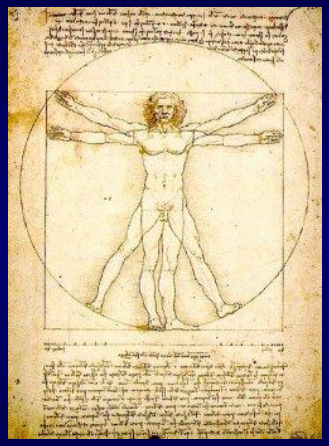
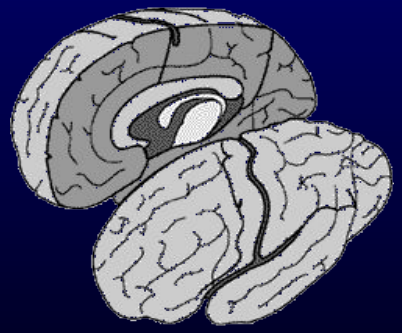
Cerebral asymmetry and the specific functions of the right hemishere



Leonardo Da Vinci

Anke
Bouma

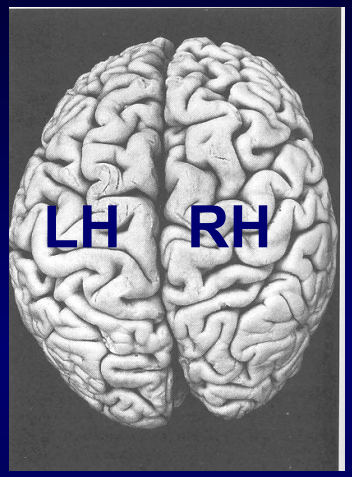


Dept. of Clinical and Developmental Psychology
RijksUniversiteit van Groningen

Cerebral asymmetry and the specific functions of the right hemishere

- General overview of the cerebral asymmetries and the functions of the corpus callosum
- Specific functions of the right hemisphere, and consequences for neuropsychological assessment

Cerebral asymmetry



Left hemisphere

Right hemipshere

Corpus callosum

Cerebral asymmetry

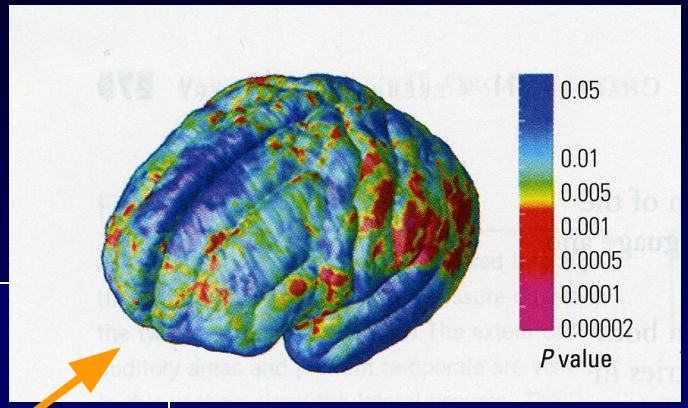
Brain asymmetry has been observed in animals and humans structurally, functionally, and behaviorally. This lateralization is thought to originate from evolutionary, hereditary, developmental, experiential and pathological factors”

Toga & Thompson, Nature Reviews Neuroscience, 2004

Human brain asymmetries

Research methods

- Structural brain asymmetries
- Functional brain asymmetries
- Perceptual asymmetries
- Motor asymmetries
- Neurochemical differences

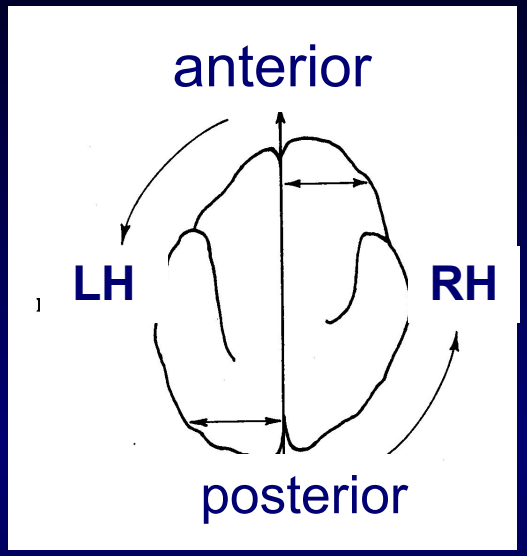


Human brain asymmetries

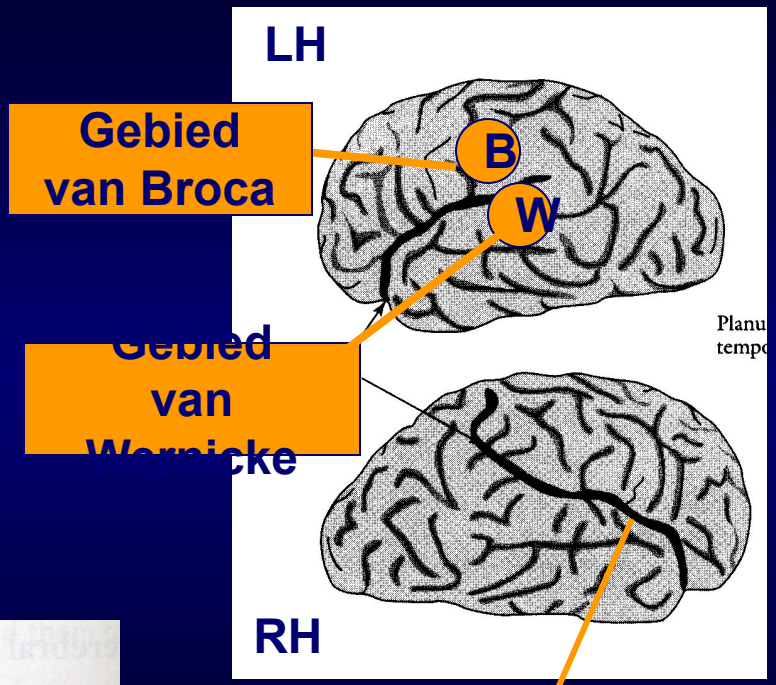
Clinical relevance

- Patients with unilateral lesions
- Split-brain patient
- Normal subjects (*age, sex, hand preference*)
- Bilateral lesions *(e.g., Alzheimerpatiënten*)
- Developmental disorders
- Psychiatric patients

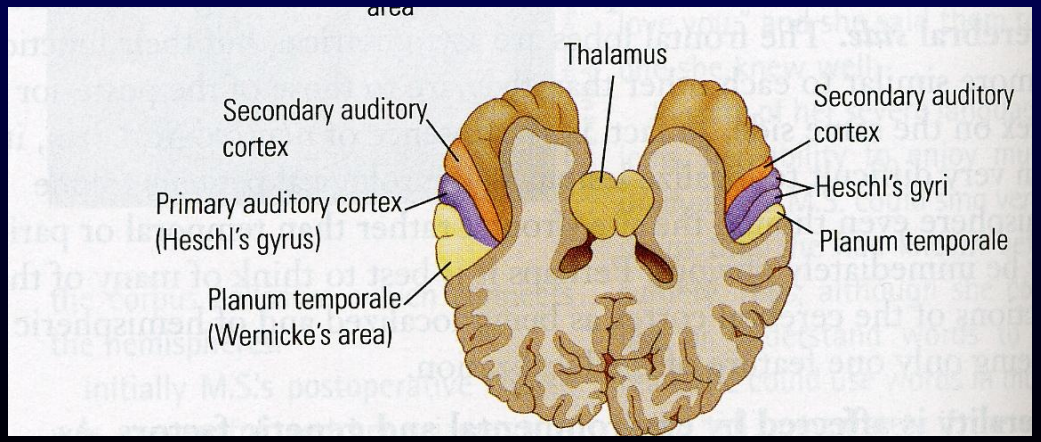
Structural brain asymmetries
Macroscopical



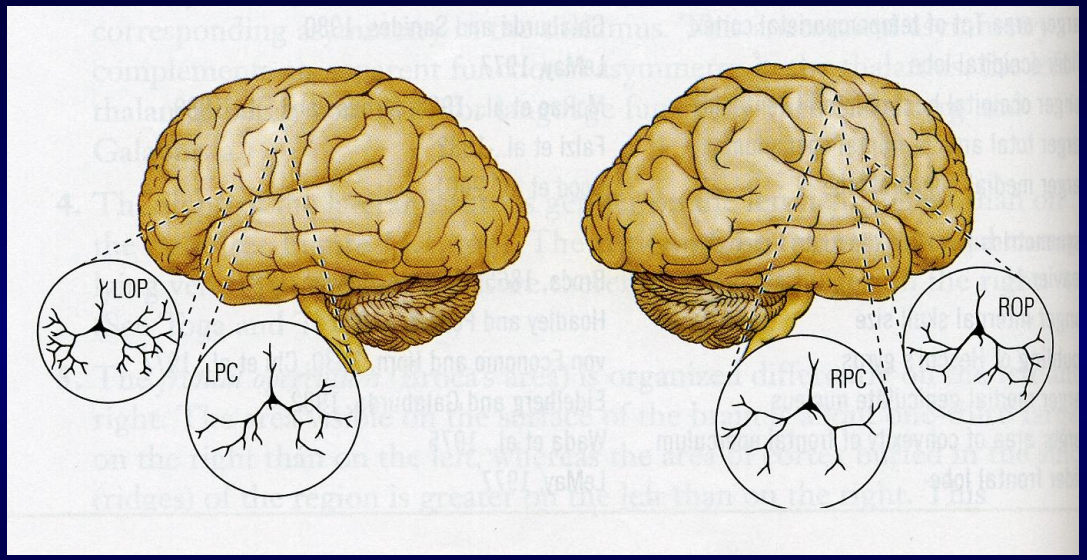
Counterclockwise torque



Sylvian fissure



Structural brain asymmetries
Microscopical



Left hemisphere: more detailed processing and expression of information

Right hemisphere: more focused on connectivity between different brain regions

Structural brain asymmetries
Neurochemical

Left hemisphere: dopamine (motor activation)

Right hemisphere: norepinephrine (alertness, orientation to new stimuli)

Functional brain asymmetry

- Not a simple dichotomy
- Not a modern phrenology
- Is not absolute, but relative
- Modular brain circuits (neuronal networks)
  - subprocesses
  - patterns of activations (intra- and inter-hemispheric connectivities)

Unilateral lesions of the left hemisphere

- primary perceptual and motor disturbances at the right side of the body (contralaterally)

- aphasia

‘conscious awareness’

- language-related disorders and verbal disorders
  (alexia, agraphia, acalculia, verbal memory disorders)

- apraxia

- disturbances in temporal order / sequencing

Unilateral lesions of the right hemisphere

- primary perceptual and motor disturbances at the left side of the body (contralaterally)

- hemi-inattention (neglect); anosognosie and denial

- nonverbal information processing and nonverbal memory
  (faces, visuospatial processes, environmental sounds, music (melodies, but not rhythm; LH involved by experienced musicians)

- Semantic, paralinguistic and affective aspects of language *('context')*

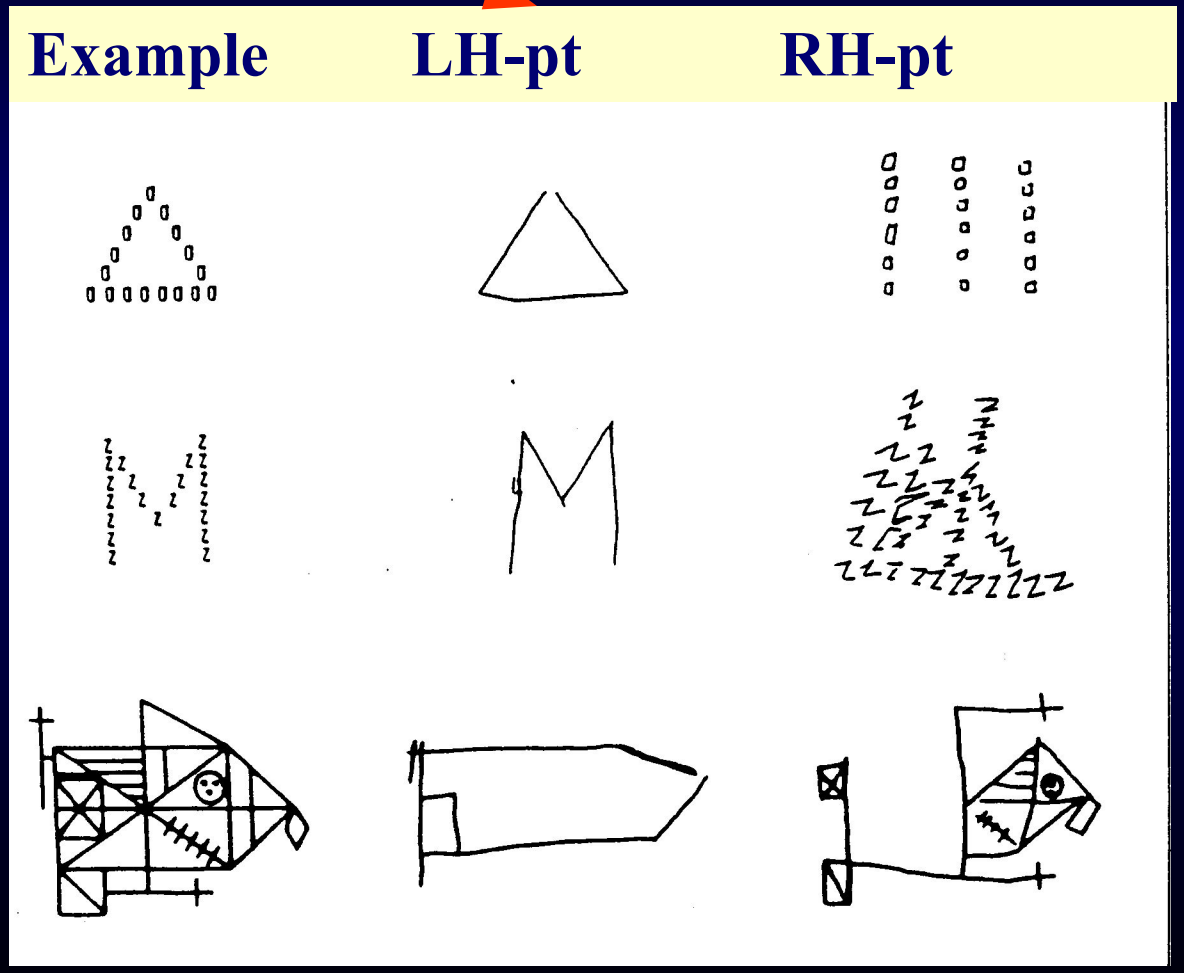
- emotions *('somatic markers')*; m.n. negative emotions

LH patients draw the overall global form of the figure, not on local parts of the figure

RH patients draw the local parts of the figure, but the overall global form is incorrect

Constrctive apraxia

Task: drawing



Right hemisphere:

Examples of emotional and social behavior

Actual social interaction

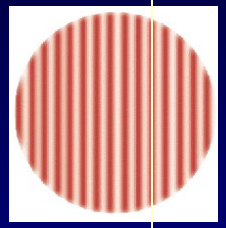
Ekman's faces varies from anxiety to depression

Anxiety in animals

Functional brain asymmetries

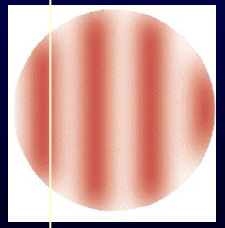
Left hemisphere

- high spatial frequency
- local processing
- analytic, detailed processing



Right hemisphere

- low spatial frequency
- global processing
- holististic processing



Right hemisphere: stronger ‘connectivity’ between different brain regions than the left hemisphere

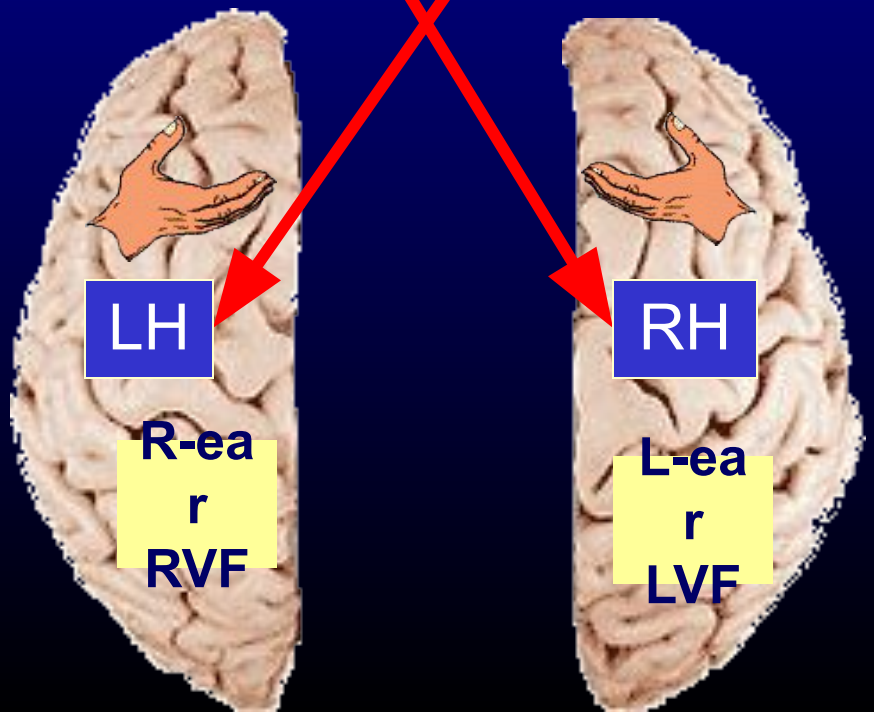
Left and Right

Left side of the body

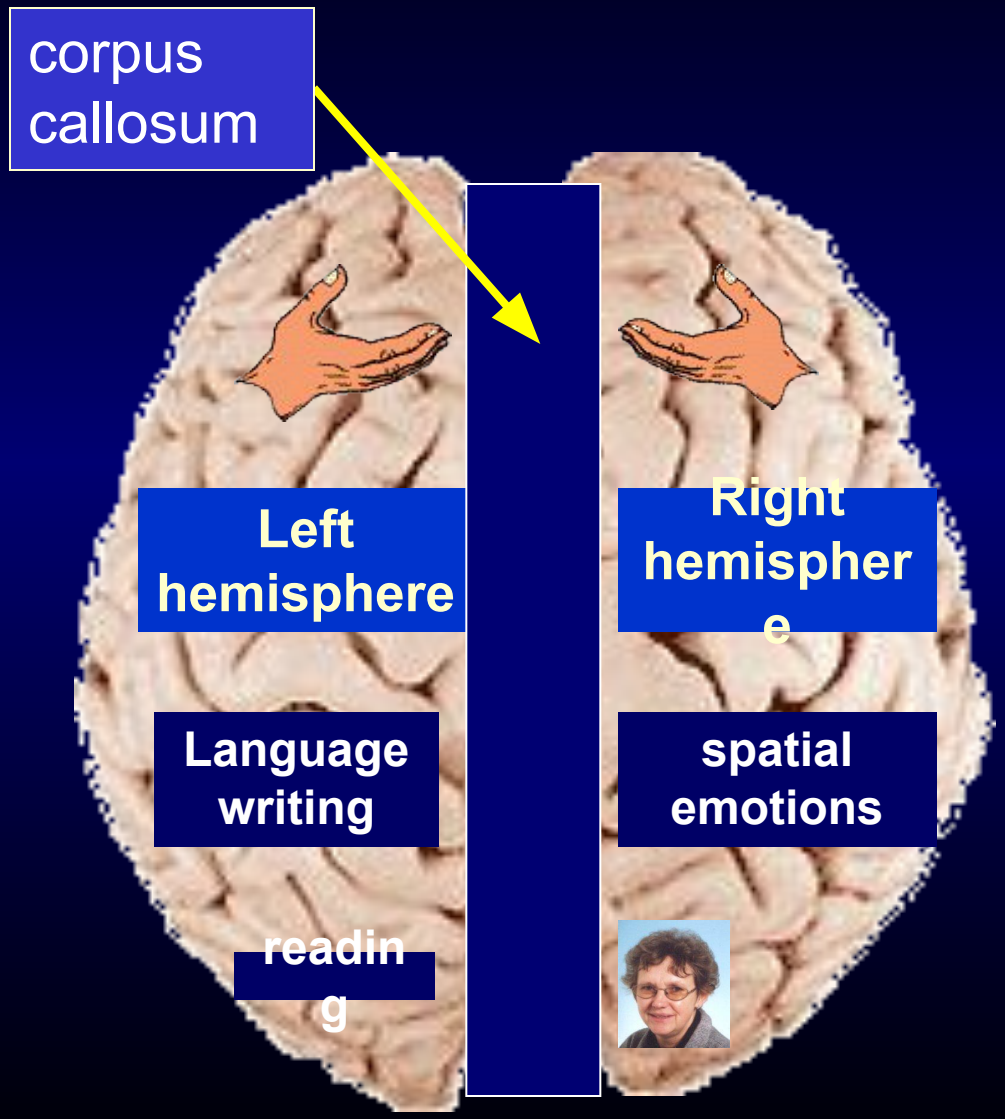
- Left hand
- Left ear
- Left Visual Field (LVF)

Right side of the body

- Right hand
- Right ear
- Right visual field (RVF)



Brain asymmetries and the role of the corpus callosum

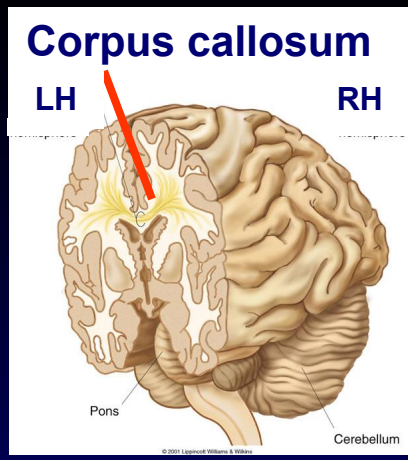


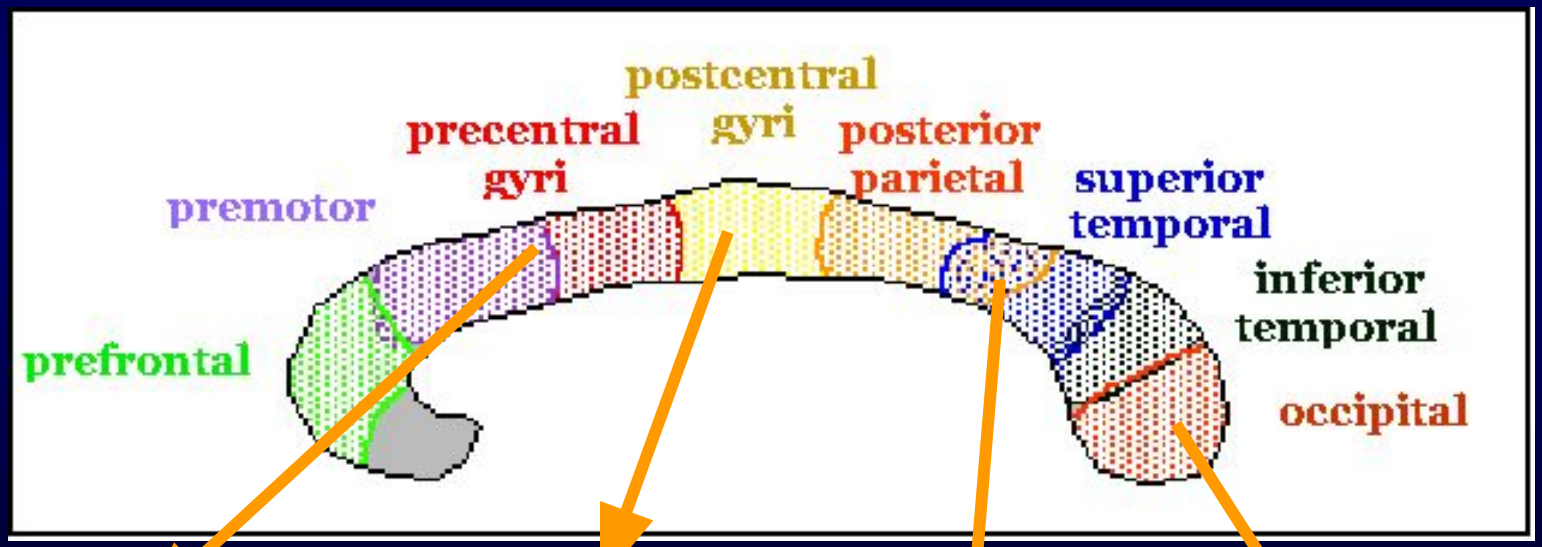
Inter-hemispheric interaction across the corpus callosum

- Transfer of information from the LH to the RH, and vice versa
- Inhibition of equivalent regions in the other hemisphere, and at the same time increased activation of the surrounding neurons for encoding related or contextual informaton

Split-brain patiënten

Corpus callosum





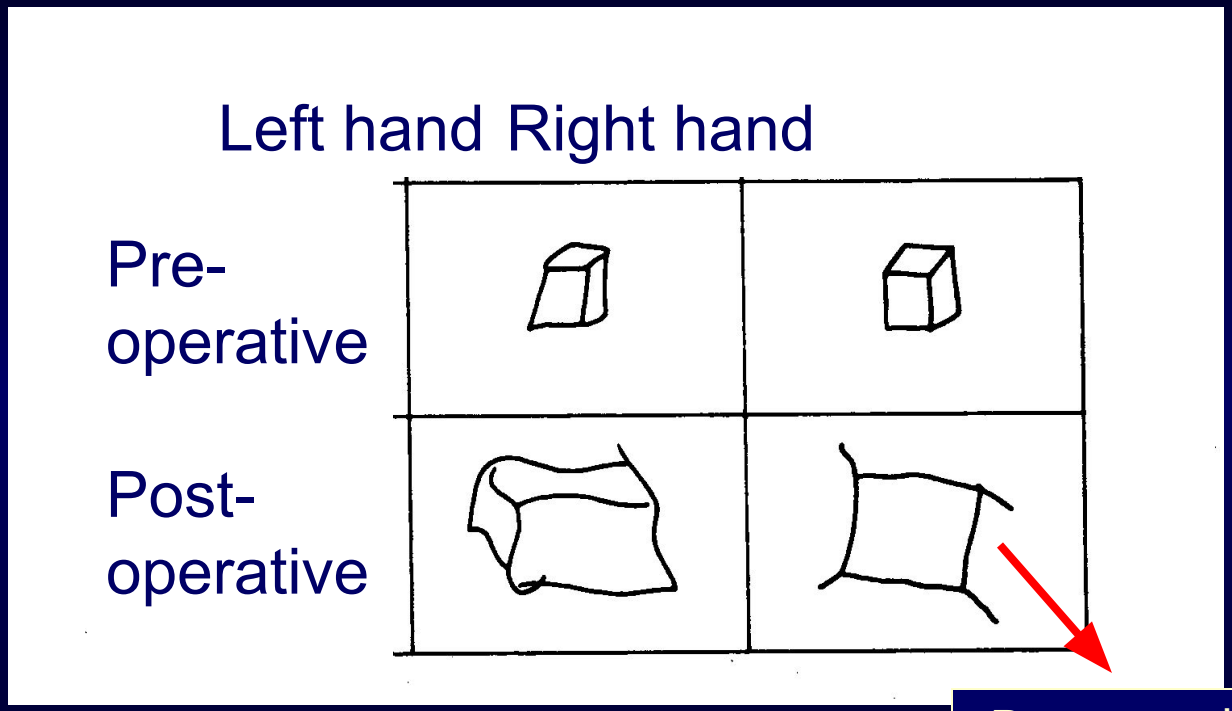
Motor system

Somatosensory system

Auditory system

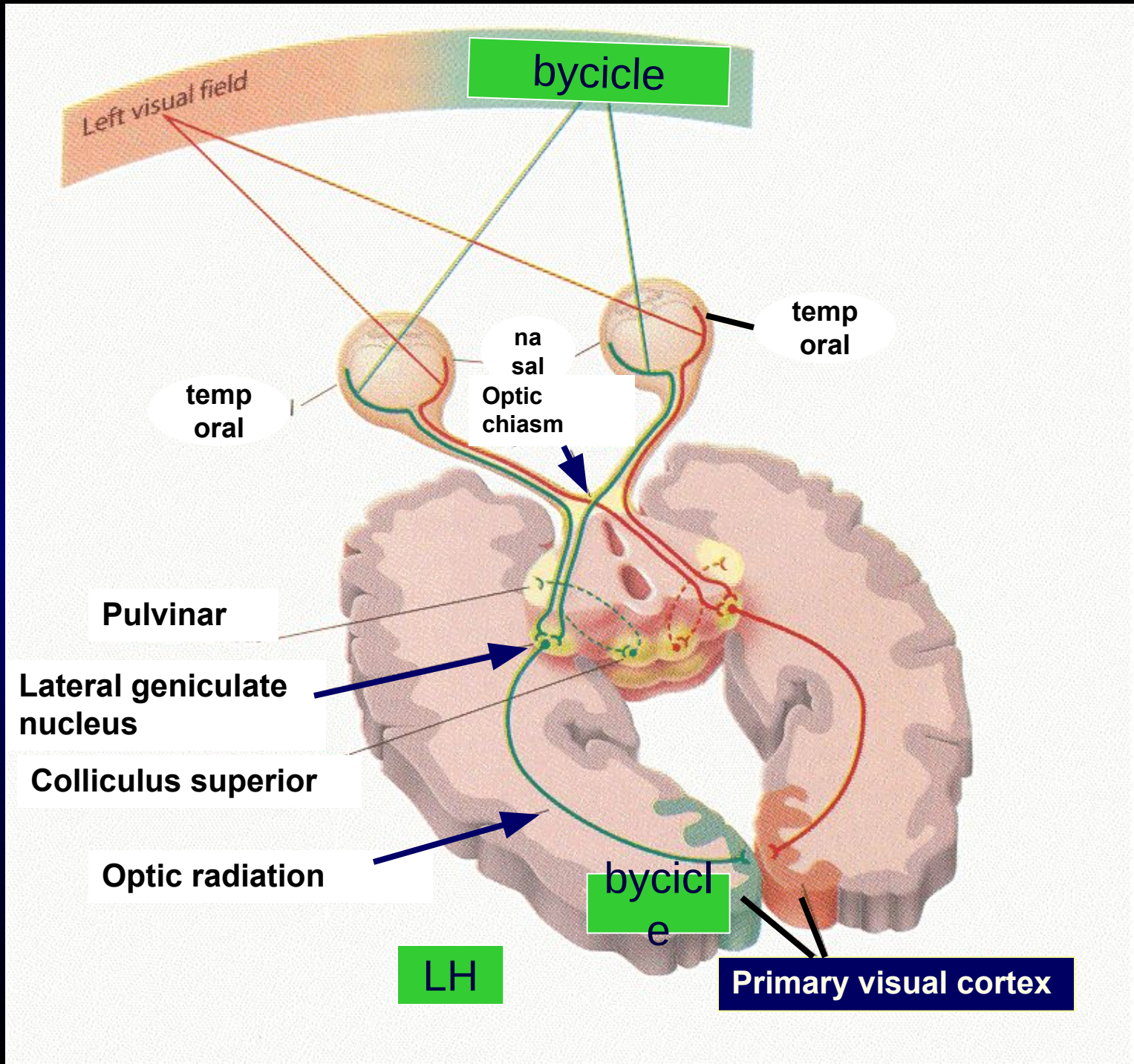
Visual system

Split-brain patiënt

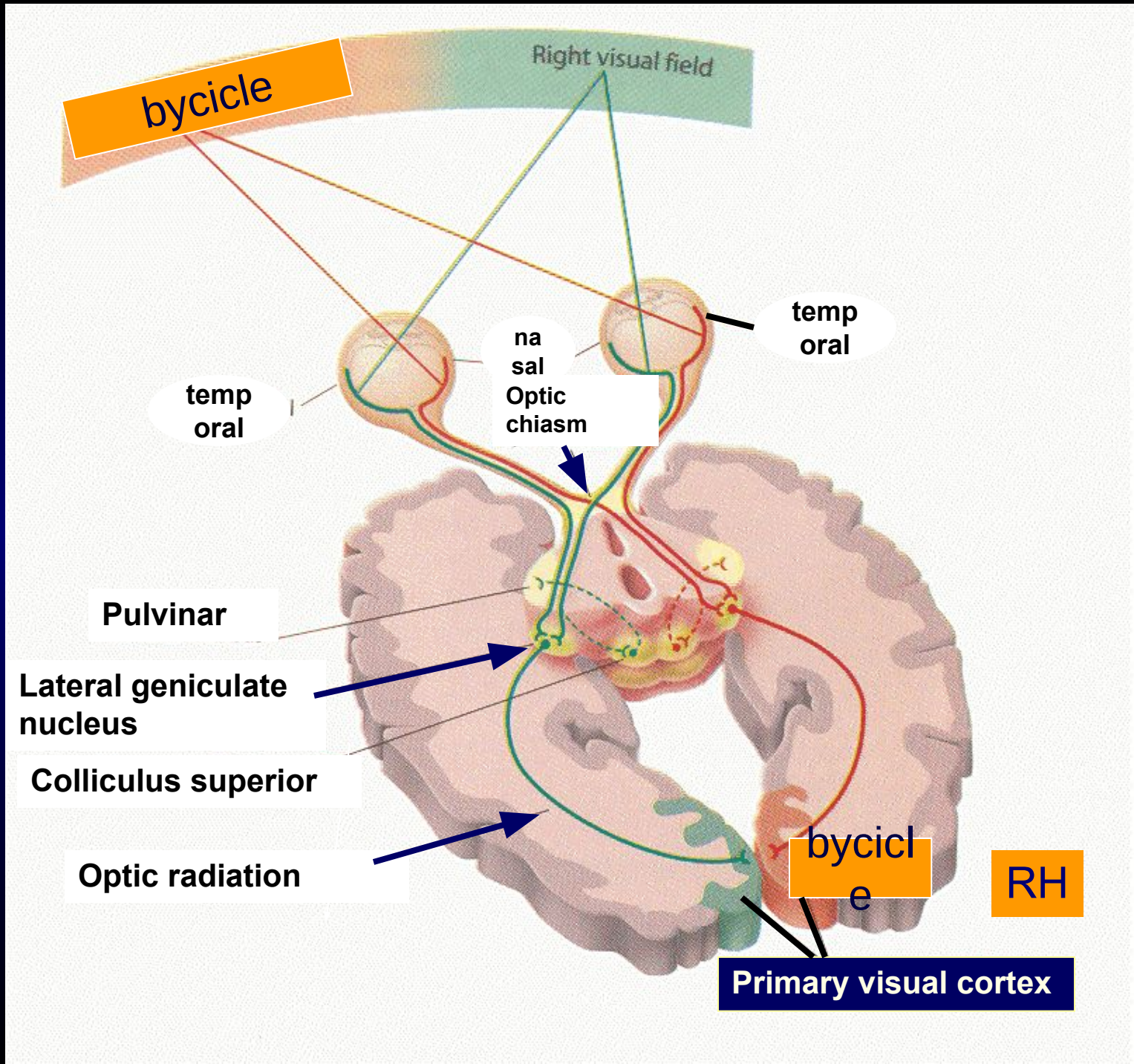


Postoperatively, the right hand performed poorly due to the disconnection of the LH (right hand) and the RH (spatial functions)

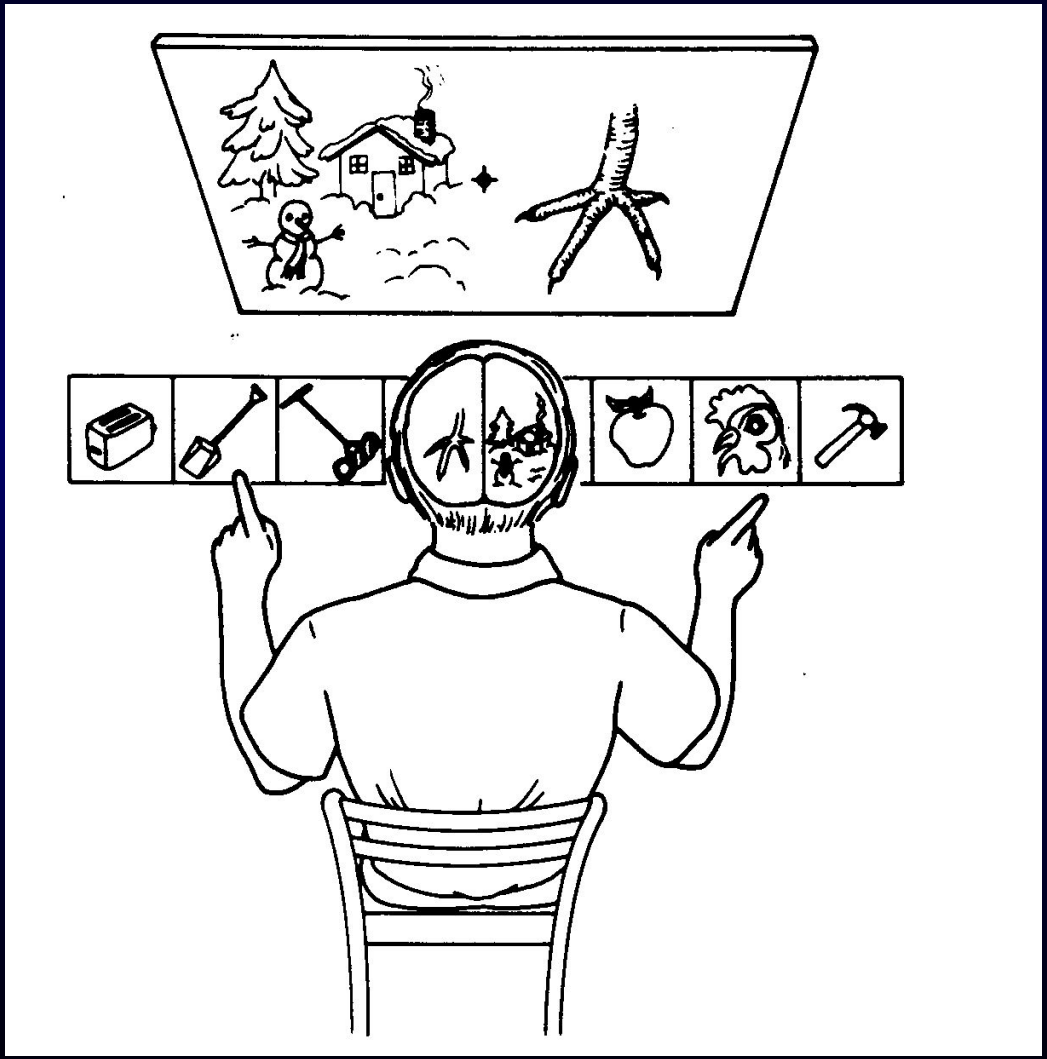
Visual system



Visual system



Split-brain patient



Disconnection syndromes in patients with lesions of the corpus callosum

(split-brain patients, partial disconnection)

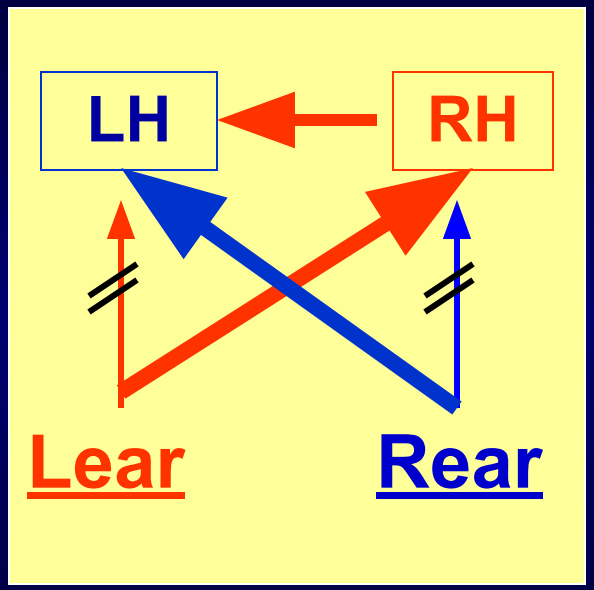
- ‘alien’ hand syndroom (Lh)
- unilateraal L-hand anomie
- hemi-alexie (LV)

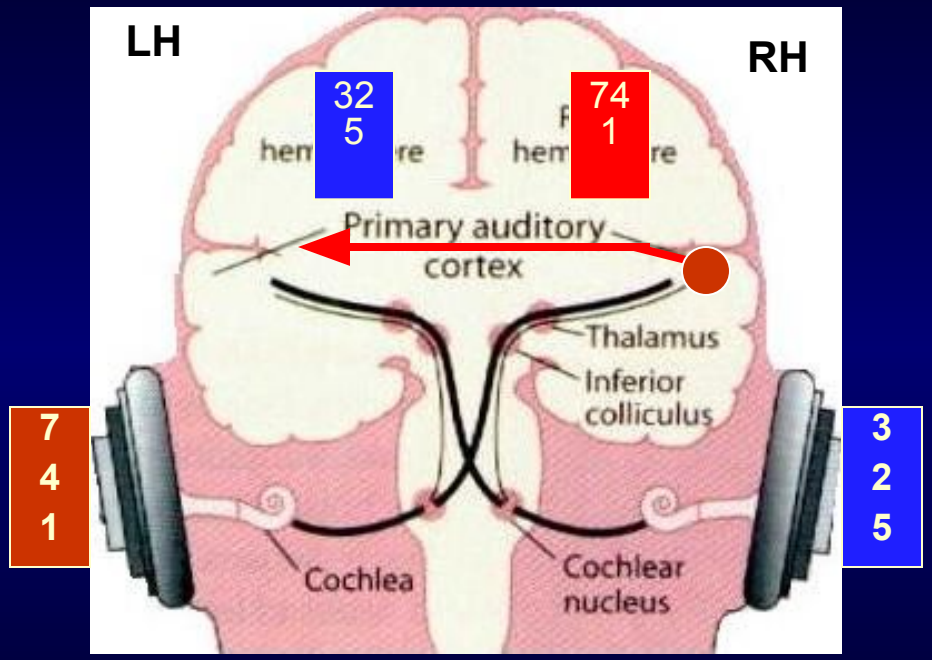
Perceptual asymmetries

- Visual half-field method
- Dichotic listening task

Dichotic listening and hemispheric asymmetry

Kimura's structural model





Presentation time:

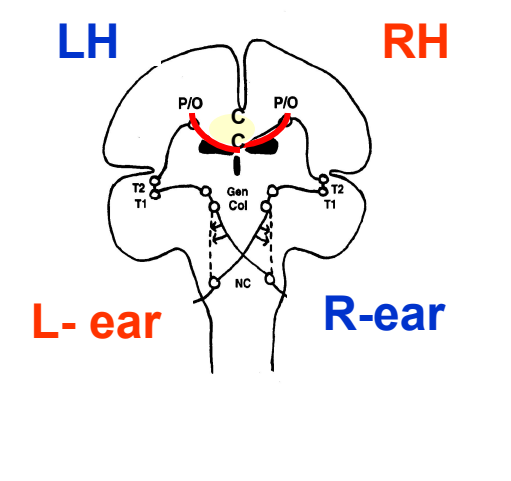
500 msec pear stimulus pair

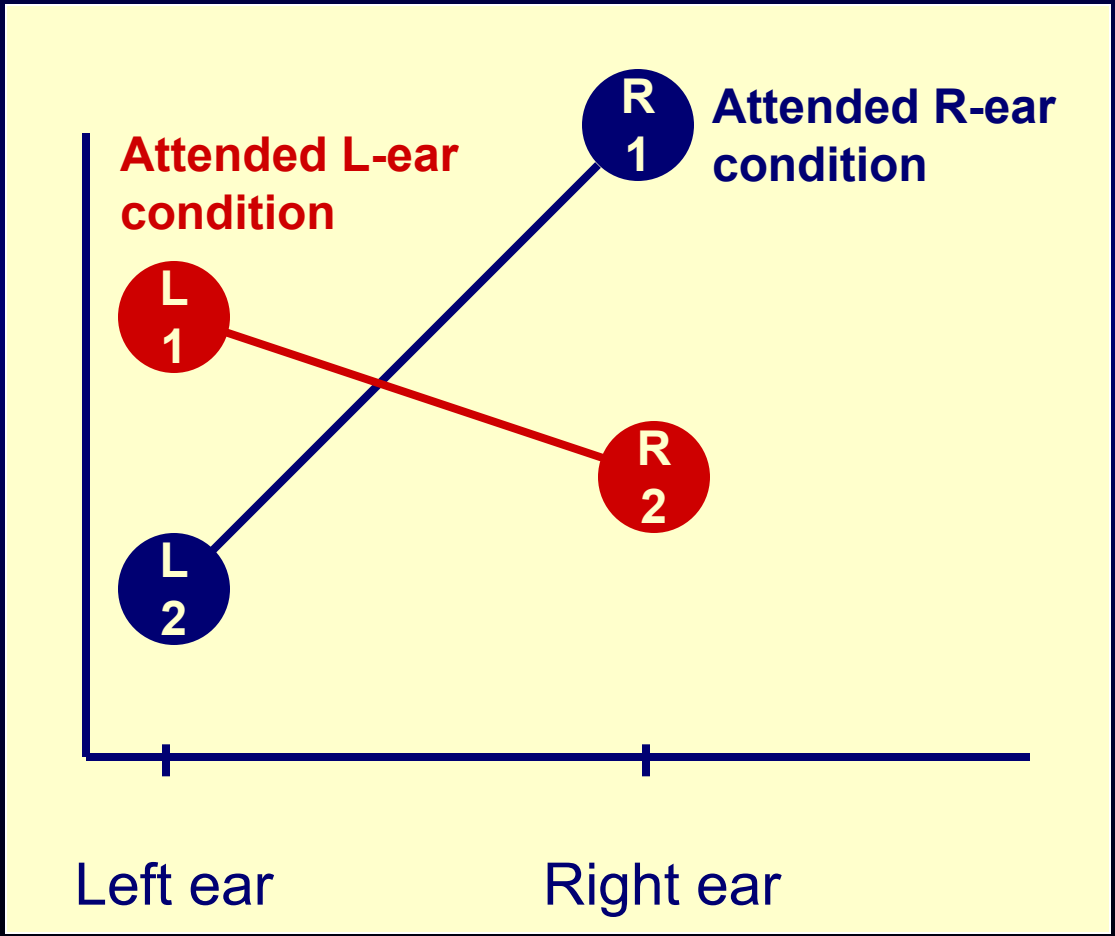
Results: R-ear > L-ear

Bouma, 1998

Effects of attention on dichotic listening

(focused attention task)





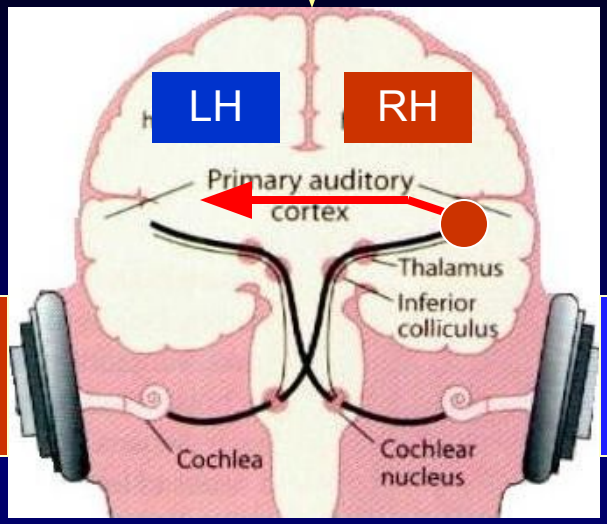
<u>Attended Rear condition:</u>

Recall first Rear digits and then Lear digits

<u>Attended Lear condition:</u>

Recall first Lear digits and then Rear digits

Dichotic listening: language perception and laterality



7
4
1

3
2
5

<u>Attented L-ear condition</u>

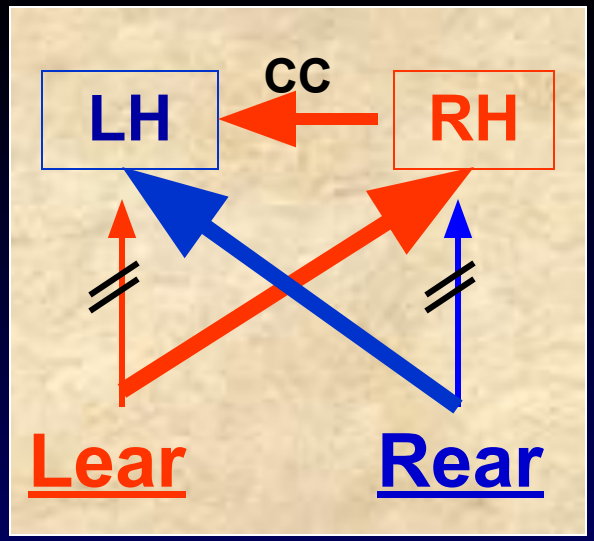
Inhibitory control / EF

= *'top down' process*

<u>Attented R-ear condition</u>

automatic processiing

= *'bottom up' process*



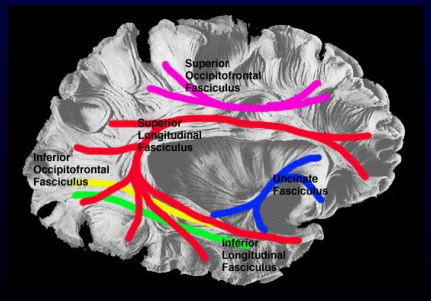
Dichotic listening is based on a distributed network of different hemispheric regions

intra-hemispheric *(temporal, frontal, parietal)*

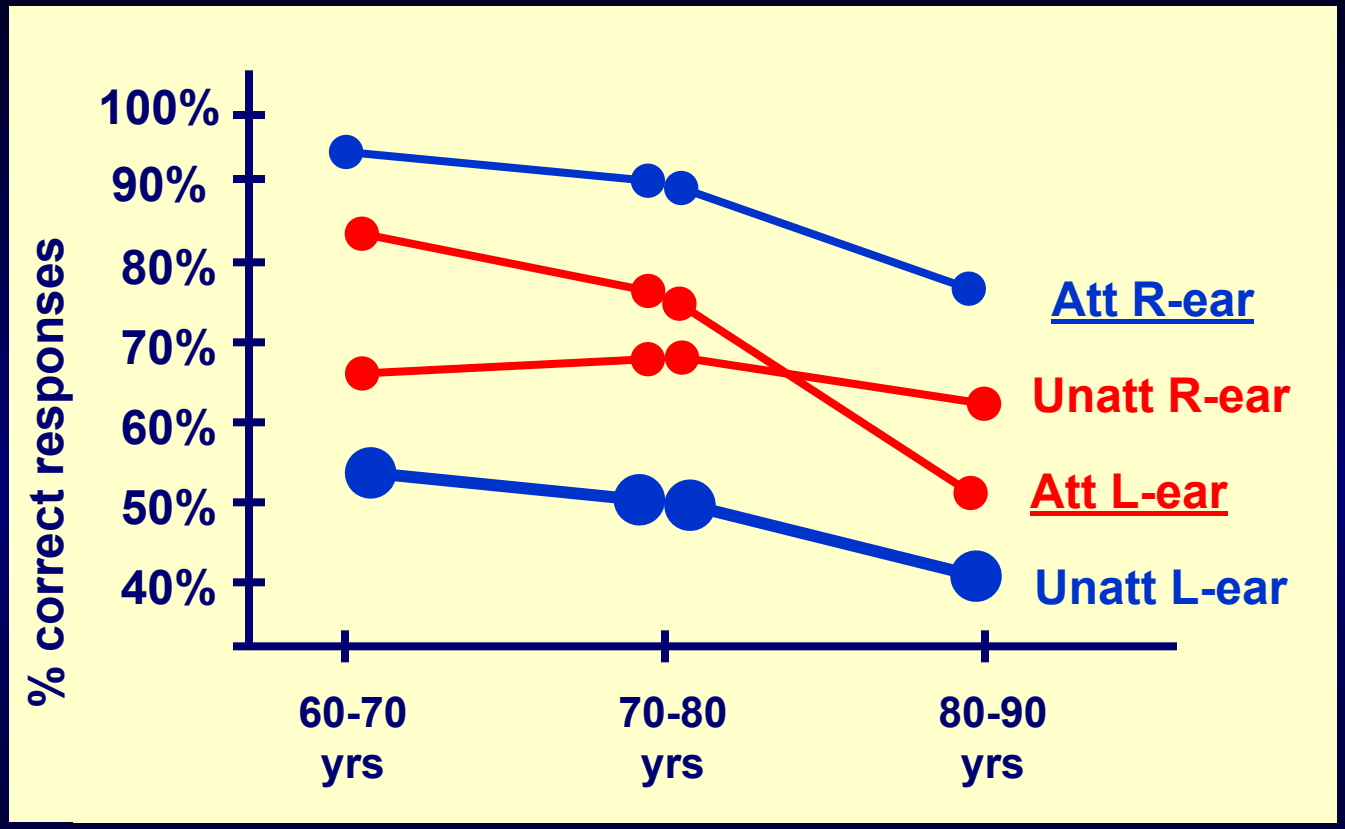
inter-hemispheric *(corpus callosum)*

Attended L-ear condition:

= particularly sensitive to disconnectivy



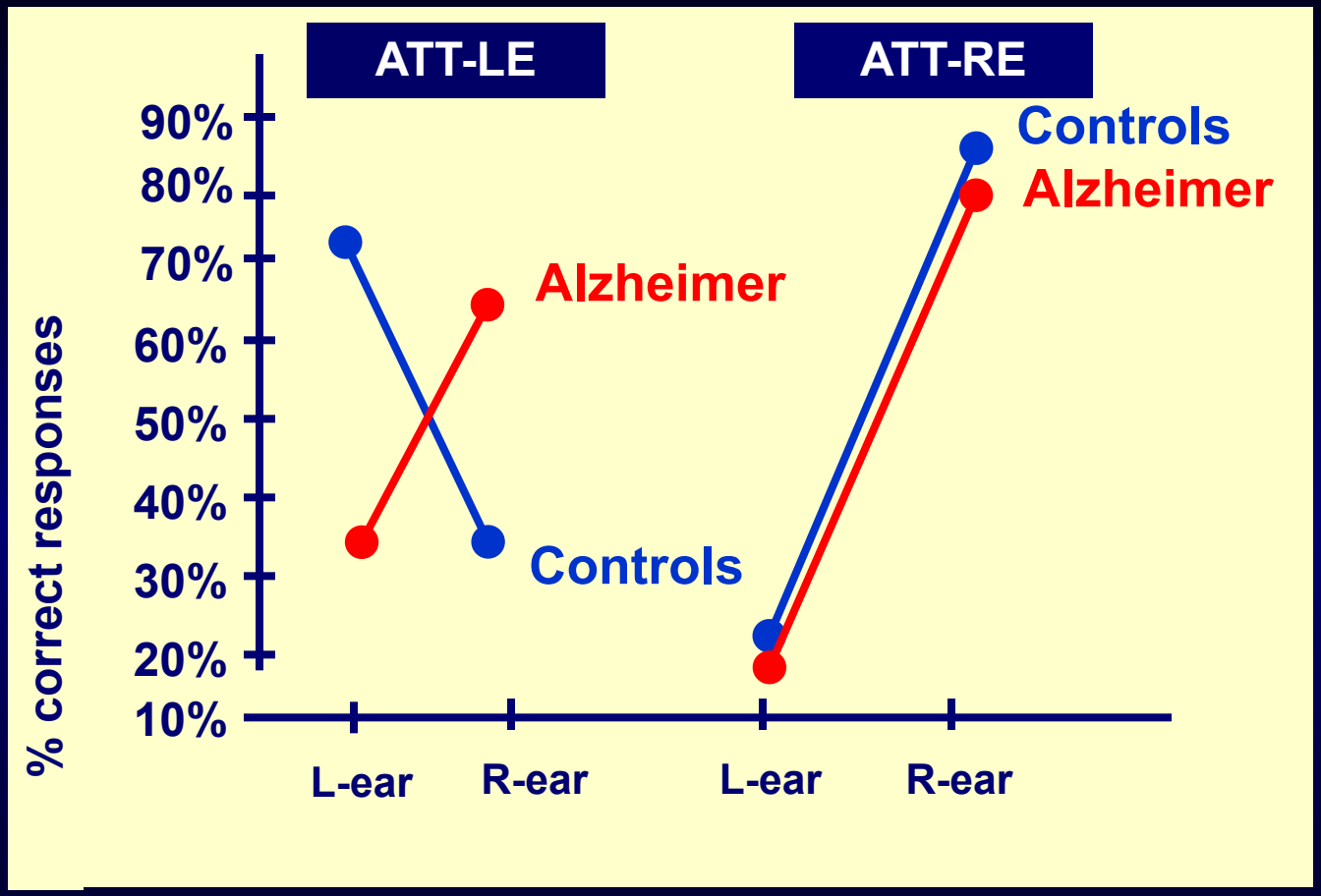
Age effects in dichotic listening



(a) corpus callosum dysfunction
(b) RH-dysfunction ('hemi-aging')
(c) attentional deficits (EF: inhibitory control dysfunctions)

Bouma, 1998

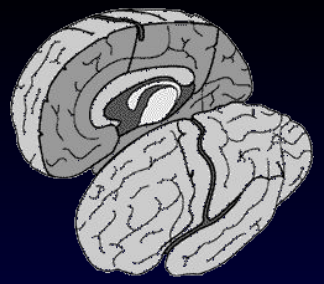
Dichotic listening in Alzheimer's Disease



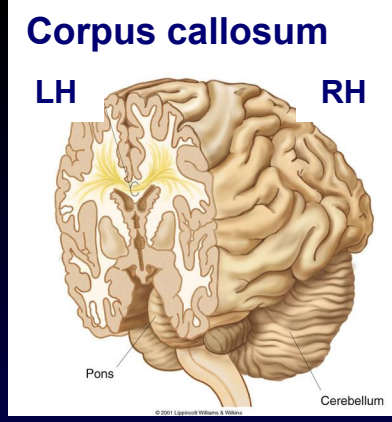
Effects enhanced in Alzheimer patients

(a) corpus callosum dysfunction
(b) RH-dysfunction ('hemi-aging')
(c) attentional deficits (EF: inhibitory control dysfunctions)

Bouma, 1998



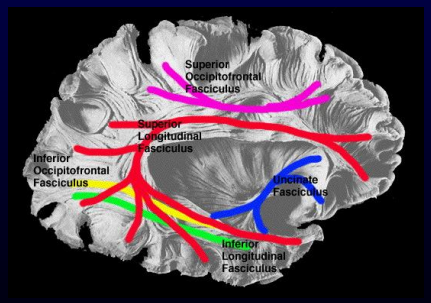
Methods of cerebral asymmetry



Methods of cerebral asymmatry play an important role in measuring:

- inter-hemispheric connectivity (corpus callosum)
- intra-hemispheric connectiviy

RH > LH



Clinical applications in neuropsychological assessment

- patients with unilaterale lesions
- aging and dementia (e.g., Alzheimer patiënten)
- patients with (partial) lesions of the corpus callosum
- patients with multiple sclerose
- psychiatric patients
- developmental disorders

Left-right asymmetries

- <u>Handedness</u>
- Footedness
- Head turning
- Eye preference
- Ear preference
- Facial expression
- Cradling

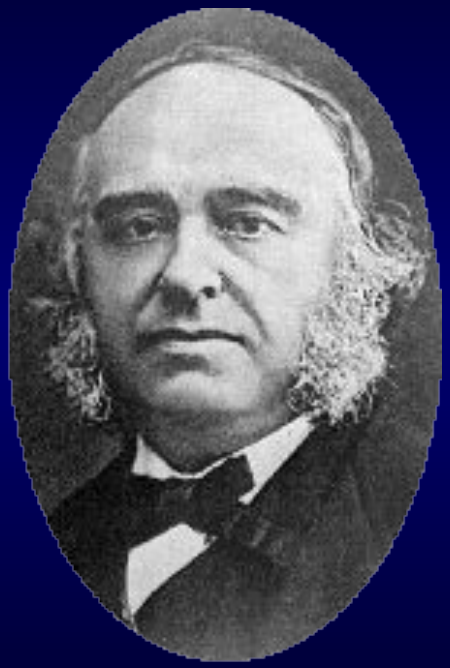
Handedness questionnaire (Van Strien & Bouma)

Writing hand (social pressure?)

1. drawing left / right / both
2, tooth-brush left / right / both
3. bottle opener left / right / both
4. throwing ball left / right / both
5. hammer left / right / both
6. (tennis)racket left / right / both
7. cutting robe with knife left / right / both
8. stirring with spoon left / right / both
9 rubbing out left / right / both
10. Striking a match left / right / both

Scoring -1 / +1 / 0 (range –10, + 10)

Handedness and language dominance



Broca's law of contralateral dominance:

(until mid-20th century):

- In right-handers, the left hemisphere is dominant for language and the use of the preferred hand
- In left-handers the right hemisphere is dominant

Broca's law is <u>not</u> supported by the data!

Handedness and language dominance

Likelihood of right-hemisphere dominance (%)

- extreme left-handedness : 25%
- ambidexter : 15%
- extreme right-hander : 5%

Formula: 15% - handedness score (-10 to + 10)

Left-handedness - prevalence

In the Netherlands, but also in other countries

-females 9.6%

-males : 11.8%

CBS (1985)

Left-handedness

a) genetic models *('nature')*

b) developmental factors *('nurture')*

- prenatal environment *(hormonal factors: testosterone; stress)*
- developmental disorders *(e.g., neural tube defects, stuttering, dyslexia, schizophrenia, autism)*
- birth stress *(e.g., premature birth, respiratory problems)*
- low birth weight

c) cultural influence *(e.g., cultural pressure; costs of left-handedness)*

d) evolutionary factors *(benefits of left-handedness)*

Sex differences in cerebral asymmetries

Male advantage:

- visuospatial skills
  - mental rotation
  - perceptual closure
  - embedded figures
- mathematical reasoning
- target directed motor skills

Females advantage:

- verbal skills
  - verbal fluency
  - speed of articulation
  - grammar
  - earlier language acquisition
- perceptual speed
- fine motor skills and rapid sequential movements

Sex differences in cerebral asymmetry

Cerebral asymmetries tend to be *smaller in females* than in males, presumably related to stronger *inter-hemispheric connectivitiy*

Higher level of testosterone during development of the brain*:*

leads to

- reduced inter-hemispheric connectivity and
- increased cerebral asymmetries

Functions of the right hemisphere: neuropsychological assessment