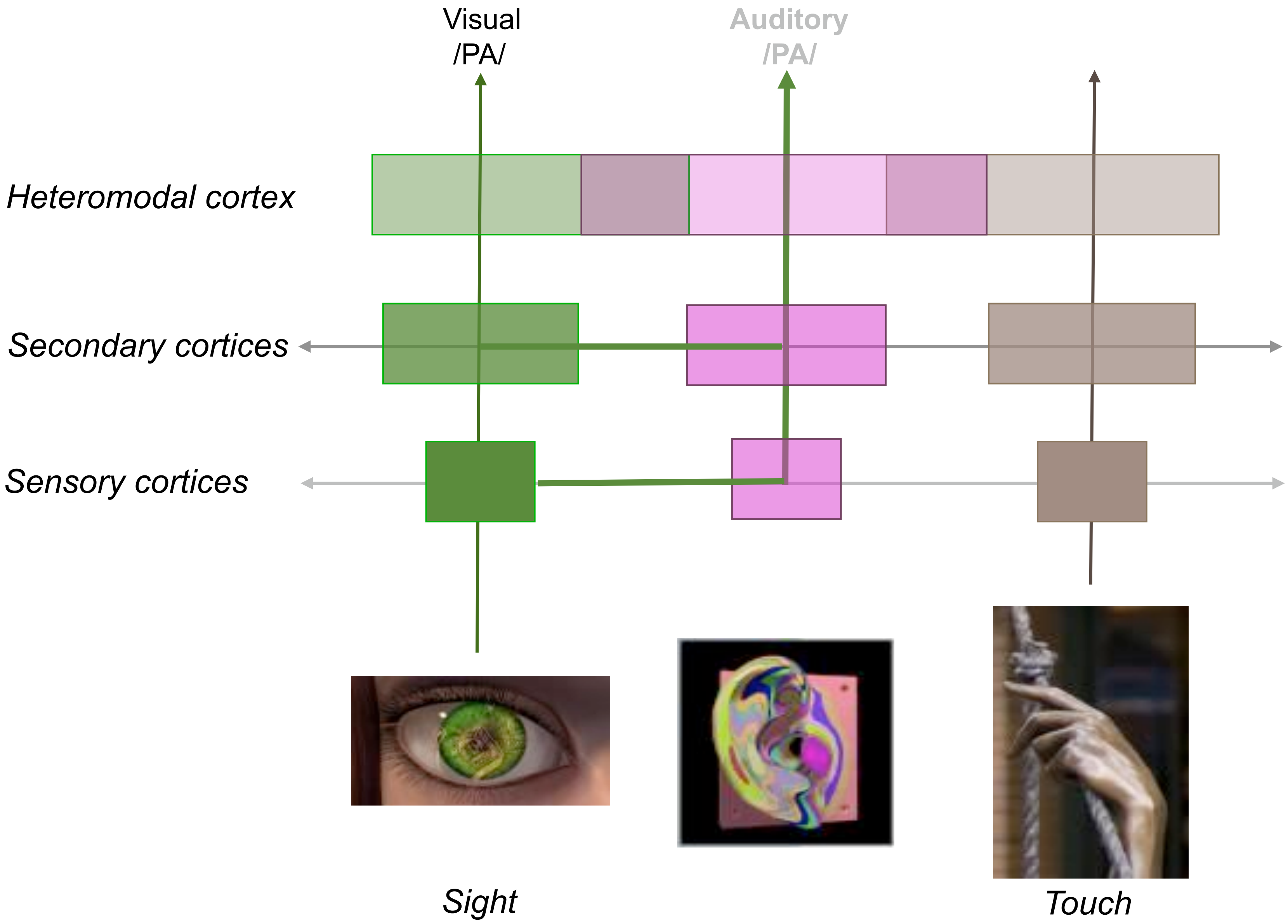
Audio-visual cooperation in 97 post-lingual CI users

This sample includes patients who are unable to gain from visual input to improve phonology,
i.e. those with already poor phonological representations before deafness, or due to progressive deafness

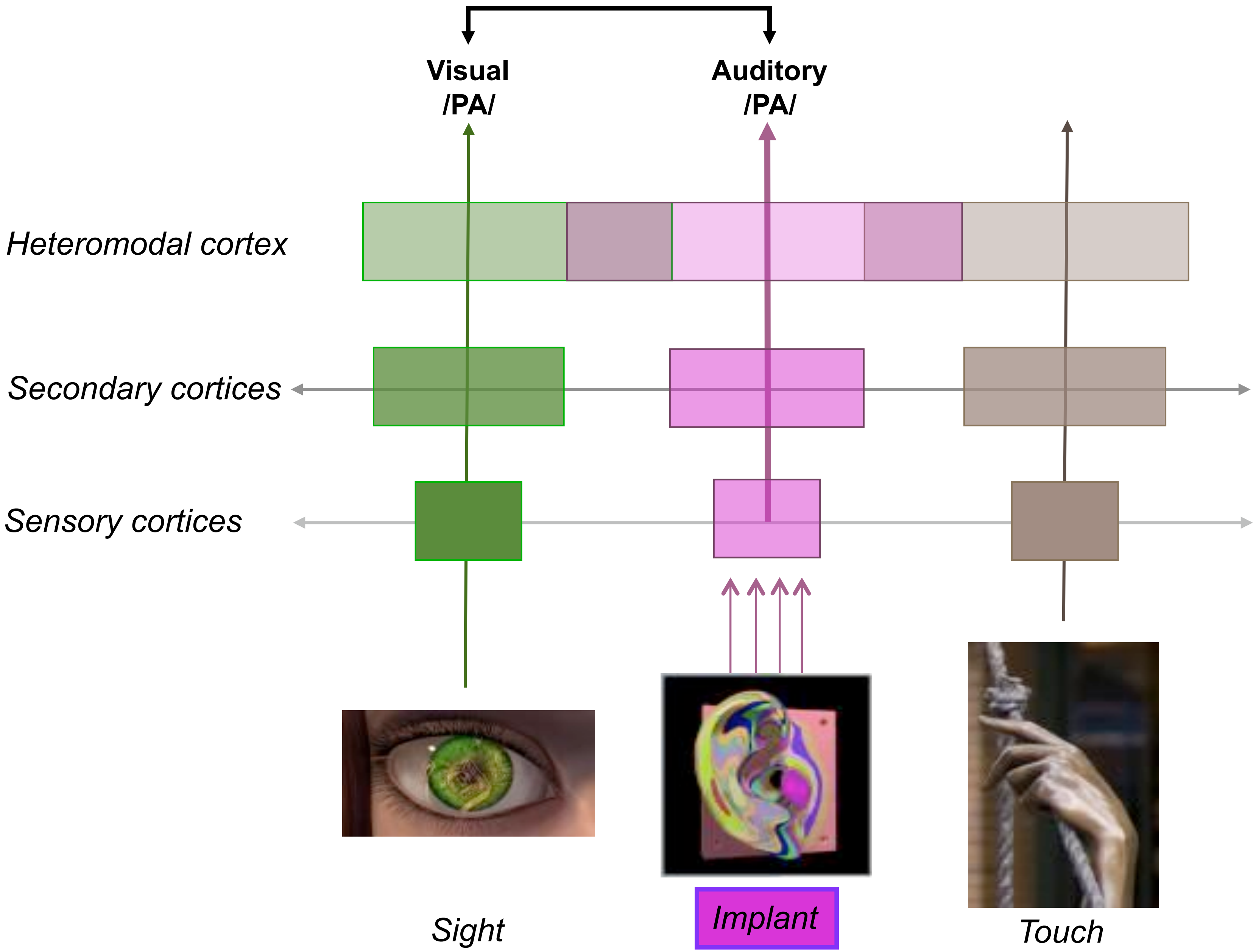


Rouger et al., PNAS 2007

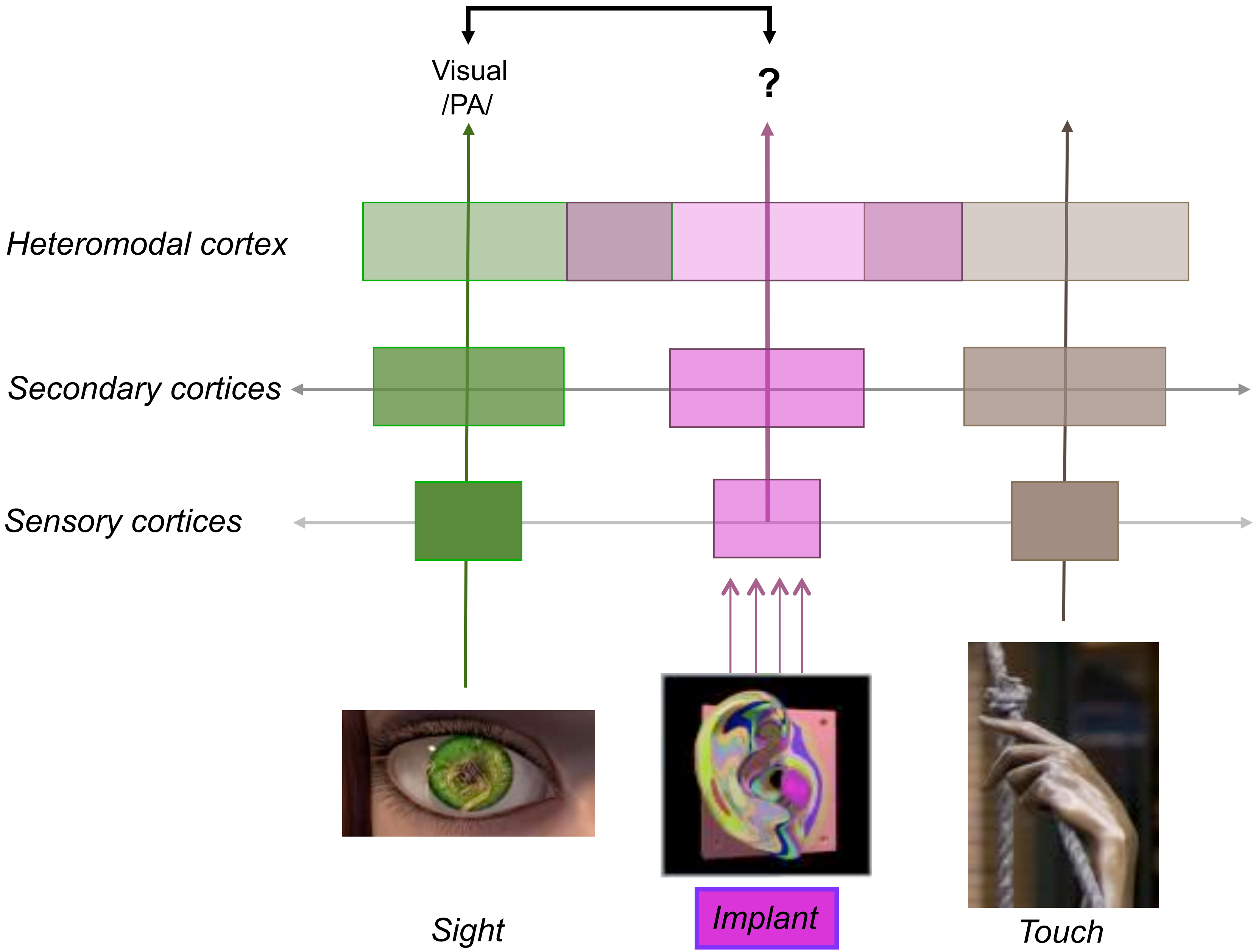
Weakened phonological representations during deafness …



… restored audio-visual phonological matching



… yet, only possible in the presence of phonological remains



Conclusion

Audio-visual speech **and visual speech alone** improve after implantation, suggesting that rehabilitation training should emphasize audio-visual coupling.

The pre-existence of solid audio-visual phonological representations is essential for the use of visual phonology during deafness and for the success of subsequent implantation.

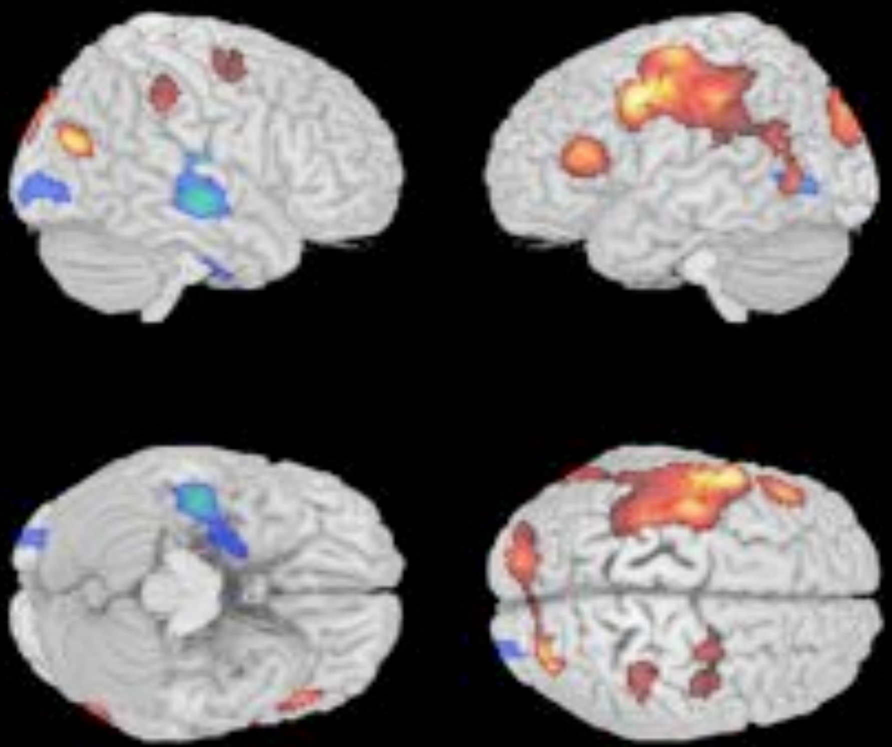
In congenitally deaf children, only very early exposure to audio-visual input can assure optimal speech perception.

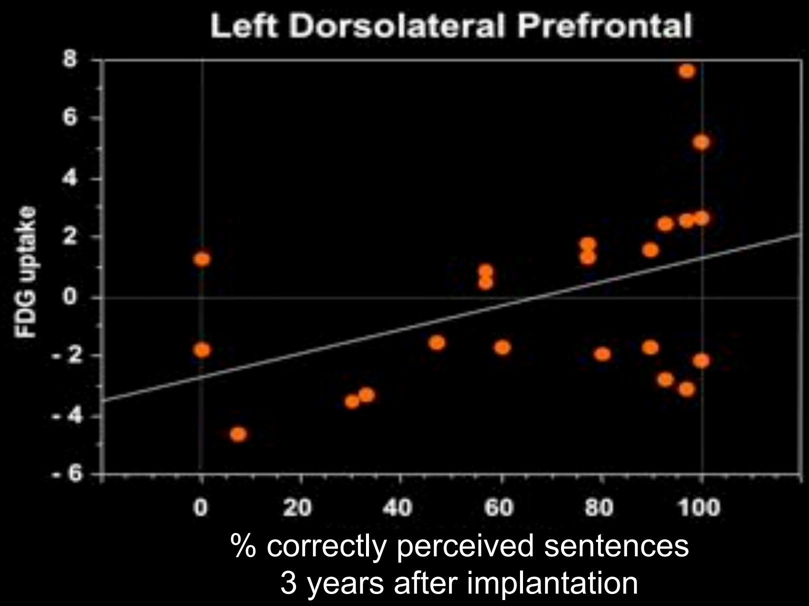
General cognitive abilities…

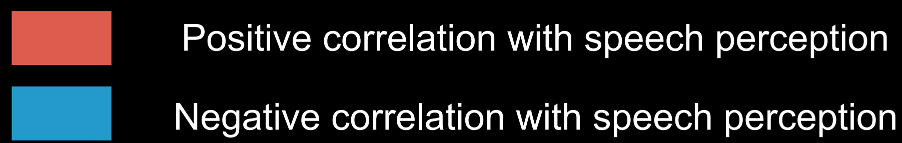
Do higher cognitive functions play a role in speech outcome?

Neurometabolic profiles (FDG-PET): Correlation with speech comprehension measured 3 years after cochlear implantation irrespective of age at implantation (deafness duration)

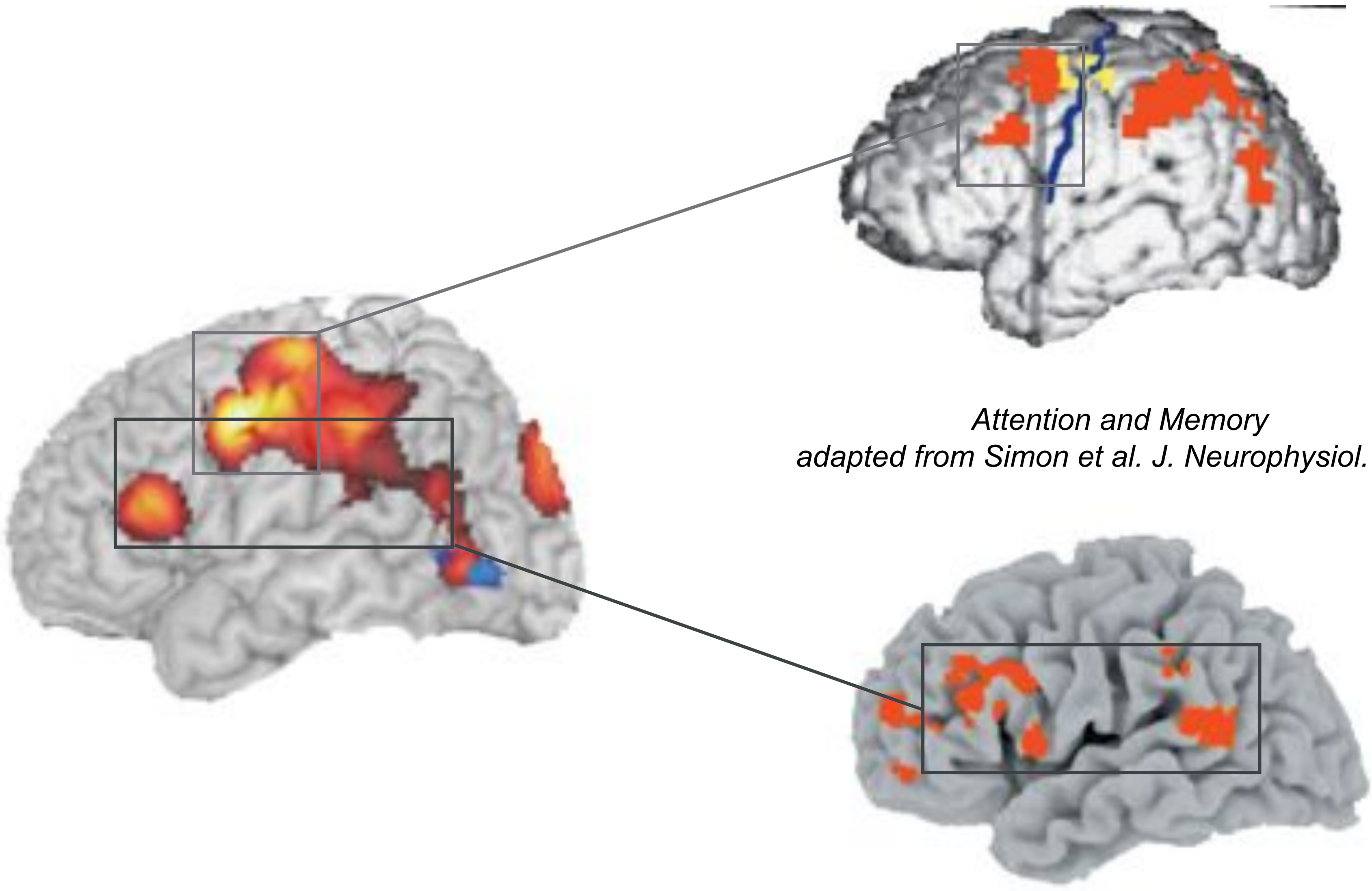
33 congenitally deaf children, age : 1.5 to 11 years







Lee HJ et al., Cerebral Cortex 2006



Attention and Memory
adapted from Simon et al. J. Neurophysiol. 2002

General Intelligence
(where gF predict activity during a 3-back task)
adapted from Gray et al. Nature Neuroscience 2003

Positive correlation with speech perception

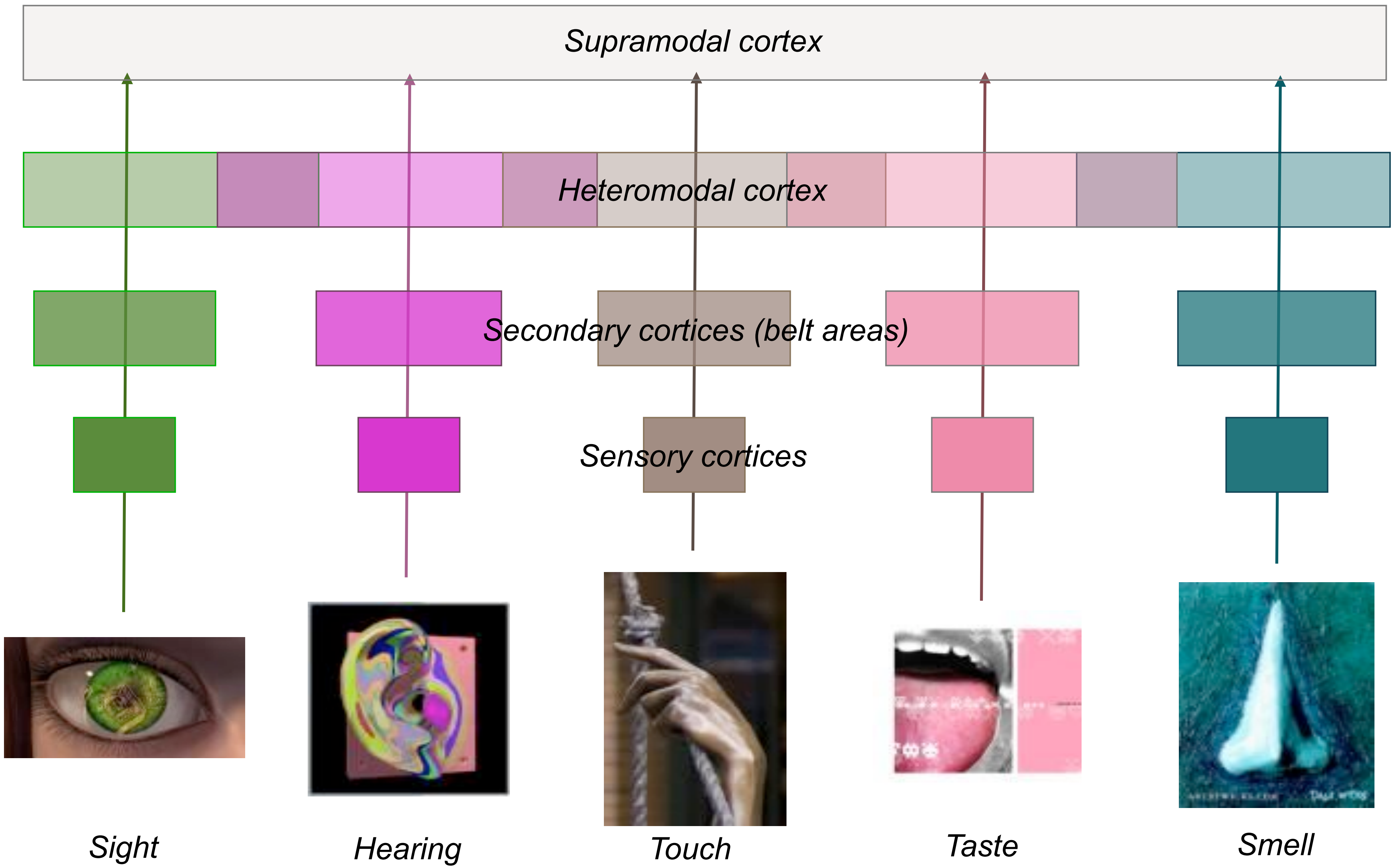
Negative correlation with speech perception

Conclusion

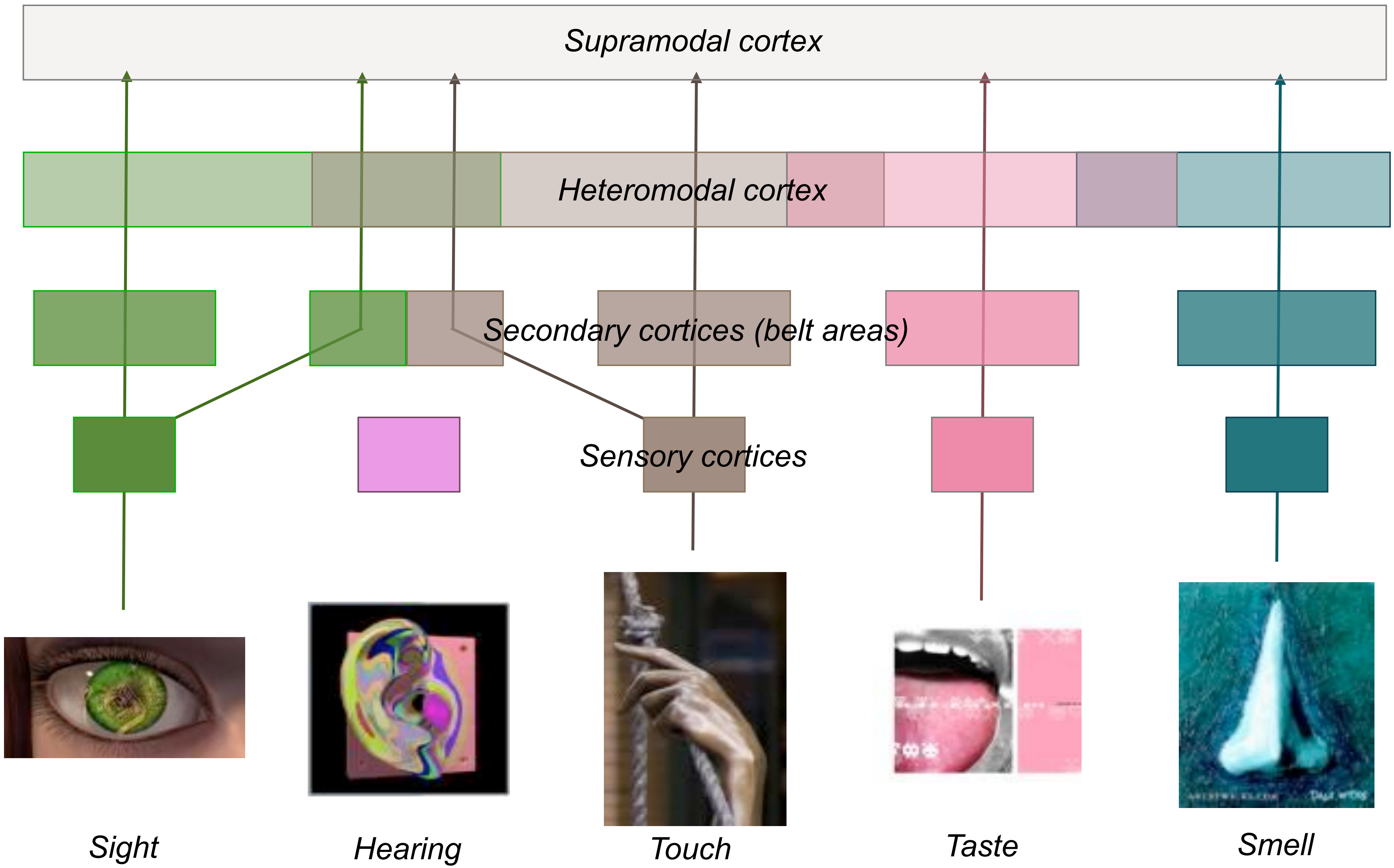
Good speech performance in children and adults are observed in those patients with high spontaneous activity during deafness in dorsal brain regions (fronto-parietal) involved in higher cognitive functions, attention, memory, and non-specific functions requiring on-line manipulation of sensory stimuli.

Rehabilitation strategies after implantation may be more efficient if they capitalize on general cognitive abilities & attention mechanisms over auditory patterns recognition.

Hierarchical multimodal processing

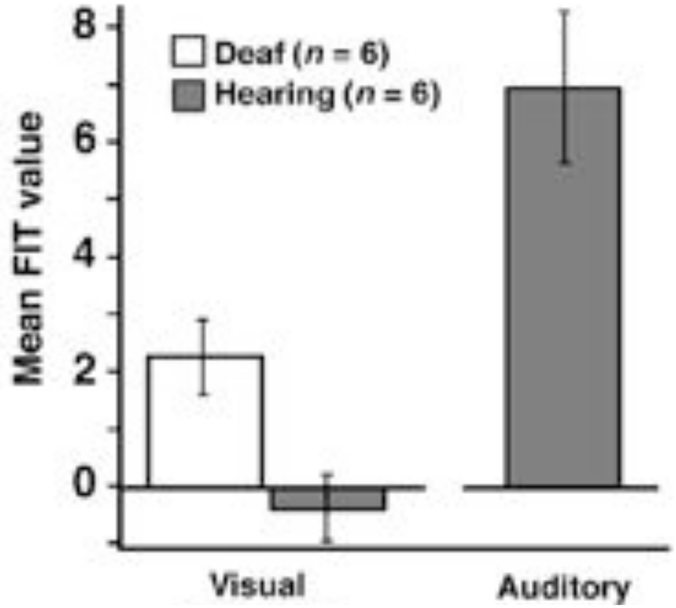


Hierarchical multimodal processing

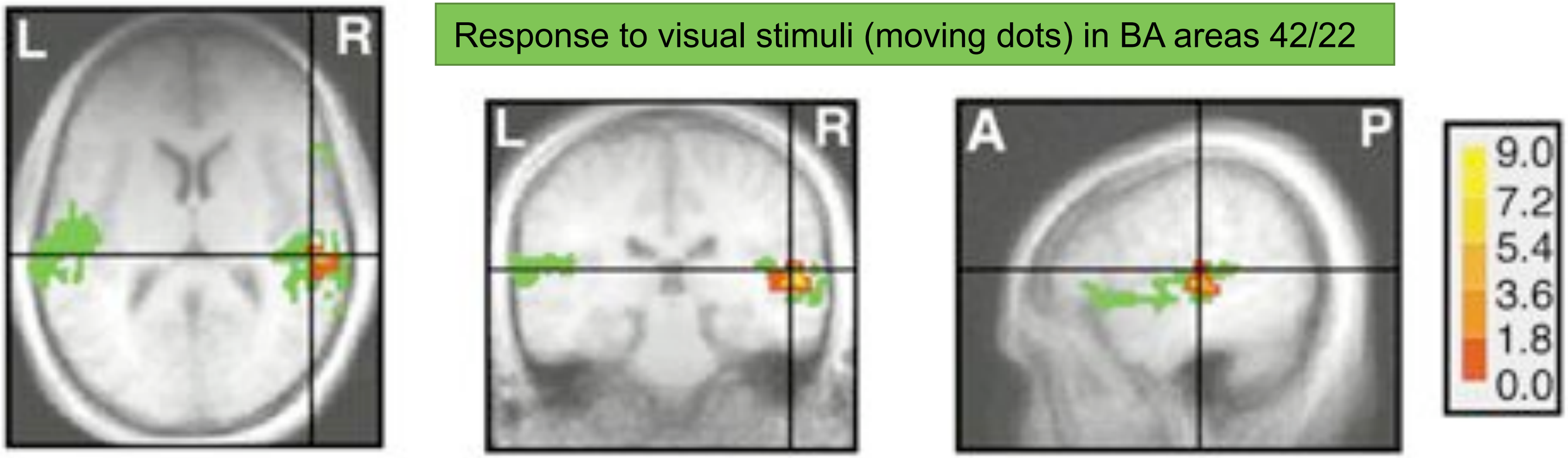


Visual responses in deaf auditory cortex

Finney et al., Nature Neuroscience 2001



Response to visual stimuli (moving dots) in BA areas 42/22



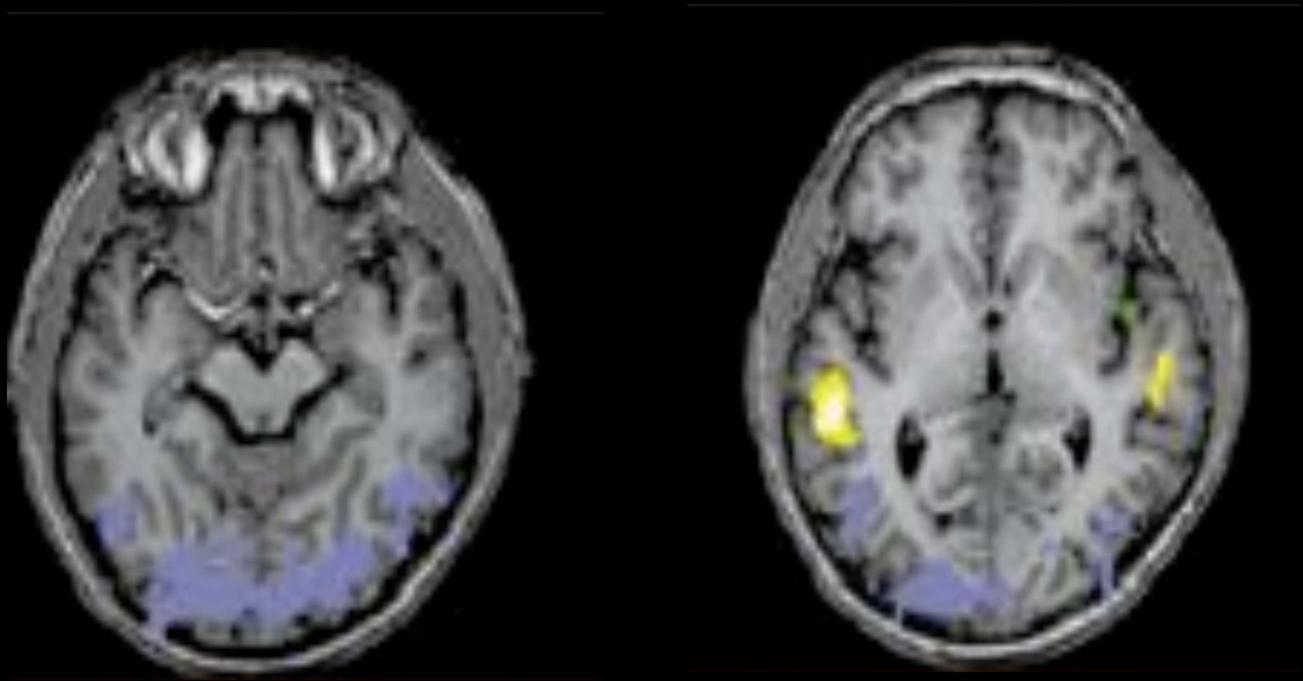
auditory responsive regions

Competition between the senses for the occupation of cortical space

One sense disappears… the others take over the free space

How much is spared?

Visual and auditory activation in implanted congenitally deaf adults (H_20-PET)



Visual areas activated by meaningless hand movements

Primary auditory area activated by auditory words after cochlear implantation

Auditory association areas activated by sign language

Nishimura et al., Nature 1999

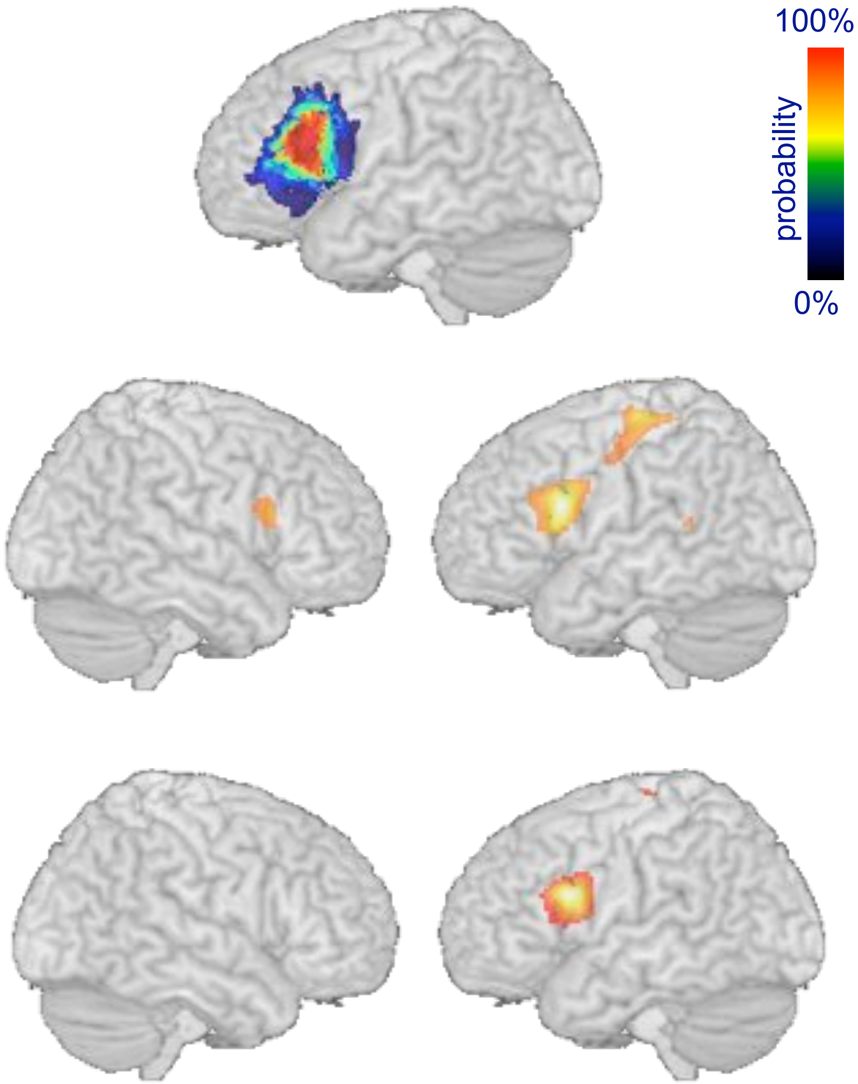
Cross-modal reorganisation
in congenital deaf children before implantation?

Interregional correlation of brain metabolism
(FDG-PET, functional networks)

Seed Region

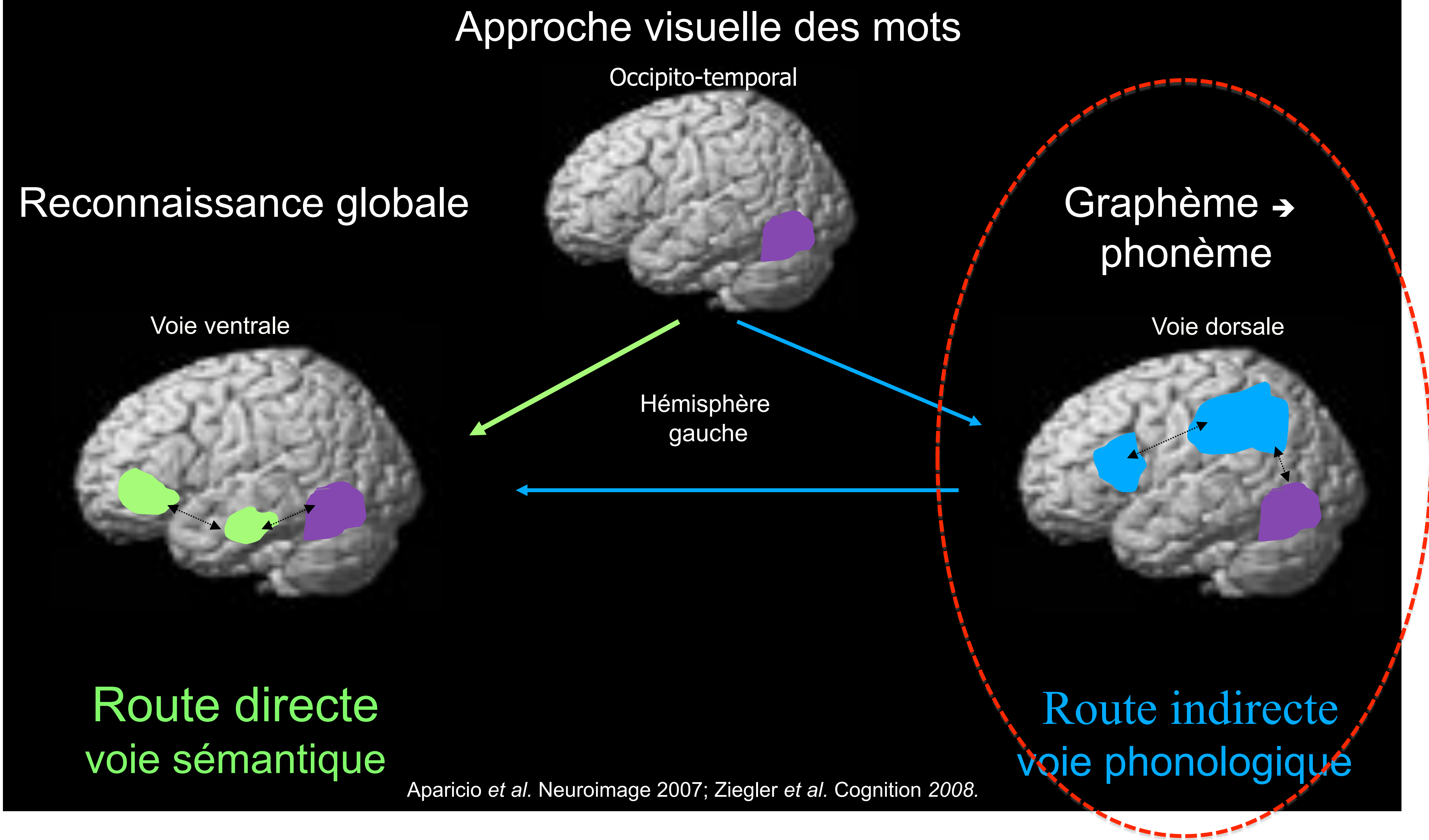
GOOD performers

POOR performers



Lee et al., ARO 2006

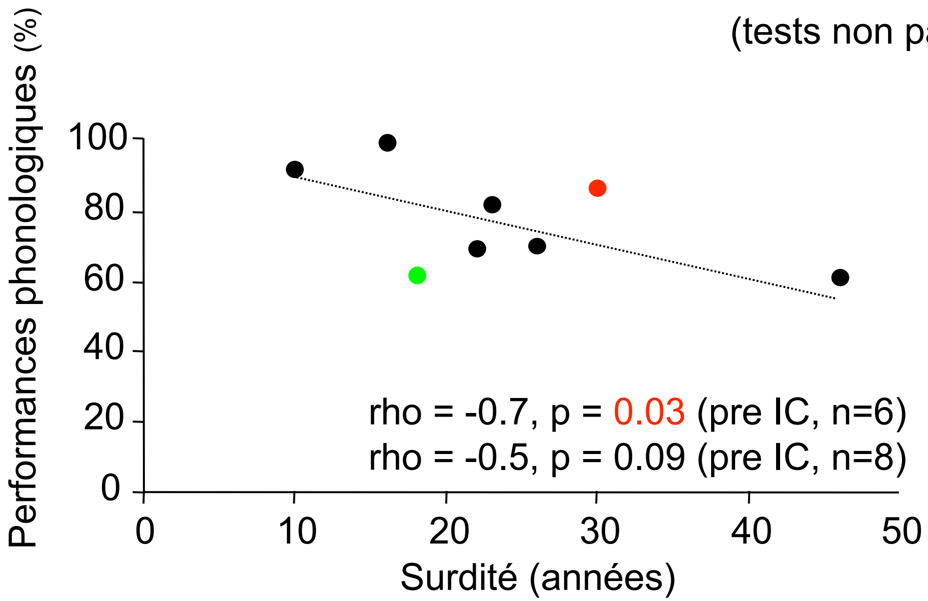
Stratégie de lecture



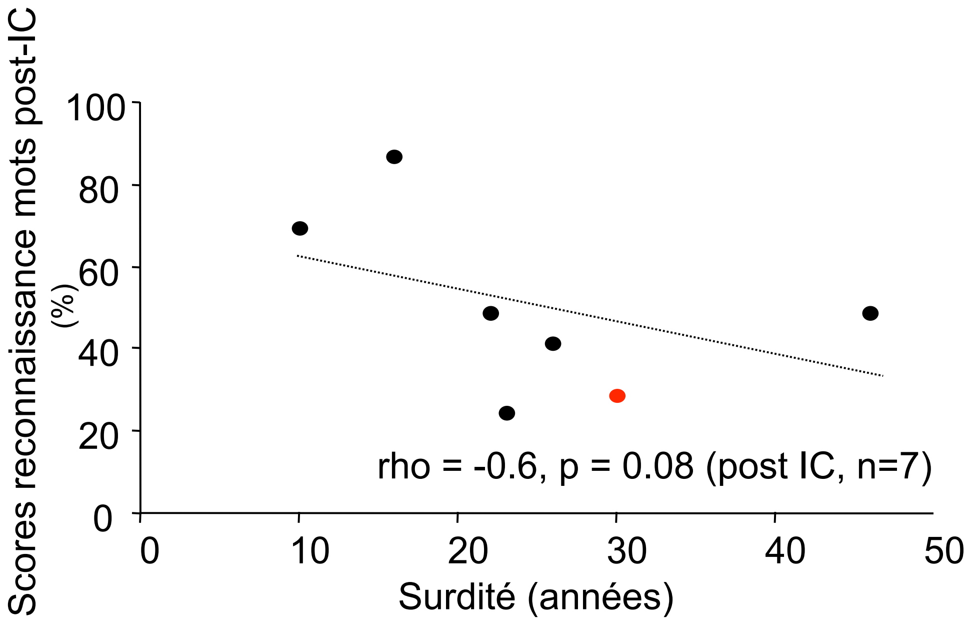
Aparicio *et al.* Neuroimage 2007; Ziegler *et al.* Cognition *2008.*

Corrélations cliniques

(tests non paramétriques)



Les performances phonologiques se détériorent avec l'augmentation de la durée de la surdité



La durée de la surdité a tendance à diminuer les capacités de reconnaissance av. IC

Les performances av. IC sont corrélées aux réseaux de lecture dominants

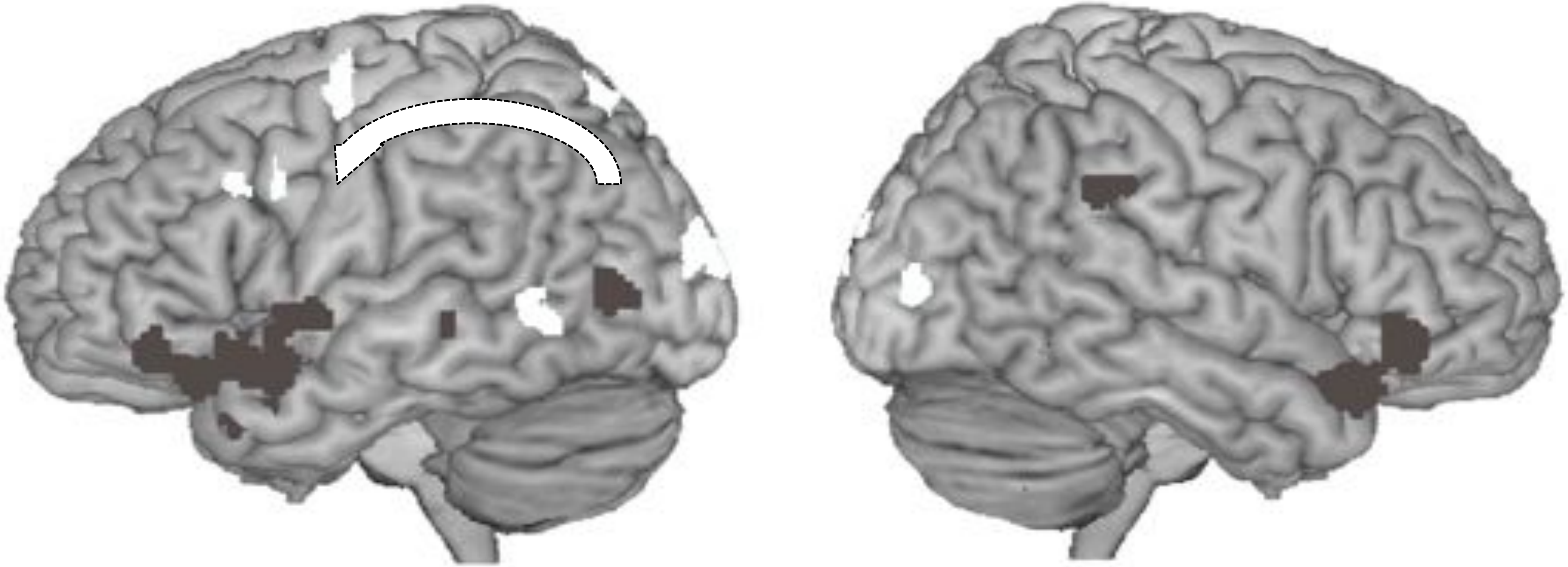
Réseau dorsal <=> bonnes performances IC

Corr Positive

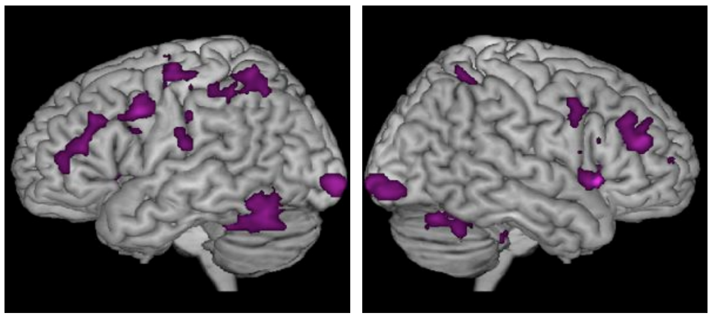
Corr Negative

Hémisphère G

Hémisphère D



Sujets contrôles pdt la tâche : réseau dorsal



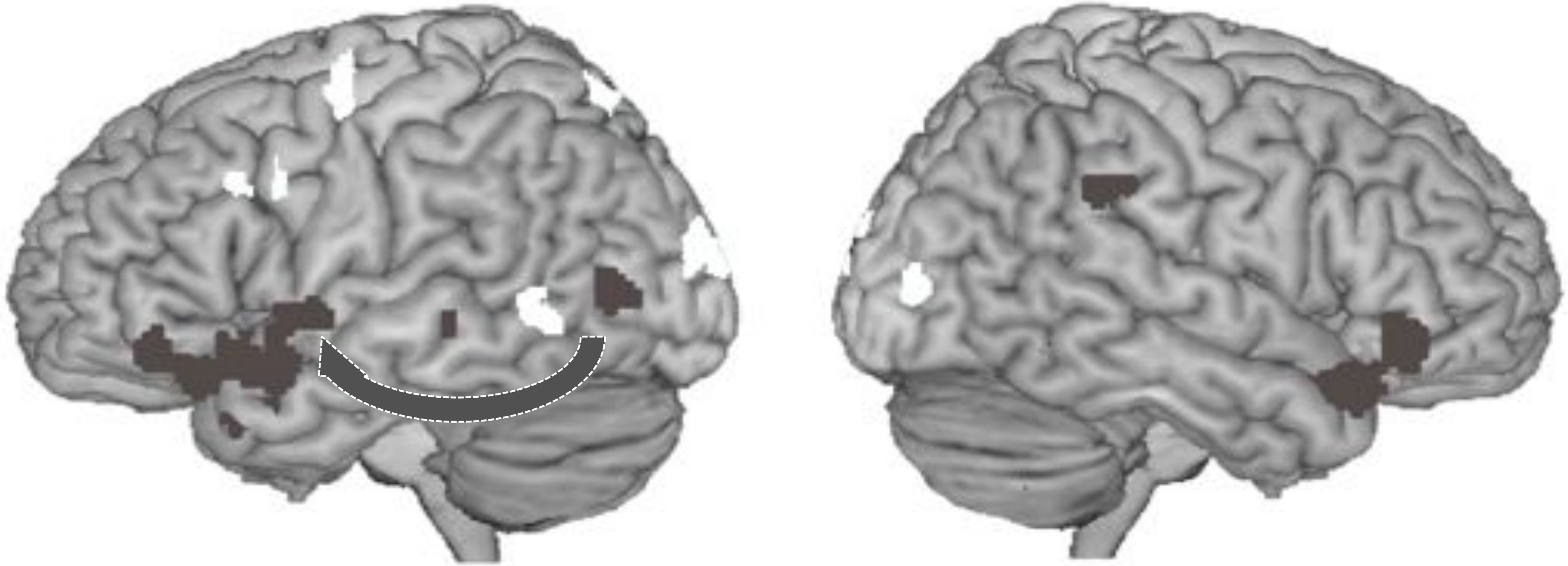
Les performances post-IC sont corrélées aux réseaux de lecture dominants

Corr Positive

Corr Negative

Réseau dorsal <=> bonnes performances IC

Hémisphère G



Hémisphère D

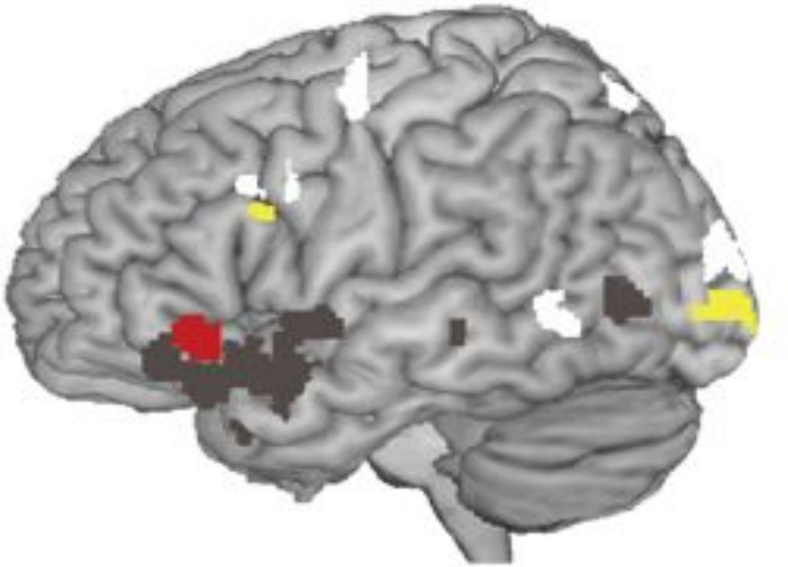
Réseau ventral et région surpa-marginale D <=> mauvaises performances IC

Corrélations IRMf et :

Durée de la surdité

L'utilisation du réseau dorsal diminue avec la durée de la surdité.

Corr Negative
Corr Positive

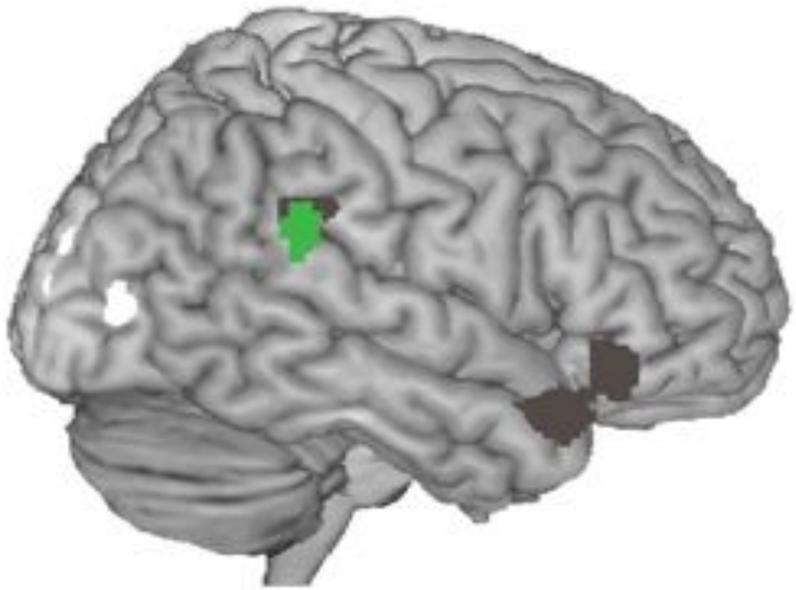


Hémisphère G

L'utilisation de la région frontale inférieure augmente avec la durée de la surdité.

Zone cérébrale recrutée par les patients comparativement aux contrôles pour réaliser la tâche phonologique

Région Supra Marginale droite



patients > contrôles

Hémisphère
D

Stratégie d'adaptation à la surdité

Language comprehension 3 years after implantation as a function of age at implantation (deafness duration)

33 congenitally deaf children, age : 1.5 to 11 years